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Technical Memorandum

Prepared for US Environmental Protection Agency Region 1 under EPA RAC Task Order #0004-RS-BD-0140

June 15, 2015

INNOVATIVE TECHNOLOGIES FOR USE IN CAP DESIGN AND CONSTRUCTION AT THE PETERSON/PURITAN, INC. SUPERFUND SITE, Operable Unit 2

Peterson/Puritan, Inc. Superfund Site
Operable Unit 2
Cumberland and Lincoln, Rhode Island

INTRODUCTION

The Remedial Investigation/Feasibility Study (RI/FS) process has been completed for Operable Unit 2 (OU 2) of the Peterson/Puritan, Inc. Superfund Site (the Site), and EPA is in the process of preparing a Record of Decision (ROD). The ROD summarizes the findings of the remedial investigations and the feasibility study; presents the cleanup alternatives that were considered and evaluated and the remedy selection process; and describes the final OU 2 selected remedy. The purpose of this technical memorandum is to provide a number of potential innovative restoration technologies that may be relevant to addressing concerns raised during public meetings and the public comment period regarding enhancement of the selected remedy in terms of post-closure Site reuse, aesthetics, and ecological revitalization of the area.

To start the remedy selection process, EPA presented its Proposed Plan for remedial actions to be taken at the Site at a public information meeting on August 7, 2014. Two formal public hearings were then held on August 21 and October 8, 2014. The purpose for the hearings was for EPA to accept oral comments from interested parties, organizations, and individuals. Written comments were also submitted to EPA during this public comment period. In response to the Town of Cumberland's request (and others), the public comment period was extended and remained open through January 23, 2015.

Once a remedy has been selected and the ROD has been finalized, the project enters the Remedial Design phase. It is during this future phase of work that the actual materials, components, construction methods, and construction sequencing are developed that meet the required objectives and satisfies Applicable or Relevant and Appropriate Requirements (ARARs).

During the first public hearing on August 21, representatives of the Potentially Responsible Parties (PRPs) introduced four previously-unseen design concept renderings on poster boards. Three renderings showed the PRPs' interpretation of how the area would look if EPA's Preferred Alternatives (JM SO-2 and NP SO-3), as presented in the Proposed Plan, were implemented. The three conceptual renderings envisioning EPA's Preferred Alternative showed substantial barren riprap barrier slopes (approximately 5 feet tall) along the edge of the Blackstone River at both the J. M. Mills Landfill and the Nunes parcel. Near-vertical gabion walls (appearing to be approximately 5 to 8 feet tall) rose above the riprap slopes, above which the J. M. Mills Landfill and the Nunes Parcel were shown as grassed, benched slopes with numerous exposed gas vents. The rendering of the Nunes Parcel, which was an aerial view, showed the surface rising well above its current elevation. The two renderings of the J. M. Mills Landfill, which were views from river level, appeared to reflect the approximate elevation of the landfill in its current state.

The fourth rendering showed the PRPs' vision of how the J. M. Mills Landfill would look if the PRP Group's proposed hybrid cap (presented as Alternative JM SO-3 in the Proposed Plan) were implemented. In stark contrast to the other three posters, the rendering of the hybrid cap shows no riprap or gabion walls along the river but instead portrays a riparian buffer with a moderately-dense cover of mature trees. Although the rendering is an oblique aerial view, the landfill appears to have a much shallower slope and to be lower than its current height. Its surface is covered with grass and areas of flowers with well-spaced trees and shrubs, some of which partly hide a minimal number of gas vents.

The PRPs' renderings convey significant, and perhaps over-stated, differences between the appearances of the Site under the PRPs' concepts of EPA's Preferred Alternatives versus the PRPs' rendering of their alternate hybrid cap within a hypothetical Site setting. In reality, there would likely be little difference between the outward appearances of either cleanup proposal since the controlling design features that will be required to develop a protective remedy apply to each proposal. Specifically, because the landfills are located within the 500-year floodplain of the Blackstone River, any alternative will need to incorporate substantial flood control measures to prevent floods from washing or leaching out contaminants from the landfills. Accordingly, there is a range of potential flood control measures that could be applied to either alternative, from "hard" structures such as riprap slopes and gabion walls (as portrayed by the PRPs) to "softer" approaches such as planting trees and other vegetation within flood protection structures on the landfill slopes to create a vegetated floodplain buffer along the toe of the landfill slope. Given the requirements for the remedy to protect floodplain resources, and in response to public comments supporting maintaining the natural aesthetics of the floodplain corridor, many design options are available for achieving both a remedy that protects the floodplain from OU 2 contamination and allows for habitat and aesthetic floodplain resources to be reestablished once the landfill is capped (as discussed below). The type of cap, as represented by the different alternatives presented in the Proposed Plan, is not expected to significantly affect the floodplain mitigation measures that will be required during remedy implementation. Specific discussions and decisions on what measures will be taken will occur during the formal design process for OU 2 that will start after a ROD is signed. At that time, many important design features can and will be fully vetted through a coordinated design process and stakeholder involvement.

Public comments on the Proposed Plan have raised concerns regarding the (1) lack of shrubs and trees once the landfills are closed; (2) lack of riparian habitat along the bank of the Blackstone River; (3) use of riprap as an erosion control measure along the Blackstone River, which will affect the aesthetics and ecological usefulness of the landscape; (4) use of retaining walls along the Blackstone River which will affect the aesthetics and ecological usefulness of the landscape; (5) multitude of gas vents emanating from the closed landfills; (6) the need for emergency access to and through OU 2, specifically regarding access to the Pratt Dam from across the Nunes Parcel; (7) restrictions on the public's access through OU 2 to the Blackstone River, which will limit post-closure recreational use activities such as hiking and kayaking that may be associated with the Blackstone River Valley National Historical Park; (8) management of stormwater releasing from the RCRA Subtitle C cap; and (9) floodplain storage compensation for the landfill cap and Site re-grading.

As stated above, the purpose of this technical memorandum is to provide a number of potential innovative restoration technologies (not otherwise represented by the PRPs' renderings) that may be relevant to addressing the concerns raised during public meetings and the public comment period regarding enhancement of the selected remedy in terms of post-closure Site reuse, aesthetics, and ecological revitalization of the area. This memo does not provide design directives or requirements. Rather it serves as a general guide to convey engineering concepts and technologies that could be considered during the development of the Site design and potentially be applied for final closure of OU 2, while also meeting the equivalency of the required State and Federal floodplain protection and RCRA Subtitle C cover system performance standards.

ECOLOGICAL REVITALIZATION

Part of the EPA's proposed Site remediation involves ecological revitalization of OU 2, including the riparian area surrounding the Blackstone River. Ecological revitalization serves to remove the stigma associated with past uses of land, repairs damaged land, enhances property value, provides for recreational reuse, creates animal habitat, controls landfill leachate, and protects against potential contamination migration. Two examples of ecological revitalization at Superfund sites are shown in Figures 1 and 2.

Figure 1. Before and after ecological revitalization at a Superfund site in Indiana (images from EPA - http://www.epa.gov/superfund/accomp/news/ecological_revitalization.htm).

Figure 2. Before and after ecological revitalization at a Superfund site in Colorado (images from EPA - http://www.epa.gov/superfund/accomp/news/ecological_revitalization.htm).

The performance standards that apply to a RCRA Subtitle C cap at OU 2 do not preclude revegetation, as long as it doesn't interfere with the cap's capability to prevent contaminants from migrating from the capped waste. For example, in lieu of planting a single species (i.e., monoculture) of grass on the surface of the RCRA Subtitle C cap, native tall grasses, shrubs, and even trees can be used to enhance the landfill. Planting a variety of native plants has a number of advantages, relative to a grass monoculture. Native plants will enhance the natural ecosystem of the landfill cover, attract migratory birds and other species, and provide an aesthetically pleasing landscape. The use of native plants has the potential to decrease maintenance costs by reducing the use of fertilizers, pesticides, and water once the landfill cover develops into a self-sustaining ecosystem. Covers using a variety of native plant species also help prevent erosion of the landfill cover's surface soil layer.

As shown in guidance documents prepared by the EPA, as re-produced in Attachment A, research has shown that properly designed native plant species and cover systems can co-exist without damaging the functionality of a landfill cap. This research indicates that specific shrubs and trees will build roots that grow laterally along the protective impermeable barriers instead of pushing through the barriers, which may cause damage to the engineered cover system. Native plant species have been used on capped landfills in Maryland, Pennsylvania, Delaware, and other states.

One potential issue with using native plant species is that they are often more difficult to plant and sometimes take longer to become well established. Sometimes a portion of a planted area will need to be re-seeded if the plants do not establish. In addition, ecological revitalization may require other considerations to ensure successful creation of habitat, such as controlling invasive plant species. Technical performance measures (TPM)[1] would be developed during design to determine/monitor the success of ecological revitalization as part of the cleanup process. Ecological revitalization can also create attractive nuisances; however, these can be planned and designed for. For example, temporary protection may be required to limit the access of deer and other animals to newly seeded native plants to protect them from over-consumption during establishment.

The riparian area along the edge of the Site can also be restored/revitalized to nearly its present state by replanting native tree species along the river bank to enhance the ecological viability of OU 2. Native plants and trees can serve as habitat to native animal species and enhance the riparian zone by stabilizing the river bank and controlling runoff.

Several EPA fact sheets summarizing the importance of ecological revitalization, including *Ecological Revitalization: Turning Contaminated Properties Into Community Assets,* are provided in Attachment A. These fact sheets contain recommendations and technologies that will be useful for the revitalization and remediation of the Site. Guidance from the EPA on implementing native grass, shrubs, and trees on top of RCRA Subtitle C caps is also included. These guidance documents include advice on selecting the species of plants and implementing plans to establish native ecosystems at contaminated sites.

EROSION CONTROL

In EPA's proposed remedy for OU 2, there remains a requirement to actively restore the lower portion of the floodplain, to the extent practical, with adaptation measures aimed at increasing remedy resilience in response to climate change. Such measures will be considered during design and may include, but not be limited to, erosion control and bank stabilization methods (including bioengineering solutions) outlined in the Rhode Island Soil Erosion and Sediment Control Handbook[2] (Revised August 2014), or as may otherwise be specified in the Rhode Island Stormwater Design and Installation Standards Manual[3] (as amended March 2015), among other guidance.

As part of the RCRA Subtitle C cap protectiveness requirements, the design will need to achieve performance standards which include, but are not limited to, long-term minimization of infiltration and promoting drainage and minimizing erosion, especially during flood events. Rather than provide erosion protection from flow along the Blackstone River with only riprap, bioengineering practices and turf reinforcement mats (TRMs), potentially in combination with stone and rock (if needed), are some options to stabilize the river banks. These practices allow for native grasses, shrubs, and trees to work in conjunction with engineered products to provide sustainable "soft" erosion control in lieu of or in addition to "hard" riprap solutions. Soft solutions can be more aesthetically pleasing, provide superior habitat for native species, and create greater flexibility in providing for potential sustainable passive recreational use.

TRMs are permanent products that serve to control soil erosion from high-velocity runoff, streams, or rivers. They are composed of interwoven layers of non-degradable geosynthetic material such as polypropylene, nylon, and polyvinyl chloride netting, stitched together, as shown in Figure 3. TRMs work together with vegetation, allowing vegetation to grow through the mats and provide further erosion control. These mats serve as a permanent surface feature, continually reinforcing soil and vegetation. However, after vegetation grows, these mats are typically not noticeable (see Figure 2 in *Turf Reinforcement Mats* fact sheet in Attachment B).

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[1] For additional information on TPMs, visit the following Web site: www.clu-in.org/products/tpm.

[2] See: http://www.dem.ri.gov/soilerosion2014final.pdf

[3] See: http://www.dem.ri.gov/pubs/regs/regs/water/swmanual15.pdf

Figure 3. Turf Reinforcement Mats (image from Caltrans - http://www.dot.ca.gov/hq/LandArch/ec/recp/trm.htm).

"Soft" erosion control allows for suspended solids removal as a result of vegetative growth within the mats that is superior to riprap. Native seed mixes can be designed for use with TRMs to establish attractive habitat for animals. Soft solutions are typically regarded as being better able to reestablish the aesthetics of a riparian corridor and to be more sustainable than hard armoring solutions.

TRMs are limited to areas that meet certain conditions. For example, TRMs do not prevent deep-seated slope failures, nor do they have the ability to protect against extremely high flow velocities that riprap can, and they do not apply to applications where significant waves are expected.

The EPA has developed a fact sheet on the use of TRMs as an alternative or an enhancement to riprap. As stated in the fact sheet, TRMs typically cost considerably less than concrete and riprap-based erosion control. This fact sheet is reproduced in Attachment B.

For areas of OU 2 that may be subjected to relatively low water flow rates (e.g., away from the Blackstone River), temporary erosion control blankets can be used to assist permanent vegetation to take root and eventually allow the vegetation to serve as the standalone final erosion control measure. If the plants to be established on the ground surface are expected to provide adequate long-term erosion control, temporary geosynthetics can be used to support the soil surface prior to vegetation establishment. Temporary erosion control is often designed to last up to three years. A number of biodegradable, non-toxic, geosynthetic products are available that can control erosion on bare ground and allow vegetation to grow through the product and establish permanent ground cover.

These temporary erosion control blankets are often made of reinforced mulches. Biodegradable erosion control blankets are often made from straw or coir fibers that are mechanically stitched to netting. Natural and synthetic woven fiber netting can be used. Additional information on erosion control blankets is provided by a Caltrans document included in Attachment B.

Another option for bioengineering erosion control at OU 2 along the Blackstone River are logjams. Logjams are permanent installations of large logs stacked and tied together along a river bank, as shown in Figure 4. Logjams can be installed into the banks of rivers to slow the flow of water and create habitat for fish to spawn and migrate. Logjams often extend into the river approximately 10-15 ft, which creates roughness in the river to slow the flow of water along the bank, reducing erosion, and creating pools for fish habitat. Vegetation can be established within the logjams to structurally reinforce the logjams with roots and provide additional habitat and ecological utility. FEMA has produced a document on sustainable engineering solutions for river erosion control which includes a description of bioengineered logjams (also included in Attachment B). A number of case histories in which logjams have been used for erosion control and habitat creation are provided in the attachment.

Figure 4. Logjams installed in Washington State (image from "Engineering With Nature – Alternative Techniques to Riprap Bank Stabilization," FEMA; included in Attachment B).

RETAINING STRUCTURES AND SLOPE STABILIZATION

Retaining structures and other slope stabilization technologies may be required at OU 2 to ensure slope stability when a RCRA Subtitle C cap is installed on the steep slopes at OU 2. Some limited use of retaining walls, especially along the existing railroad adjacent to the J.M. Mills Landfill on the opposite side of the river, or site re-grading may be necessary to support the RCRA Subtitle C cap. As a part of ecological revitalization and beneficial Site reuse, and also as a result of public comments, it is desirable for any retaining structures installed at OU 2 to blend into the area, provide useful habitat, and not obstruct potential post-closure reuse of the Site.

Some gabion walls, segmental retaining walls, and mechanically stabilized earth walls are capable of supporting vegetation. Using a vegetated wall enhances the surrounding ecosystem and the can help with beneficial reuse of the Site. It also addresses aesthetic-related public comments concerning not wanting the capping of the landfills to include unsightly slope stabilization measures. Gabion walls are typically steel wire or polymer strand baskets filled with cobbles. When stacked together, they form inexpensive gravity retaining walls. These walls are typically viewed as being easier to install than other options. Vegetation will eventually grow through the walls to blend into the environment. Segmental retaining walls function similarly to gabion walls except that concrete blocks are typically used instead of wire baskets filled with cobbles. Vegetation can grow through some types of segmental retaining walls. Benching of the wall can provide additional plantable space. These walls are usually easy and inexpensive to install compared to other wall types. Mechanically stabilized earth (MSE) walls are retaining walls that use horizontal inclusions to internally reinforce the retained earth instead of resisting earth movement with heavy gravity blocks. MSE walls can be constructed with geotextile wrapped faces, allowing vegetation to grow through the wall face. When finished, they can easily blend into the surrounding environment. They are recognized as having relatively low cost and providing low impact construction.

Benching is another way of stabilizing steep slopes without the use of retaining walls. Benches function to increase the base resistance of a shallow slide mass by using the weight and shear strength of the cover soil overlying the geosynthetic components. Benches can serve other uses as well such as holding stormwater conveyance drains, controlling erosion and sedimentation, and providing foot path and vehicle access to the top portion of the landfill.

Geogrid and geocell geosynthetics can be installed in the cover system to increase the slope stability of steep landfill slopes by reinforcing the cover soil. These geosynthetics function by changing cover shear stress into tension forces and transferring that load into anchor trenches at the benches and top deck of the landfill. The geocell and geogrid geosynthetics interlock with the overlying cover soil to reduce shear stress transferred to the geosynthetic cap interfaces in the RCRA Subtitle C cover system. The geosynthetics need not cross the impermeable cap layers. A summary of the use of geosynthetics for reinforcement applications is provided in Attachment C.

LANDFILL GAS COLLECTION

Landfill gas collection (active or passive) may be required as a part of the final site-closure design to prevent uncontrolled gas releases. Features such as wells, headers, treatment devices, vents, and/or flares may visually impact the Site, as suggested by public comments, so measures to reduce the visual impact of these features will be needed.

A number of options exist for mitigating the aesthetic impact of gas collection systems. First, buried gas wells can be attached to a gas header underneath the ground surface in a vault, as shown in Figure 5. The landfill gas can then be piped and manifolded to a limited number of locations where the gas is treated, vented, or flared. This would reduce the number of aboveground gas collection features and therefore limit their aesthetic impacts on OU 2. It still may be necessary to limit public access to the landfill gas collection system; however, the size of the restricted areas would be minimized if manifolding were utilized in the remedial design. Second, above grade features can be concealed with shrubs and trees or by painting the features to blend into the natural environment. If designed properly, the public may not consider the features to be obtrusive to the landscape, while the system can be reasonably accessed, operated and maintained for the protection of human health and the environment.

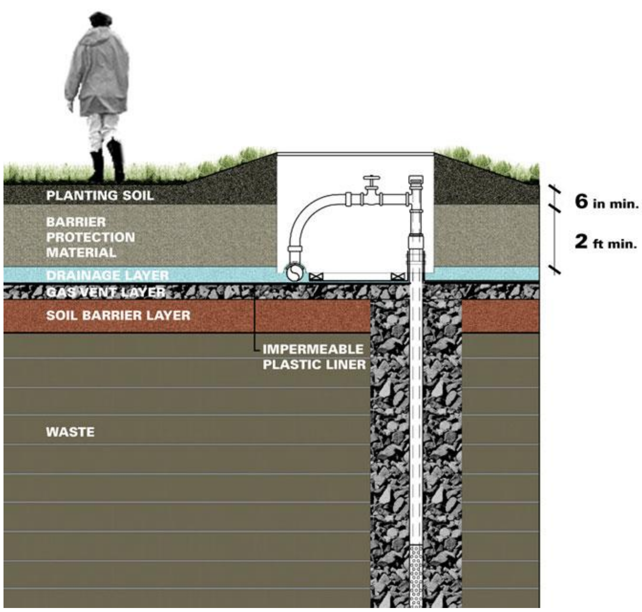


Figure 5. Landfill gas wells and headers in a vault at the Freshkills Park in New York (image from NYC Parks - http://www.nycgovparks.org/park-features/freshkills-park/about-the-site).

EMERGENCY ACCESS

Some public comments pertained to emergency vehicle access through the Nunes Parcel to the Pratt Dam and the surrounding area. The use of a RCRA Subtitle C cover system would not preclude the construction of a road on top of the landfill. Any road that is required to be constructed over the landfill surface can be engineered with geogrid reinforcement to mitigate damage to the road or cap components, including an impervious barrier. Preloading of the road area can also be used to minimize future settlement beneath the road. The presence of a paved or unpaved road on the cap is not expected to impede the functionality of the RCRA Subtitle C cover system, if properly designed.

Therefore, road access across OU 2 can be incorporated into the final design. For example, a road could be constructed along the western and southern perimeter of OU 2 to allow access to the Blackstone River and the Pratt Dam. However, it is worth noting that at OU 2 any potential future public access to the Site is controlled by private property owners.

POST-CLOSURE SITE REUSE

Similar sites with environmental caps that have been designed with post-closure reuse in mind include Spectacle Island Park in the Boston Harbor Islands, the Davison Avenue Landfill in Woonsocket, Rhode Island, and the BASF Rensselaer site on the Hudson River. These sites serve as some of the many examples of how closed landfills can be designed to include post-closure reuse, although at OU 2 any potential future reuse and access to the Site is under the control of private property owners. Additional examples of post-closure reuse are presented in the EPA document *Closed Waste Sites as Community Assets: A Guide for Municipalities, Landfill Owners, and Regulators* provided in Attachment D.

Spectacle Island Park, as shown in Figure 6, is an island in the Boston Harbor that previously served as a landfill. The site is a part of the Boston Harbor Islands National Recreation Area. The site was capped and re-graded. Hiking trails, a visitor center, wildlife habitat, shrubs, trees, brush, boat docks, recreation, restroom facilities, and erosion control were added to the site as a part of the site cleanup. A brief factsheet on the Spectacle Island Park and history is provided in Attachment D.

Figure 6. Spectacle Island (image from the National Park Service – see Attachment D).

The Davison Avenue Landfill in Woonsocket, Rhode Island (the Woonsocket Landfill) is a landfill near OU 2 where a geosynthetic cover system was installed and is currently being used by the public for recreation. The closed Woonsocket Landfill is located in the same corridor of the Blackstone River Valley National Historical Park on the bank of the Blackstone River, just a few miles from the subject Site. This former landfill now serves the public by providing soccer fields, parking, pitch and putt, a snack bar, bikeway, and river access. The landfill includes a riparian buffer between the landfill and the river. Landfill gas is vented with low-profile concrete dispersion vents. The cover system at the Woonsocket Landfill is a local example of how various reuse options can be achieved following the capping of a closed landfill. An aerial photo of this former landfill is reproduced in Figure 7.

Figure 7. Aerial photo of the Woonsocket Landfill showing post-closure site use (image from RIGIS, 2014 USGS Digital True Color Orthophotography, flown April 2014, 0.3 m resolution - http://www.arcgis.com/home/item.html?id=031a9d58324c47478f9bb9d2814dc448).

At the BASF Rensselaer site on the Hudson River, several project elements will be implemented to restore natural resources to the site. These measures are designed to allow the site to have post-closure value for the environment by letting wildlife utilize the site. In the portion of the site along the Hudson River, approximately 5,000 square feet of fringe wetland will be created. Wildlife ramps, as shown in Figure 8, will be installed to provide an ecological link from the river habitat to a newly created wooded buffer zone. The wooded buffer zone is a 50-ft wide, 600-ft long wooded area adjacent to the river that provides habitat for near shore wildlife. A 10-acre upland wildlife refuge was installed along with a half-acre fresh water pond. In addition, a LEED-certified on-site educational classroom was created to provide interpretative nature programs centered on the site wildlife.

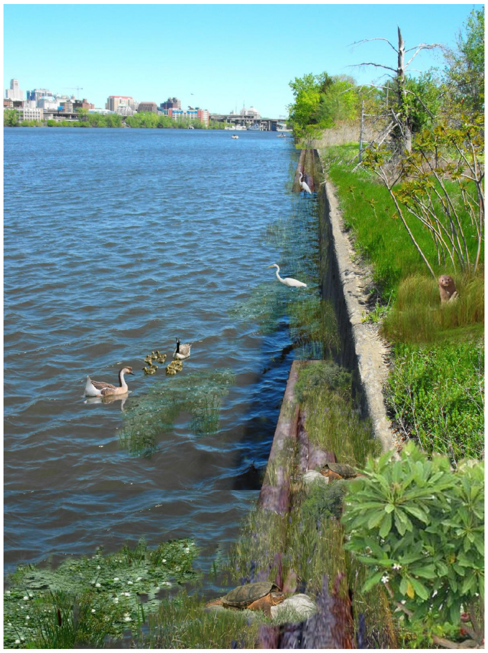


Figure 8. Conceptual rendering of the wildlife ramps at the BASF Rensselaer site (Taken from "Natural Resource Restoration Work Plan, Hudson River Operable Units 1 and 2, BASF Rensselaer, Rensselaer, New York," AECOM, February 2014).

These sites serve as some examples to illustrate that properly closed landfills can still serve high-quality post-closure uses. However, not unlike the featured example sites discussed above, ownership of OU 2 remains with private parties. Thus, any reasonably anticipated future use for OU 2 (aside from passive uses) remains speculative unless or until any prospective future land use agreements are finalized between the landowners and other parties.

STORMWATER MANAGEMENT

Federal requirements for stormwater management at landfills are summarized in part in Attachment E (state requirements are not presented, but are similar in nature). Rhode Island guidance on stormwater management can be found in the following documents:

- Rhode Island Soil Erosion and Sediment Control Handbook, Revised 2014 [http://www.dem.ri.gov/soilerosion2014final.pdf]
- Rhode Island Stormwater Design and Installation Standards Manual, December 2010 (as Amended March 2015) [http://www.dem.ri.gov/pubs/regs/regs/water/swmanual.pdf]
- Stormwater Management Plan Guidance, October 2013 [http://www.dem.ri.gov/programs/benviron/water/permits/swcoord/pdf/swmpguid.pdf]

Stormwater best management practices (BMPs) potentially applicable to OU 2 include both pollution prevention components (e.g., erosion control) and mitigation components (e.g., sedimentation basins).

BMP prevention components include good housekeeping practices (which includes capping waste), minimizing exposure (e.g., consolidating waste into one area), and erosion and sediment control (e.g., turf reinforcement mats). Many of these aspects are incorporated into the EPA's proposed cleanup alternatives for OU 2 in terms of consolidating, capping, and isolating waste and contaminated materials. Erosion control is discussed in a separate section of this memo.

Stormwater treatment BMPs could, depending on flow rates and pollutant (if any) contents, potentially be accomplished by transmitting stormwater to adjacent wetlands. Retention ponds could be constructed onsite to help reduce pollutant conveyance to the Blackstone River during rainfall events. Swales and other green infrastructure can be incorporated into the remedial design to facilitate removal of pollutants and infiltration of runoff, as appropriate.

The capping and closure of OU 2 could potentially alter the area's flood elevations by removing floodplain storage or by otherwise changing the flood hydrology of the area. This could cause a rise in flood elevations that could impact future floods if the OU 2 cleanup is not properly designed and implemented. Federal floodplain requirements (applicable to the site) for addressing up to a 500-year flood event are provided in Attachment E, and need to be considered in the remedial design for the Site.

Typically, a hydraulic model can be developed to ascertain the effect of floodplain development on potential floods. A hydraulic model can be used to compare the floodplain effects of various remedial designs. The hydraulic model can take credit for the contaminated soil removal planned as a part of this project as a benefit to the hydraulic behavior of the area.

If the preferred remedial design alternative has a net negative effect on flood elevations in the area, compensatory storage can be designed or the landfill side slopes can be steepened or cut back (within limits of design requirements) to mitigate negative floodplain effects. One of the comments on the EPA proposed plan was that potentially required compensatory storage may have a negative effect on the environment. However, any compensatory flood storage created would need to meet protectiveness standards for the environment. Therefore, if storage compensation is needed for this Site, it should be designed to have a net positive influence on the environment. Native habitat would be established in the areas where compensatory storage is created such that a net positive environmental impact is obtained. As an alternative, the side slopes of the landfill could potentially be steepened (within limits of design requirements) to offset the thickness of the installed cover system. This would be addressed through use of techniques presented in the above discussion on the use of geosynthetics to stabilize landfill caps.

Furthermore, a design consideration may be to cut-back the landfill and send the removed waste or soil to be recycled or disposed of offsite. In providing this design flexibility, and guided by a floodplain analysis and other factors, options to minimize the loss of flood storage and maximize riparian protection/restoration for the Blackstone River can be realized in the design and construction of the protective caps.

SUMMARY

- Contrary to the figures submitted by the PRPs during the public comment period, it is possible to design ecological restoration measures on the landfills under any of the landfill capping alternatives described in the Proposed Plan. All of the alternatives need to be designed to be protective up to a 500-year flood event and each underlying cap system does not preclude the development of native vegetation (including trees and shrubs) on the landfills' surfaces.
- Included in EPA's proposed RCRA Subtitle C cap system on the landfills is the requirement for ecological restoration/revitalization of OU 2.
- A RCRA Subtitle C cap system is compatible with native vegetation such as shrubs, bushes, and trees. The cover need not be limited to a grass monoculture.
- A restored riparian zone with natural habitat is compatible with proper closure of OU 2 and a RCRA Subtitle C cap system.
- Erosion control practices necessary to prevent the Blackstone River from eroding OU 2 are not limited to "hard" armoring systems such as riprap. A recommendation is to consider bioengineering to naturally protect the river bank in combination with turf reinforcement mats and other geosynthetics.
- Slopes at OU 2 could be steepened and stabilized as needed to accommodate a RCRA Subtitle C cap using aesthetically pleasing retaining walls, benches, and geogrid/geocell reinforcement.
- Another design alternative to reduce the need to create additional flood storage compensation and to address riparian habitat mitigation concerns is to cut back the slopes of the landfills and to recycle or dispose of the removed material at a licensed off-site disposal facility.
- It is possible to conceal and manifold landfill gas collection infrastructure (actual or passive) that is likely required at OU 2, to limit its aesthetic impact. This should be considered during design.
- It is possible to construct roads over the RCRA Subtitle C cap system (if needed), including for emergency access. This should be considered during design.
- A RCRA Subtitle C cap system is compatible with potential post-closure Site reuse for passive recreation along the river corridor that is compatible with the goals of the Blackstone River Valley National Historical Park. Post-closure Site reuse can be wide ranging, as illustrated by examples from other sites, but would be subject to the approval of the OU 2 landowners.
- It is possible to control stormwater runoff from the RCRA Subtitle C cap system with appropriate BMPs for appropriate pollution and watershed management. This should be considered during design.
- An evaluation of the effect that Site closure may have on floodplain hydraulics can be modeled to determine if compensatory storage for the proposed closure is required. If needed, it is possible that such storage can be designed and constructed in an environmentally beneficial way. This should be considered during design.

ATTACHMENT A

ECOLOGICAL REVITALIZATION

ECOLOGICAL REVITALIZATION:

Turning Contaminated Properties Into Community Assets

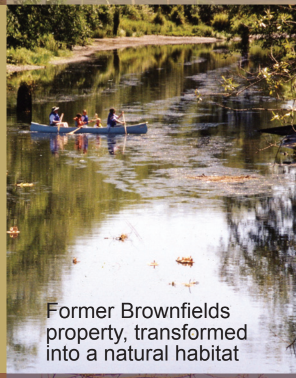
A pocket park at a former service station

Former RCRA Corrective Action facility, restored to a wetland

Constructed wetland on a Superfund landfill site

Former Superfund site restored to natural habitat

Former weapons manufacturing site, now a national wildlife refuge

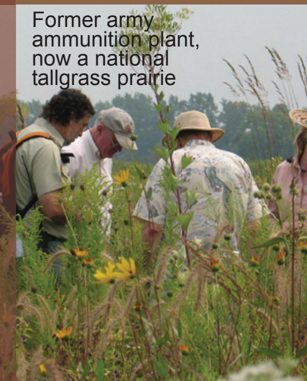


Former Brownfields property, transformed into a natural habitat

Former RCRA Corrective Action facility, now part of the Audubon Trail

February 2009

Former Brownfields property, restored to natural habitat



Former army ammunition plant, now a national tallgrass prairie

About the cover page: Ecological Revitalization in Action

Descriptions are in a clock-wise direction, starting with top right.

1. **Former RCRA Corrective Action facility, restored to a wetland**: Ecological revitalization at the AMAX Metals Recovery Inc. (now Freeport McMoRan) in Braithwaite, Louisiana, where a water retention pond was dewatered to form a wetland that provided a home to alligators relocated due to Hurricane Katrina in 2005. *Photograph courtesy of U.S. Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA) Corrective Action Program.*

2. **Former weapons manufacturing site, now a national wildlife refuge**: Nearly 27 square miles at Rocky Mountain Arsenal (RMA) in Colorado, one of the worst hazardous waste sites in the country, have been transformed into one of the nation's largest urban national wildlife refuges. The open space surrounding a former weapons manufacturing facility at RMA provides a home for nearly 300 species of wildlife including birds, mammals, reptiles, amphibians, and fish. *Photograph courtesy of EPA Office of Superfund Remediation and Technology Innovation (OSRTI).*

3. **Former RCRA Corrective Action facility, now part of the Audubon Trail**: At England Air Force Base in Louisiana, areas excavated during cleanup became part of the Audubon Trail, provided habitat and a stopping point for migratory birds, and expanded an 18-hole golf course. *Photograph courtesy of EPA RCRA Corrective Action Program.*

4. **Former army ammunition plant, now a national tallgrass prairie**: At the Joliet Army Ammunition Plant (JOAAP) in Illinois, nearly 19,000 acres of land contaminated with explosives and other chemicals were remediated and transformed into the Midewin national tallgrass prairie, one of the first in the country. About a third of Midewin is now open to the public with trails for hiking, biking, or horseback riding, and areas to observe habitat revitalization. *Photograph obtained from a JOAAP brochure titled "From War to Peace" provided by EPA Federal Facilities Restoration and Reuse Office (FFRRO).*

5. **Former Brownfields property, restored to natural habitat**: With assistance from an EPA Brownfields Assessment grant, Lancaster County, Pennsylvania, was able to turn blighted land into natural and recreational greenspace. The 23.5-acre former industrial property has been transformed into hiking trails, picnic grounds, scenic overlooks of the Susquehanna River, and nesting habitat that fostered the reemergence of the Bald Eagle in this area. *Photograph courtesy of EPA Office of Brownfields and Land Revitalization.*

6. **Former Brownfields property, transformed into a natural habitat:** At the Hoquarton Natural Interpretive Trail in Tillamook, Oregon, a former lumber mill was transformed into a recreational and educational greenspace using an EPA Revolving Loan Fund. Weeds and invasive plants were removed, more than two tons of trash was disposed of, and over 2,000 native plants were introduced in riparian areas. A nature trail provided walking and bird watching opportunities. *Photograph courtesy of Oregon Department of Environmental Quality.*

7. **Constructed wetland on a Superfund landfill site**: At the 1.2-acre landfill at the Naval Amphibious Base Little Creek Superfund Site in Virginia Beach, Virginia, 29,000 tons of non-hazardous soil and debris were removed and 6,300 cubic yards of clean fill were imported to convert the landfill to a tidal wetland. Plants were placed along designated elevations to establish tidal wetland vegetation, using the neighboring marsh as a reference. *Photograph courtesy of Bruce Pluta, EPA Region 3, Biological Technical Assistance Groups (BTAG).*

8. **A pocket park at a former service station**: The small West Ogden Pocket Park property in urban Chicago, Illinois, was a former service station that included a derelict building where underground storage tanks (UST) ranging in size from 600 to 10,000 gallons were dumped illegally. At this site, eleven USTs containing gasoline, diesel, heating oil, and used oil were present. UST removal, site cleanup, and revitalization led to the opening of the pocket park in summer of 2001 and added much-needed greenspace to the surrounding neighborhood. *Photograph courtesy of EPA Office of Underground Storage Tanks and Wildlife Habitat Council fact sheet, EPA-510-F-04-007.*

9. (Center) **Former Superfund site, restored to natural habitat:** At the Jacks Creek/Sitkin Smelting & Refining, Inc. Superfund Site in Maitland, Pennsylvania, wetlands were recreated in the riparian corridor along Jacks Creek. Vernal pools were created, woody debris was placed in the wetland as invertebrate habitat, and a wet meadow seed mix was used. *Photograph courtesy of Bruce Pluta, EPA Region 3, BTAG.*

Office of Solid Waste
and Emergency Response

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http://clu-in.org

Ecological Revitalization: Turning Contaminated Properties Into Community Assets

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Appendices

Notice and Disclaimer

The U.S. Environmental Protection Agency (EPA) funded preparation of this document under Contract No. EP-W-07-078. It was prepared by EPA's Office of Solid Waste and Emergency Response (OSWER) cleanup programs, including the Office of Superfund Remediation and Technology Innovation (OSRTI), Office of Resource Conservation and Recovery (ORCR) (formerly known as Office of Solid Waste), Federal Facilities Restoration and Reuse Office (FFRRO), Office of Brownfields and Land Revitalization (OBLR), and Office of Underground Storage Tanks (OUST).

This document has undergone EPA and external review by subject matter experts. All web links provided in this document were accurate and valid at the time of publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. If you have questions about this document, please contact Ms. Michele Mahoney, EPA, by phone at 703-603-9057 or via e-mail at mahoney.michele@epa.gov.

To view or download a portable document format (PDF) version of *Ecological Revitalization: Turning Contaminated Properties Into Community Assets* (EPA 542-R-08-003), visit the Hazardous Waste Clean-up Information (CLU-IN) system Web site at www.clu-in.org/download/issues/ecotools/Ecological_Revitalization_Turning_Contaminated_Properties_into_Community_Assets.pdf. A limited number of printed copies are available free of charge and may be ordered via the Web site, by mail, or by fax from:

EPA/National Service Center for Environmental Publications
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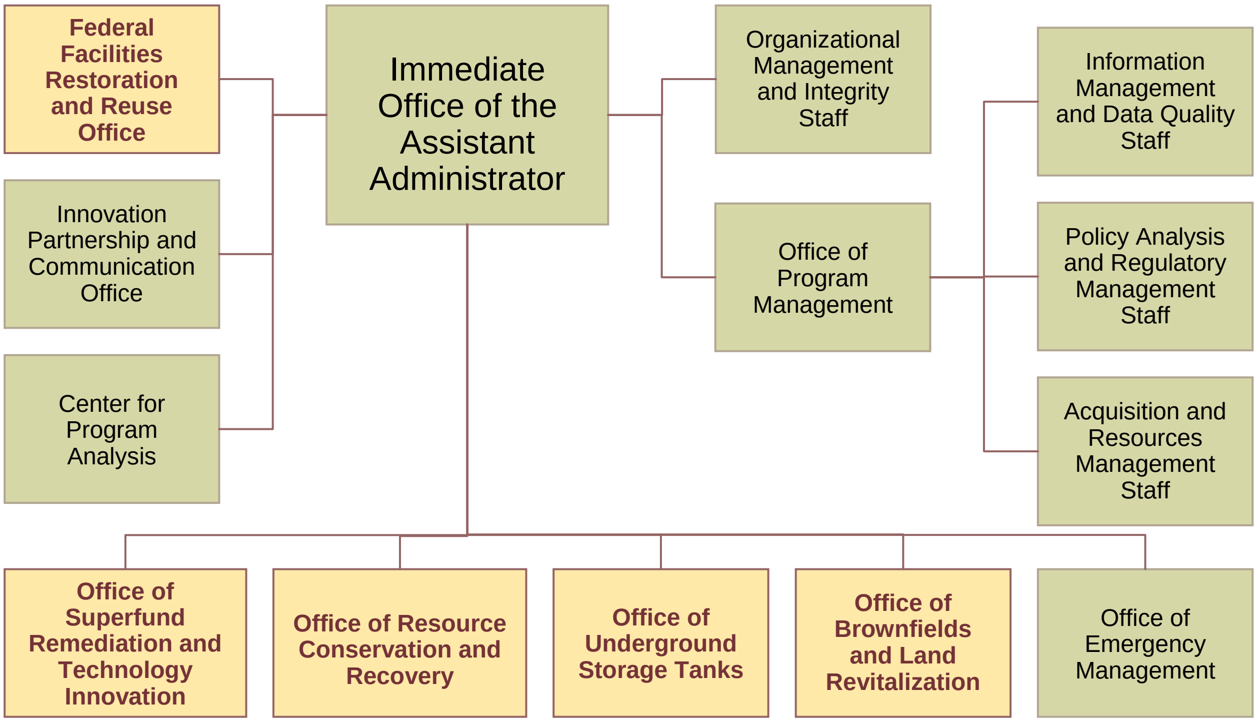
Cincinnati, OH 45242-2419
Telephone: 800-490-9198
Fax: 301-604-3408
Web site: www.epa.gov/nscep

EPA Office of Solid Waste and Emergency Response Organizational Chart

(As of January 2009)



Note: Highlighted EPA offices contributed to the development of this document.

Executive Summary

Ecological revitalization refers to the process of returning land from a contaminated state to one that supports a functioning and sustainable habitat. Although the final decision on how a property is reused is inherently a local decision that often rests with the property owner, the U.S. Environmental Protection Agency (EPA) actively supports and encourages ecological revitalization, when appropriate, during and after the assessment and cleanup of contaminated properties under its cleanup programs. This document (1) provides an overview of EPA's cleanup programs and resources available to support ecological revitalization; (2) addresses technical considerations to help cleanup project managers and other stakeholders carry out ecological revitalization at contaminated properties; and (3) presents general planning and process considerations for ecological revitalization of wetlands, streams, and terrestrial ecosystems as well as successful long-term stewardship. Appendix A at the end of the document presents additional case studies on ecological revitalization.

Ecological Revitalization Under EPA Cleanup Programs. Ecological revitalization of contaminated properties is consistent with EPA's mission to protect human health and the environment, and it is an integral component of EPA's cleanup programs. Under its cleanup programs, EPA ensures that (1) ecological revitalization does not compromise the protectiveness of the cleanup and (2) the best interests of stakeholders are considered. EPA's cleanup programs have established initiatives that support ecological revitalization and provide a variety of tools, information resources, and technical assistance. Collaboration and coordination with stakeholders is important for promoting ecological revitalization across EPA's programs.

Technical Considerations for Ecological Revitalization. Technical considerations for ecological revitalization include selecting appropriate cleanup technologies, addressing waste left in place, and minimizing ecological damage during the cleanup. When selecting a cleanup technology, the following may reduce ecosystem impacts during cleanup:

- Preventing access by animals that could cause damage to a cleanup technology
- Locating equipment and utilities to minimize disruption to on-site and surrounding habitat
- Selecting surface vegetation that will thrive and not interfere with the cleanup
- Evaluating the effects of amendments

Excavation and earthmoving equipment can significantly disrupt existing habitat during cleanup. Cleanup project managers are encouraged to consider the following steps to minimize habitat effects and encourage successful ecological revitalization:

- Developing and communicating ecology awareness
- Designing property-wide work zones and traffic plans
- Minimizing excavation and retaining existing vegetation
- Phasing work to stabilize one area of the property before another is disturbed
- Considering property characteristics
- Protecting on-site fauna
- Locating and managing waste and soil piles to minimize erosion
- Designing containment systems with habitat considerations
- Reusing indigenous materials whenever practical
- Controlling erosion and sedimentation
- Ensuring that borrow areas minimize effects on habitat
- Avoiding the introduction of new sources of contamination or undesirable species

For properties where waste is left in place, this document provides solutions and considerations for certain ecological revitalization issues that may arise. These include restoring soils, stabilizing metals, maintaining surface vegetation, and managing attractive nuisance issues.

Wetlands Cleanup and Restoration. Wetlands are of particular concern because in addition to intercepting storm runoff and removing pollutants, they provide food, protection from predators, and other vital habitat factors for many of the nation's fish and wildlife species. Important considerations for planning and designing wetland cleanup and restoration include:

- Evaluating the characteristics, ecological functions, and condition of wetlands
- Determining beneficial wetland functions and structures after the cleanup
- Developing a wetlands design that will achieve the stated ecological functions
- Ensuring that cleanup activities and wetland features have minimal effects on existing wetlands
- Specifying and implementing explicit maintenance requirements

Stream Cleanup and Restoration. Stream cleanups often disrupt stream flow and habitat. Considerations for (1) designing and implementing cleanups that facilitate ecological revitalization of streams and stream corridors and (2) mitigating adverse ecological effects of constructing cleanup features include:

- Stream channel restoration decisions about channel width, depth, cross-section, slope, and alignment
- Streambank stabilization measures (temporary and permanent)
- Streambank vegetation approaches
- Management of watershed processes such as increased runoff or sediment loading from construction

Bioengineering techniques that stabilize the soil or streambank by establishing sustainable plant communities have become an increasingly popular approach to streambank restoration. Stabilization techniques may include using a combination of live or dormant plant materials, sometimes in conjunction with other materials such as rocks, logs, brush, geotextiles, or natural fabrics.

Terrestrial Ecosystems Cleanup and Revitalization. Establishing a plant community that will thrive with minimal maintenance is a critical step in developing a healthy terrestrial ecosystem on cleanup properties. Factors to consider when establishing terrestrial plant communities in disturbed areas include:

- Soil suitability and the need for soil amendments or soil stabilization
- Property-specific plant selection with a preference for native plants
- Protection from disturbances (such as from grazing animals and vehicles)
- Timing to ensure optimal plant establishment

Long-Term Stewardship Considerations. On cleanup completion, operation and maintenance (O&M) activities through responsible stewardship protect the integrity of the cleanup and the functioning of the associated ecosystems. Specifically for properties where waste is left in place, long-term stewardship is necessary to ensure protectiveness of the remedy. When designing a successful O&M program for ecological revitalization, it is important to consider the following:

- Planning early for long-term stewardship
- Incorporating ecological revitalization components into general maintenance activities
- Establishing a monitoring program that incorporates the ecological revitalization components
- Using institutional controls to prevent activities that could potentially interfere or disturb ecologically revitalized areas

1.0 Introduction

Revitalizing properties for ecological purposes helps to achieve U.S. Environmental Protection Agency (EPA)'s goal of restoring contaminated properties to environmental and economic vitality. The term "ecological revitalization" refers to the process of returning land from a contaminated state to one that supports functioning and sustainable habitat. Although the final decision on how stakeholders will reuse a property is inherently a local decision that often rests with the property owner, EPA supports and encourages ecological revitalization as part of the cleanup of contaminated properties across all of its cleanup programs. Ecological revitalization has many positive effects that apply to a variety of stakeholders (see text box below). The objectives of ecological revitalization and those of the remediation process are best accomplished if they are carefully coordinated. To this end, this document provides general information for coordinating ecological revitalization during the cleanup of contaminated properties, as well as technical considerations for implementing ecological revitalization of wetlands, streams, and terrestrial ecosystems during cleanup.

The purpose of this document is to assist cleanup project managers and other stakeholders to better understand, coordinate, and carry out ecological land revitalization at contaminated properties during cleanup. The focus of this document is primarily on planning-level issues, not detailed design approaches, along with technical information and references for executing ecological revitalization activities at contaminated properties. This document highlights (1) several considerations and initiatives under EPA's Office of Solid Waste and Emergency Response (OSWER) cleanup programs that support ecological revitalization, (2) a variety of tools and resources that are available to assist cleanup project managers and other stakeholders, and (3) case studies that provide examples of ecological revitalization at cleanup properties. Another purpose of this document is to help facilitate cross-program networking while planning, designing, and implementing cleanups to help increase valuable ecosystems that are created or improved through ecological revitalization. To that end, Appendix A provides case studies on ecological revitalization approaches taken at various cleanup properties and identifies specific points-of-contact who can provide valuable insights for those interested in implementing ecological revitalization at their properties.

Ecological Revitalization Benefits a Variety of Stakeholders

Cleanup Project Managers. A restored habitat can reduce long-term operation and maintenance (O&M) requirements without compromising the effectiveness of the cleanup action. A restored habitat can also help optimize property engineering controls, such as using vegetation to reduce surface water infiltration or using wetlands as part of stormwater controls.

Potentially Responsible Parties. A valuable restored habitat could enhance a company's image and reputation in the community. Getting a property cleaned up and reused can also ease liability concerns, which in turn may have a positive financial impact.

Local Government. An ecological reuse may increase tourism, tax revenues, property values, and quality of life for residents.

Local Citizen Groups and Individuals. Increasing habitat and passive recreational activities can improve the character of the neighborhood, employment opportunities, and area air and water quality.

Environmental Organizations. Ecological revitalization projects may provide the opportunity to protect or improve local and regional habitats.

The document is organized into the following sections:

- **Section 2** presents an overview of EPA's cleanup programs and their revitalization initiatives, tools, and resources available to support ecological revitalization.
- **Section 3** provides general technical considerations for implementing ecological revitalization, including cleanup technology considerations, cleanup planning and design issues, and considerations for minimizing ecological damage during cleanups.
- **Section 4** provides technical considerations for planning and designing wetland cleanups and restoration efforts.
- **Section 5** provides technical considerations for designing and implementing cleanups that facilitate ecological reuse of streams and stream corridors and for mitigating potential adverse ecological impacts of constructing cleanup features.
- **Section 6** presents factors to consider for establishing terrestrial plant communities in disturbed areas, including general revegetation principles; protecting or creating natural terrestrial ecosystems, meadows, or prairies; and establishing vegetation on semi-arid or arid lands.
- **Section 7** provides considerations for operation and maintenance (O&M) activities to ensure the ongoing integrity of the cleanup and functioning of the associated ecosystems after cleanup completion.

This document was developed by EPA's OSWER cleanup programs, including the Office of Superfund Remediation and Technology Innovation (OSRTI), Office of Resource Conservation and Recovery (ORCR) (formerly known as Office of Solid Waste), Federal Facilities Restoration and Reuse Office (FFRRO), Office of Brownfields and Land Revitalization (OBLR), and Office of Underground Storage Tanks (OUST) (see the OSWER organizational chart, shown on page iii). **Figure 1-1** on the following page identifies specific elements of each OSWER program office's strategic plans, action plans, or program policies that establish support for ecological revitalization. EPA also encourages other public and private interests, including state and local governments and land trusts, land banks, and nonprofit organizations to participate in ecological revitalization activities, particularly in long-term stewardship at cleanup properties. While the scope of this document includes the EPA offices listed above, the information could be useful to a wide variety of additional stakeholders with an interest in the reuse or redevelopment of a cleanup property, specifically to create, restore, improve, or protect ecological resources. Therefore, this document also provides information that can be applicable to cleanup project managers, potentially responsible parties, Resource Conservation and Recovery Act (RCRA) corrective action facility owners/operators, local governments, citizen groups, environmental organizations, and other interested individuals.

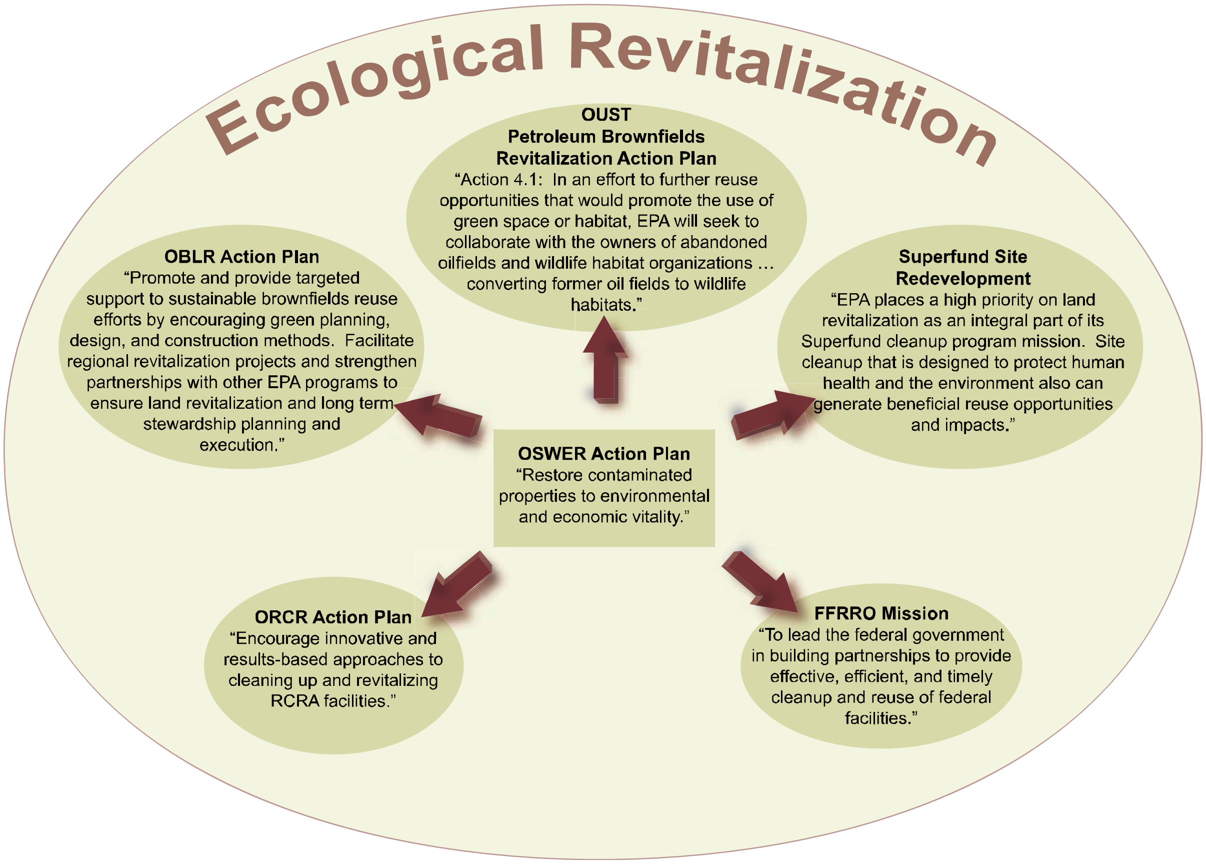
1.1 Ecological Revitalization and Ecological Reuse

The terms "ecological revitalization" and "ecological reuse" are often used interchangeably. However, there is a subtle distinction between the terms. Ecological revitalization refers to *the technical process* of returning land from a contaminated state to one that supports functioning and sustainable habitat. Ecological reuse refers to the *outcome* of a cleanup process and includes those areas where proactive measures (such as a conservation easement) have been implemented to create, restore, protect, or enhance a habitat for terrestrial or aquatic plants and animals (EPA 2006e). In this sense, the process of ecological revitalization of a property can lead to an ecological reuse outcome.

Ecological Revitalization and Ecological Reuse

There is a distinction between the terms ecological "revitalization" and "reuse" but they are related. Ecological revitalization returns land to a functioning and sustainable habitat. Ecological revitalization of a site can lead to an ecological reuse, where proactive measures have been implemented to create, restore, protect, or enhance a habitat for terrestrial or aquatic plants and animals (EPA 2006e).

Figure 1-1. Ecological Revitalization as a Component of EPA Cleanup Programs



Ecological reuse is different from greenspace use in that, in addition to habitat, the latter can include parks, playgrounds, and gardens; ecological reuse strives to restore native habitat and does not include active recreation activities. However, low-impact or passive recreation, such as hiking or bird watching, may occur at ecological reuse properties. In addition, ecological revitalization can occur on a portion of a cleanup property adjacent to greenspace use (for example, a golf course with native plant species surrounding the course), commercial operations, or industrial use. Further, ecological revitalization can occur at varying degrees; some areas of a property may be restored to relatively pristine, historic conditions, while other areas may be planted with native or other compatible species. Both degrees of ecological revitalization lead to habitat that one may accurately characterize as ecological reuse.

1.2 General Program Initiatives

EPA's 2006-2011 Strategic Plan (EPA 2006a) restates EPA's commitment to protect human health and the environment, including restoring the nation's contaminated land and enabling communities to return restored properties safely to beneficial economic, ecological, and social use. As part of the strategic plan, EPA established five goals, including:

- Clean Air and Global Climate Change (Goal 1)
- Clean and Safe Water (Goal 2)
- Land Preservation and Restoration (Goal 3)
- Healthy Communities and Ecosystems (Goal 4)
- Compliance and Environmental Stewardship (Goal 5)

Ecological revitalization contributes to each of these goals. For example, EPA's cleanup programs (under Goal 3) have set a national goal of returning formerly contaminated properties to long-term, sustainable, and productive use (EPA 2006a). These programs include Superfund (under authority of the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] of 1980, as amended), Corrective Action (under authority of RCRA), Underground Storage Tanks (UST), Federal Facilities Restoration and Reuse, and Brownfields (under Goal 4). In 2003, EPA introduced the Land Revitalization Initiative to (1) promote cross-program coordination on land reuse and revitalization projects and (2) ensure that stakeholders clean up contaminated properties and make them available for productive use. At properties that involve multiple cleanup programs, land revitalization encourages a "one cleanup program" approach to improve consistency, management, and cost-effectiveness of the program. Cleaning up previously contaminated properties for reuse reinvigorates communities, preserves open space, and prevents sprawl. This initiative goes beyond ecological revitalization, and stakeholders can use land in many ways, including new public parks, restored wetlands, and new businesses. For more information on land revitalization, visit the following Web site: www.epa.gov/oswer/landrevitalization/basicinformation.htm.

Interstate Technology and Regulatory Council (ITRC) Collaboration on Ecological Revitalization

ITRC, a state-led coalition working with the federal government, industry, and other stakeholders to achieve regulatory acceptance of environmental technologies, has compiled a wealth of information on ecological revitalization. ITRC's document "Planning and Promoting Ecological Land Reuse of Remediated Sites" (ITRC 2006) provides recommendations that are applicable to active and inactive properties and all programs. Visit the following Web site for more information: www.itrcweb.org.

In 2006, OSWER issued the Interim Guidance for OSWER Cross-Program Revitalization Measures (CPRM) (EPA 2006b, 2006e) to help track land revitalization at the national level. These revitalization measures show how EPA cleanup programs currently track their revitalization activities, as shown in **Table 1-1**.

While all environmental restoration activities that lead to reuse options are beneficial, this document focuses on ecological revitalization, which is becoming even more important as communities are increasingly seeing ecological revitalization as a desirable process to achieve a viable reuse outcome.

1.3 General Process Considerations

Ecological revitalization activities can occur on a wide variety of properties and could be compatible with several types of end uses. When considering ecological revitalization at a property, it may be useful to consider the following:

- It is important to begin the ecological revitalization process early in the cleanup.
- Ecological revitalization is not a short cut for cleanup and can have strict cleanup standards.
- Habitat can be created on an entire property or on a portion of a property, and can be created adjacent to other end uses such as intermodal centers or industrial areas.
- Ecological revitalization is not typically considered an "enhancement," so it can generally be funded by EPA (under the Superfund Program, for example), and may be needed under Section 404 of the Clean Water Act.
- Ecological revitalization provides a variety of environmental, economic, and social benefits.

The remainder of this document further discusses these considerations.

Table 1-1. Cross-Program Revitalization Measures Tracked by Each EPA Cleanup Program

Performance Measures and Indicators	EPA Cleanup Program				
	OSRTI	ORCR	FFRRO	OBLR	OUST
Universe Indicator: The number of contaminated, potentially contaminated, or previously contaminated properties and surface acres for which OSWER's cleanup programs have an oversight role for assessment or response action.	a	b	a	c	d
Protective for People (PFP) measure: The number of acres at which there is no complete pathway for human exposures to unacceptable levels of contamination based on current property conditions.	a	b	a	c	d
Ready for Anticipated Use (RAU) measure: The number of acres at a property that meets the criteria for the PFP measure, as well as (1) all cleanup goals have been achieved for current and reasonably expected land uses and (2) all institutional or other controls have been put in place.	a	b	a	c	d
Status of Use Indicator: How the acres at a property subject to the Universe Indicator are being used at the point in time when the determination is made.	a	**	a	--	--
Type of Use Indicator: For programs, regions, states, local governments, or tribes that are looking for measures they could use to help describe in more detail how contaminated or potentially contaminated properties under their jurisdiction are currently being used. For example, "ecological use" is a type of use under this indicator.	a	**	a	c	--

References: EPA 2007e; f; g and EPA 2009

Notes:

** Reporting of Indicator is voluntary at this time.

-- Indicator not tracked.

a New Land Reuse Module in Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) used to track CPRM information, independent of Government Performance and Results Act (GPRA) goals. OSRTI reports "Ready for Reuse" as a GPRA measure (based on status of cleanup and institutional controls [IC]), which equates to both PFP and RAU.

b Through 2008, the RCRA facility Indicator Universe will consist of all RCRA Corrective Action 2008 GPRA baseline facilities. For 2009 and beyond, the RCRA facility Indicator Universe will consist of all RCRA Corrective Action 2020 facilities. The Current Human Exposures Under Control Environmental Indicator (HE EI) will be used to report the PFP measure. A "RCRA RAU Documentation" form has been developed to assist in implementing this performance measure. Status of Use and Type of Use indicators are not being required at a national level. Universe and RAU data elements have been incorporated into the RCRA Information System (RCRAInfo Version 4.0 released in December 2008).

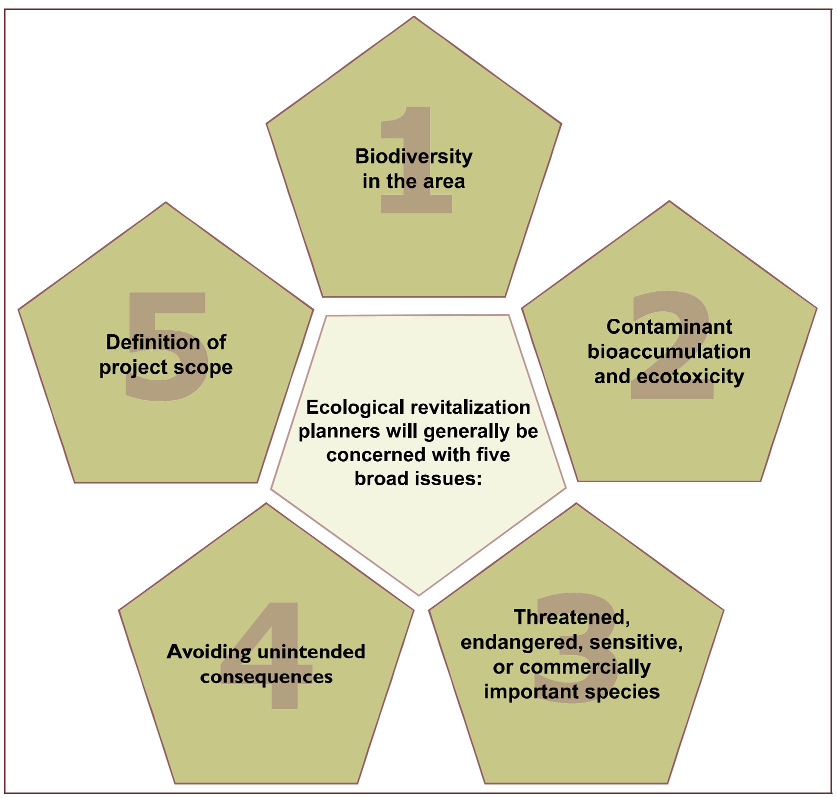
c OBLR is using Property Profile Form data to report on the Universe Indicator (properties and acres where assessment or cleanup are reported as complete for the first time under a Brownfields grant) and Type of Use Indicator (Greenspace, Residential, Commercial, Industrial, and Mixed Use). OBLR is also using their Property Profile Form to collect information on the "Ready for Reuse" measure (based on status of cleanup and IC), which equates to both PFP and RAU measures and is being reported as a Government Performance and Results Act measure by OBLR. Indicator and measure information is being tracked in the EPA OBLR Assessment, Cleanup, and Redevelopment Exchange System (ACRES) database.

d OUST's "Confirmed Release" will equal one site and one acre for the Universe Indicator; OUST's "Cleanup Completed" will equal one acre for both the PFP and RAU performance measures.

Figure 1-2: Before and after photographs of the Bunker Hill Superfund Site in Idaho where contamination was left on-site and capped with biosolids compost and wood ash. A long-term O&M plan was established to ensure that attractive nuisance (see definition on page 3-2) issues did not result. See Appendix A for additional information. *Photographs courtesy of Dr. Sally Brown, University of Washington*.

Ideally, the process of ecological revitalization begins during the assessment or investigation phase of a cleanup rather than after the remedy is underway; this allows for the greatest range of potential options and end uses. As discussed throughout this document, ecological revitalization needs additional considerations to ensure protection of wildlife that could end up inhabiting the cleaned up property, in addition to protecting human health and the environment. Some of these additional considerations are included in **Figure 1-3**.

Figure 1-3: Considerations When Planning for Ecological Revitalization



Ecological revitalization is not a short cut for property cleanup, but rather a viable and productive reuse option that also ensures protection of human health and the environment. Potential challenges to consider early in the process include (1) liability if additional cleanup or maintenance is needed, especially in the long term;

(2) public health and access if the cleanup property is converted to habitat; (3) how ecological revitalization, which can be slower than other reuse alternatives, will impact surrounding areas, and (4) transfer of land and long-term stewardship. Therefore, while ecological revitalization can be considered at all contaminated properties, it may not be appropriate for all properties. There are a variety of considerations needed to ensure protectiveness (further discussed in Section 2), including conducting an ecological risk assessment (ERA), avoiding attractive nuisances (see definition on page 3-2), and bioaccumulation issues. For example, at the Bunker Hill Superfund Site in Idaho (shown in **Figure 1-2**), attractive nuisance issues were taken into account while ecological revitalization was being considered as an option. For additional information on bioaccumulation and EPA's persistent, bioaccumulative, and toxic chemical program, visit the following Web site: www.epa.gov/pbt/index.htm. In addition, ecological revitalization may require other considerations to ensure successful creation of habitat, such as controlling invasive plant species. Technical performance measures (TPM) are available to determine the success of ecological revitalization as part of a cleanup process. For additional information on TPMs, visit the following Web site: www.clu-in.org/products/tpm.

Although commercial, industrial, residential, and some recreational uses are not ecological reuse, habitat can be incorporated as a portion of or adjacent to these redeveloped areas. For example, at the Joliet Army Ammunition Plant (JOAAP), a tallgrass prairie was created among large intermodal centers and other industrial areas. British Petroleum (BP) also plants native vegetation at its refineries adjacent to areas where occasional spills may occur to provide phytoremediation, if necessary. See Appendix A for additional information regarding the JOAAP in Illinois and the BP Former Refinery in Wyoming (a photograph of JOAAP revitalization is also included on the cover of this document).

Ecological revitalization provides a variety of positive environmental, economic, and social impacts. Some positive impacts of ecological revitalization are as follows (Interstate Technology and Regulatory Council [ITRC] 2006; EPA 2006d):

- Repairs damaged land
- Improves soil health
- Supports diverse vegetation
- Reduces erosion
- Sequesters carbon
- Controls landfill leachate
- Protects surface and ground water from potential contamination
- Helps remove stigma associated with prior waste site
- Enhances property values and raises tax revenue (www.epa.gov/superfund/programs/recycle/pdf/method.pdf)
- Provides passive recreational opportunities
- Contributes to a green corridor or infrastructure

Additional environmental, economic, and social impacts are listed in the ITRC's document, "Making the Case for Ecological Enhancements" at www.itrcweb.org/Documents/ECO-1.pdf.

The remainder of this document provides background information on ecological revitalization in relation to EPA's cleanup programs, and technical information and resources to assist in implementing ecological revitalization at contaminated properties.

2.0 Ecological Revitalization Under EPA Cleanup Programs

EPA's mission across its cleanup programs is to protect human health and the environment. Ecological revitalization of contaminated properties is consistent with this mission and is an integral component of EPA's cleanup programs. EPA recognizes the important role that it plays in helping communities and other stakeholders clean up and reclaim contaminated properties, which has led to specific programs and initiatives that support the revitalization and reuse (or continued productive use) of properties as part of their assessment and cleanup. The nature and extent of EPA involvement in supporting ecological revitalization varies from program to program, as well as from property to property. Moreover, the decision on whether and how stakeholders will reuse a property for ecological or other purposes is inherently a local decision that usually rests with the property owner.

This section presents an overview of each cleanup program under EPA OSWER (see the organizational chart on page iii of this document) and its revitalization initiatives, which provides the programmatic context for evaluating and taking steps to support ecological revitalization as part of cleaning up contaminated properties. Section 2.1 provides several considerations that are common to each cleanup program; Sections 2.2 through 2.6 address each program separately.

2.1 General Programmatic Considerations

Depending on the specific circumstances at a contaminated property, EPA's OSWER cleanup programs manage, oversee, or provide assistance with investigation and cleanup under one of several different programs, including the Superfund, Federal Facilities, RCRA Corrective Action, Brownfields, and UST programs. In some cases, individual contaminated properties can be subject to multiple OSWER programs. For example, the Rocky Mountain Arsenal involves the RCRA Corrective Action, Superfund, and Federal Facilities programs (Appendix A provides a case study on this site; a photograph is also included on the cover of this document). As illustrated in **Table 2-1** below, a variety of property types can fall under the purview of one or more programs. With proper planning, these programs can support ecological revitalization as part of, or following, cleanup.

Table 2-1: Property Types Commonly Managed Under EPA Cleanup Programs

Example Property Type	EPA Cleanup Programs				
	Superfund	Federal Facilities	RCRA Corrective Action	Brownfields	UST
Foundry	X		X	X	
Gas Station				X	X
Landfill	X	X	X	X	
Manufacturing Facility	X		X	X	X
Industry/Solvent Use	X		X	X	X
Military Installation	X	X	X		X
Other Federal Facilities*	X	X	X		X
Mining	X	X		X	
Refinery	X		X	X	X
Tannery	X		X	X	

* Non-military use facilities owned or operated by the federal government

Whether being addressed under one or several of EPA's cleanup programs, several factors determine whether and how ecological revitalization can be supported at a specific property. These factors are discussed below.

Ecological Revitalization Cleanup Standards in the Calumet Region, Chicago, Illinois

On the south side of Chicago, Illinois, a roundtable team of federal, state, and local agencies developed the Calumet Area Ecotoxicology Protocol to specifically address ecological revitalization activities in this region (Calumet Ecotoxicology Technical Roundtable Team 2007). The protocol includes cleanup standards that are protective for both human health and ecological receptors, which may be more stringent than federal and state industrial and commercial cleanup goals. Sites being cleaned up in the Calumet Region follow the protocol to ensure protectiveness of human health and the environment as well as streamline the cleanup process.

Protectiveness. An important consideration when evaluating the ecological revitalization of a property is ensuring protectiveness for both human health and the environment. EPA does not lower its standards of protection for a property that will be reused, nor does it allow reuse to reduce effectiveness of cleanup measures. Under its cleanup programs, EPA ensures that contamination is either completely removed, cleaned up to acceptable levels, or managed using protective measures that reduce the possibility of exposure to the contamination. If all contamination is eliminated, then human health and the environment are fully protected and the land or water body is available for ecological or others types of use. Where protective measures are in place for waste that remains after the cleanup, EPA determines whether such measures will continue to provide protection for ecological reuse, or whether that use might impair the protective measures. In some cases, the presence of certain contaminants (for example, persistent pollutants that are readily bioavailable, such as metals and polycyclic aromatic hydrocarbons [PAH]) remaining after the cleanup may preclude ecological revitalization efforts on those portions. Cleanup project managers will make these determinations on a case-by-case basis. One of the key challenges to implementing ecological revitalization under EPA's cleanup programs is that cleanup goals applicable to habitat creation can necessitate complex analyses. Cleanup goals for ecological protection may also need to be more stringent than for protection of human health (see text box above). Another challenge stems from a lack of familiarity with ecological end uses and ways in which to quantify the value of such end uses (EPA 2005).

Enhancement. The extent of EPA's involvement in supporting ecological revitalization at a contaminated property depends on the cleanup program involved, the legal authorities under which the property operates, and the specific property at issue. For example, under the Superfund Program, EPA cannot fund ecological enhancements (that is, activities not necessary for the protection of human health and the environment); rather, it can encourage enhancement activities funded by other stakeholders and can fund aspects of a cleanup project that are necessary for the anticipated future uses of a property. Under the Superfund Program, EPA can fund activities to better understand the reasonably anticipated future land use, which informs remedy selection and implementation and helps support long-term protectiveness. Anticipating the future use of a Superfund site after cleanup completion is of key importance in selecting and designing a remedy that will be consistent with that use. Similarly, EPA's Brownfields Program provides, among other things, technical assistance to communities to support plans for ecological and other "green" enhancements to the cleanup and reuse of properties (for example, designing rain gardens, native landscaping, or green infrastructure), but not the actual revitalization or reuse activities themselves. Other programs, such as RCRA Corrective Action or UST, encourage and support ecological revitalization through their established relationships with states that have delegated programs and through collaborative efforts with governmental and non-governmental organizations. State programs may also have limitations for funding activities that are not directly needed for the protection of human health and the environment. Property owners may see the benefits of supporting the reuse of properties, including the ecological revitalization of the land, particularly when it affects public perception of their business operations and commitment to the environment. Moreover, EPA may

Empire Canyon, Daly West Mine Site, Summit County, Utah

A resort development company has proposed the construction of a hotel, spa, and condominium project at the Daly West Mine Site, to be known as the Montage Resort & Spa. The development will contribute to the cleanup of contamination at this former mining site in Park City, Utah. The developer agreed to participate in EPA's Environmentally Responsible Redevelopment and Reuse (ER3) Initiative for contaminated properties. As an ER3 participant, the Montage Resort & Spa will incorporate extensive "green" features into the design, construction, and operation of the development, including several ecological revitalization components. For example, the project involves treatment of ground water collected by foundation drains using a constructed wetland; a native vegetation management plan to improve ecosystem health and reduce the risk of wildfires around the site; and a conservation easement for 2,800 acres of open space to offset additional density from the project. By incorporating sustainable practices and principles into the project, the developer has minimized the impact of the project on the environment without sacrificing profitability.

be able to offer certain incentives to support ecological revitalization under its initiatives, such as EPA's Environmentally Responsible Redevelopment and Reuse (ER3) Initiative.

In general, most ecological revitalization efforts are not considered enhancements if the activities are necessary for the anticipated future ecological use of the property or to restore ecological function and, therefore, can be considered and incorporated into property cleanup plans. Even costs for extensive revitalization efforts to create or restore the function of an ecosystem can be justified if the revitalization is needed because of environmental stressors or adverse impacts to the property caused by the cleanup. For example, grasses, shrubs, and other native plants serve a practical function of stabilizing soil to prevent erosion, while also improving the property's aesthetics and ecological function.

Other Cross-Cutting Ecological Revitalization Considerations for EPA Cleanup Programs

- ***Liability***: Consider who will be responsible if additional cleanup or maintenance is required, especially in the long-term.
- ***Public Health and Access***: Consider whether the public will safely be allowed to use the property if it is converted to habitat.
- ***Surrounding Areas and Time***: Ecological revitalization can impact surrounding areas because, while ecological revitalization can be a more cost-effective process, the time required to return a property to functioning and stable habitat can take longer than other reuse alternatives.
- ***Transfer of Land and Long-Term Stewardship***: Ensure that institutional controls are in place and operating effectively, and consider who will be the long-term landowner responsible for stewardship of the ecological revitalization and associated natural resources.

Stakeholder Involvement. Regardless of which EPA program is involved in the assessment, cleanup, and revitalization of a contaminated property, numerous stakeholders may have an interest in the actions taken at the property, including the following:

- Other federal, state, local, or tribal agencies
- Parties responsible for the contamination
- Current landowners
- Neighboring property owners and the surrounding community
- Prospective purchasers or future users of the property

With different stakeholders potentially involved at a contaminated property, the ecological revitalization of the property will need to consider the varied interests, objectives, and requirements of those stakeholders. Successful ecological revitalization efforts have typically resulted from well-facilitated processes that encourage open communication and the exchange of information among the stakeholders at a property.

Additional Initiatives That Support Sustainable Cleanup and Reuse. In addition to specific initiatives that are supported by EPA's cleanup programs (and described in the following sections), there are other EPA initiatives that can also support ecological revitalization at contaminated properties regardless of which OSWER program is supporting the cleanup. These initiatives include the following:

EPA's EcoTools Initiative provides a variety of resources for cleanup project managers, especially under the Superfund program. In addition to technical information, the EcoTools Web site provides cleanup project managers access to ecological experts via a technical assistance service. For more information, visit www.clu-in.org/ecotools.

EPA's ER3 Initiative uses enforcement and other EPA-wide incentives to promote sustainable cleanup and redevelopment of contaminated properties. Under the ER3, EPA collaborates with federal, state, public, and private partners to identify, develop, and deliver incentives to encourage developers and property owners to implement sustainable practices during the redevelopment of contaminated properties. The primary components of ER3 are to (1) identify and provide enforcement and EPA-wide incentives to developers and property owners to encourage sustainable cleanup and development; (2) develop partnerships with federal, state, public, and private entities to establish a network of expertise on sustainable development issues; and (3) promote sustainable redevelopment of contaminated properties through education and outreach. For more information on ER3, visit www.epa.gov/compliance/cleanup/revitalization/er3/index.html.

EPA's Five Star Restoration Program brings together students, conservation corps, other youth groups, citizen groups, corporations, landowners, and government agencies to provide environmental education and training through projects that restore wetlands and streams. The program provides challenge grants, technical support, and opportunities for information exchange to enable community-based restoration projects. Visit www.epa.gov/owow/wetlands/restore/5star for additional information about the Five Star Restoration Program.

EPA's GreenAcres Initiative promotes natural and sustainable landscaping practices using native plants and other green landscaping strategies. The GreenAcres Initiative is a component of EPA's Great Lakes National Program Office and its efforts to promote an integrated, ecosystem approach to protect, maintain, and restore the chemical, biological, and physical integrity of the Great Lakes. Under GreenAcres, EPA provides information and resources on using native plants and natural landscape approaches in urban, suburban, and corporate settings. For more information, visit www.epa.gov/greenacres.

EPA's Green Infrastructure Partnership is an initiative to work with partners to promote green infrastructure as an environmentally preferable approach to stormwater management. In January 2008, EPA and its partners released an action strategy for managing wet weather with green infrastructure. The strategy provides a collaborative set of actions that promote the use of green infrastructure and outlines efforts to bring green infrastructure technologies and approaches into mainstream wet weather management. For more information about this partnership and the action strategy, visit http://cfpub.epa.gov/npdes/home.cfm?program_id=298.

EPA's Green Remediation Initiative promotes the use of best management practices (BMP) to maximize the net environmental benefits of cleanup actions. With the help of public and private partners, EPA OSWER is documenting the state of BMPs, identifying ways to improve BMPs, and forming a community of BMP practitioners. Technical assistance is offered to cleanup project managers to find new opportunities for reducing the environmental footprint of cleanup actions. For more information about this initiative, visit www.clu-in.org/greenremediation.

EPA's GreenScapes Program identifies cost-efficient and environmentally friendly solutions for landscaping. Designed to help preserve natural resources and prevent waste and pollution, GreenScapes encourages companies, government agencies, other entities, and homeowners to make more holistic decisions regarding waste generation and disposal and the associated impacts on land, water, air, and energy use. Visit www.epa.gov/greenscapes for additional information on the GreenScapes Program.

2.2 *Superfund Sites*

EPA's OSRTI carries out the Superfund Program, which addresses contamination from uncontrolled releases at hazardous waste sites that threaten human health and the environment. EPA manages the Superfund Program under the authority of the CERCLA, 1980, as amended. Under the Superfund Program, abandoned, accidentally released, or illegally dumped hazardous wastes that pose a current or future threat to human health or the environment are cleaned up. To accomplish its mission, EPA works closely with communities, potentially responsible parties, and other federal, state, local, and tribal agencies. Together with these groups, EPA identifies hazardous waste sites, investigates the conditions of the sites, formulates cleanup plans, and cleans up sites to ensure that they are protective of human health and the environment.

Superfund cleanups include both long-term and short-term response actions. Long-term cleanups or remedial actions are conducted on sites that, following an evaluation, are listed on the National Priorities List (NPL). Once on the NPL, EPA follows a thorough process to carefully investigate the site and select and carry out a remedy specific to that site. Short-term cleanups called removal actions, fall into three categories: (1) non-time critical responses at sites where on-site activities do not need to be initiated for more than six months; (2) time critical responses at sites where on-site activities must begin within six months; and (3) emergency removal actions at sites that need initiation of on-site activities within hours of the decision that action is necessary. EPA's role and ability to support ecological revitalization may vary across these different site types, as discussed below.

Coordinating Ecological Revitalization Efforts in the Superfund Remediation Process. OSRTI established the Superfund Redevelopment Initiative (SRI) to ensure that at every Superfund site, EPA and its partners have the necessary tools and information to return the country's most hazardous sites to productive use, including information related to natural resources and ecological revitalization. In addition to cleaning up Superfund sites and making them protective of human health and the environment, communities and other partners are involved in considering future use opportunities and integrating appropriate reuse options into the cleanup process. At previously cleaned sites, communities are also involved to ensure the long-term stewardship of the site remedies. For more information on the SRI, visit the following Web site: www.epa.gov/superfund/programs/recycle.

When investigating, designing, and implementing a cleanup, remedial project managers (RPMs) are encouraged to consider, to the extent practical, anticipated future land uses. With careful planning, many Superfund sites can accommodate ecological revitalization while still meeting the requirements under CERCLA and other federal and state regulations. Stakeholders best accomplish the objectives of ecological revitalization and those of the remediation process through careful coordination. For example, under CERCLA EPA needs to coordinate with all affected Natural Resource Trustees (Trustees) when conducting a remedial investigation (RI). Trustees are designated under Executive Order 12580 and defined under CERCLA as other federal, state, or tribal governments that act on behalf of the public for natural resources under their trusteeship. Trustees often have information and technical expertise about the biological effects of hazardous substances, as well as the location of sensitive species and habitats that can assist EPA in evaluating and characterizing the nature and extent of site-related contamination. Coordination at the investigation and planning stages provides the Trustees early access to information they need to assess injury to natural resources. This assists Trustees in making early decisions about whether sites need restoration in light of the response actions.

Several types of ecological studies, including ERAs and Natural Resource Damage Assessments

Multiagency Coordination at the Atlas Tack Superfund Site, Fairhaven, Massachusetts

Agency coordination is an essential part of the Atlas Tack Superfund Site remediation. As part of planning for the ecological revitalization, EPA coordinated with the U.S. Army Corps of Engineers (USACE) and used the National Oceanic and Atmospheric Administration's (NOAA) Damage Assessment, Remediation, and Restoration Program (DARRP), which acts as a Federal natural resource trustee. NOAA contributed to the development of site-specific sediment remedial goals and the wetland removal plan, and greatly assisted in the design of the mitigation resulting in ecological revitalization at no additional cost to EPA. USACE and NOAA jointly designed separate fresh and salt water marshes to outcompete an invasive species at the site. Using remedial funding, three Federal agencies worked cooperatively to create an effective, natural remedy for the site. For more information, see Appendix A and visit www.epa.gov/ne/superfund/sites/atlas.

(NRDAs), support cleanup and ecological revitalization decisions at a Superfund site. EPA utilizes an ERA as part of its process for assessing the risks of site-related contamination. ERAs are usually conducted during the Remedial Investigation/Feasibility Study (RI/FS) phase of the Superfund response process and inform RPMs about the risk associated with the site. While physical impacts of site cleanup activities are assessed during the FS, ERAs specifically evaluate the likelihood that adverse ecological effects are occurring or may occur because of exposure to chemical (for example, release of hazardous substances) stressors at a site. These assessments often contain detailed information regarding the interaction of these "stressors" with the biological community at the site. Part of the assessment process includes creating exposure profiles that describe the sources and distribution of harmful entities, identify sensitive organisms or populations, characterize potential exposure pathways, and estimate the intensity and extent of exposures at a site. The National Oceanic and Atmospheric Administration (NOAA), a natural resource trustee, and the U.S. Army Corps of Engineers (USACE) played an important role in remediation of the Atlas Tack Superfund Site in Massachusetts, including conducting a site-specific ERA (EPA 2008h) based on the cleanup goals that were established for this site (see text box on this page and **Figure 2-1**). Additional information about this remedy is available at http://www.clu-in.org/download/newsltrs/tnandt1208.pdf.

Trustees also conduct NRDAs, at sites with viable responsible parties, to calculate the monetary cost of restoring natural resources injured by releases of hazardous substances. They evaluate damages to natural resources by identifying the functions or "services" provided by the resources, determining the baseline level of the services provided by the injured resource(s), and quantifying the reduction in service levels because of the contamination. ERAs form the basis for establishing cleanup goals and may contain important information that EPA, Trustees, and risk assessors can use to evaluate ecological revitalization at a site.

While property owners and communities generally conduct land use planning with input from stakeholders, it is important for EPA to understand the anticipated future uses for the site when planning and implementing the remedy. Establishing remediation goals for ecological receptors can be challenging if there is limited data on toxicity, effects on receptor species, and contaminant bioavailability. These challenges can be overcome by planning ahead and collecting appropriate ecotoxicological data (such as contaminant bioavailability and site-specific toxicity), reviewing the open literature and previous ERAs for data, and coordinating with stakeholders to identify site-specific receptors and past incidents of exposure. Uncertainties that cannot be addressed may be documented as part of the site-specific ERA and considered when selecting the site remedy or reuse. Stakeholders have the greatest reuse flexibility if remediation and reuse plans are coordinated *prior* to cleanup. EPA plays an important role in the planning process by communicating key information about the nature of contamination at the site, remedy options, and long-term protectiveness issues.

Stakeholders can still implement ecological revitalization even after the cleanup is complete. In 2004, EPA developed the Return to Use (RTU) Initiative to remove barriers to appropriate reuse at the hundreds of Superfund sites where cleanup has been completed. A focus of RTU has been on establishing partnerships with communities and other stakeholders to address potential obstacles to reuse. Through site-specific partnerships, referred to as demonstration projects, EPA is working with key stakeholders at RTU sites to identify potential reuse barriers and appropriate solutions for those obstacles (EPA 2008a). For more information on the RTU, visit www.epa.gov/superfund/programs/recycle/activities/rtu.html.

Coordinating Ecological Revitalization Efforts in the Superfund Removal Action Process. EPA has prepared a reuse assessment guidance for non-time critical removal actions (see Reuse Assessments Directive, OSWER 9355.7-06P, at www.epa.gov/superfund/programs/recycle/policy/reuse.html); however, guidance is not currently available regarding reuse assessment for time-critical and emergency removal actions. The accelerated and time sensitive nature of these cleanups creates a challenge, as removal teams often complete their activities before there is an opportunity to consider reuse. In some cases, cleanup project managers can quickly conduct an ERA for a removal action, if there is an eminent threat to ecological receptors. However, these instances are rare and the removal action ERA follows the same process outlined for long-term ERAs conducted during the RI/FS. Because the time critical removal process is much faster than the remedial process, implementing reuse planning involves creating a targeted, expedited approach so that reuse can inform the removal action. For example, at the Calumet Container Superfund Site in Hammond, Indiana, EPA conducted a time critical removal action where ecological revitalization drove the reuse strategy for the site. In addition to contaminated soil removal, the removal action also included restoring wetlands and planting native plants. EPA worked successfully and expeditiously with stakeholders to determine future anticipated use of the site (see Appendix A for additional information about this site.)

Tools and Resources. The Superfund Program has developed and made available a variety of tools and resources supporting site reuse in general and ecological revitalization in particular (see www.epa.gov/superfund/programs/recycle/tools/index.html for a list of specific tools and resources that are available). In general, site managers can use SRI guidance documents to create and integrate reuse processes at sites undergoing either a remedial and removal action. SRI has also developed a community involvement process to advance reuse at remediation sites, which could be helpful at removal sites.

The Superfund Program has also developed several resources for site managers, consultants, and others interested in restoring disturbed sites. The Ecotools Web site (www.clu-in.org/ecotools) provides information on soil health, principles of ecological land reuse, and links to various federal, state, academic, and nonprofit agencies and organizations that support ecological revitalization. Through the Ecotools Web site, technical assistance is available for Superfund sites on various ecological revitalization topics, including ecological reuse of contaminated sites, use of soil amendments, use of native plants, control of invasive species, and re-vegetation. Fact sheets and Web-based seminars that focus on tools, methods, and technologies for implementing ecological reuse are also available. Answers to frequently

Technical Assistance for Ecological Revitalization at Superfund Sites

Regardless of the scope of the revitalization project, technical assistance can be obtained from the EPA's regional Biological Technical Assistance Groups (BTAG) (EPA 1991; see Appendix B for links to regional BTAG Web sites), EPA's Emergency Response Team (www.ert.org), EPA's Office of Superfund Remediation and Technology Innovation (OSRTI; www.epa.gov/tio), EPA's Ecotools Web site (www.clu-in.org/ecotools), and the U.S. Department of Agriculture's Natural Resources Conservation Service (www.nrcs.usda.gov).

Figure 2-1: Before and after photographs of the Atlas Tack Superfund Site in Massachusetts where the remedy resulted in preservation of wetland sediment and created a functioning wetland. See Appendix A for additional information. *Photographs courtesy of Elaine Stanley, EPA Region 1*.

asked questions related to ecological revitalization, re-vegetating landfills and waste containment areas, and attractive nuisance issues are available online at www.clu-in.org/pub1.cfm (EPA 2006c, d; EPA 2007c). The Green Remediation Web site (www.clu-in.org/greenremediation) provides various resources for cleanup project managers interested in incorporating green remediation strategies into cleanup actions. Resources include information on the use of BMPs; contracting and administrative toolkits; decision-making tools; links to initiatives involving green remediation applications; technical resources; and site-specific case studies. Technical assistance is also available for cleanup project managers in answering general inquiries about green remediation and for Superfund RPMs to build site-specific green remediation strategies. A useful resource available through this Web site is a technology primer on Green Remediation (EPA 2008j) that outlines the principles of green remediation and describes opportunities to reduce the carbon footprint of cleanup activities throughout the life of a project.

In addition, groups such as regional Biological Technical Assistance Groups (BTAG), which are typically composed of biologists, ecologists, and ecotoxicologists from EPA, and agencies such as the U.S. Fish and Wildlife Service (USFWS), NOAA, and state environmental departments, could provide assistance during cleanup of a site to support ecological revitalization efforts.

2.3 Federal Facilities

EPA's FFRRO works with other EPA offices and federal entities to facilitate faster, more effective, and less costly cleanup and reuse of federal facilities. The federal facilities universe includes NPL sites and certain Base Realignment and Closure (BRAC) facilities (each subject to their respective provisions of CERCLA). The main difference between federal facilities and private Superfund sites is that at federal facilities, EPA has an oversight role rather than primary cleanup authority, which falls to the other federal agency. Many of the site-specific considerations for Superfund sites listed in Section 2.2 also apply to the federal facilities listed on the NPL as well as federal facilities not listed on the NPL (non-NPL sites). Additional challenges that might apply to federal facilities include special circumstances based on the contamination at that facility, such as munitions constituents.

FFRRO and Interagency Coordination

In addition to EPA, FFRRO works with the following federal agencies to coordinate initiatives related to the cleanup of federal properties:

- Federal Aviation Administration
- Defense Logistics Agency
- National Aeronautics and Space Administration
- National Guard
- Small Business Administration
- U.S. Air Force
- U.S. Army
- U.S. Army Corps of Engineers
- U.S. Coast Guard
- U.S. Department of Agriculture
- U.S. Department of Defense
- U.S. Department of Energy
- U.S. Department of Interior
- U.S. Department of Transportation
- U.S. Navy

FFRRO's BRAC Program develops policies, plans, and initiatives to expedite the cleanup and reuse of closing military installations. Since 1993, the BRAC Program has worked with U.S. Department of Defense (DoD), state environmental programs, local governments, and communities to achieve its goal of "making property environmentally acceptable for transfer, while protecting human health and the environment." For more information, visit the following Web site: www.epa.gov/fedfac/about_ffrro.htm.

To implement congressionally mandated actions, EPA issued guidance on how to transfer federal facilities contaminated with hazardous wastes before cleanup completion. In the past, contaminated federal facilities had to undergo complete cleanup at least one year before transfer if hazardous waste was released from, disposed of, or stored on-site. Now, federal agencies can transfer properties prior to cleanup, as long they meet certain conditions. By transferring property that poses no unacceptable risks, communities benefit from faster reuse and redevelopment (EPA 2008c).

Ecological revitalization is a part of many Department of Energy (DOE) and DoD facility reuse projects. Examples include Pease Air Force Base, JOAAP, Rocky Mountain Arsenal, Fernald, and Rocky Flats, which all have major ecological reuse components. See Appendix A for additional information on these case studies; the cover of this document includes a photograph of JOAAP.

Coordinating With Other EPA Offices and Programs. In carrying out its mission, FFRRO works closely with other EPA headquarters offices, including OSRTI, which manages the Superfund Program; ORCR, which manages the RCRA Corrective Action Program; and the Federal Facilities Enforcement Office (FFEO), which oversees compliance with environmental laws and guidance. EPA's Regional offices are also key partners in accomplishing EPA's federal facilities mission. RPMs and

Midewin Tallgrass Prairie at the Joliet Army Ammunition Plant, Will County, Illinois

After working with the community and other stakeholders, the remediation team cleaned up contaminated soil through excavation and bioremediation. More than 19,000 acres of land was transferred to the Forest Service to create the Midewin Tallgrass Prairie, the first national tallgrass prairie in the country. While it will take years to fully restore the land, about a third is now open for the public to observe ongoing habitat restoration, as well as to hike, bike, or ride horseback on interim trails. For more detailed information about this example, see Appendix A.

A Wildlife Refuge at the Rocky Mountain Arsenal in Commerce City, Colorado

EPA is partnering with the Army, Shell Oil, and the Colorado Department of Public Health and Environment to transform the Rocky Mountain Arsenal facility, one of the worst hazardous waste sites in the country, into one of the largest urban national wildlife refuges. The partnership is addressing contaminated ground water, surface water, soils, and buildings. Under the management of the U.S. Fish and Wildlife Service (USFWS), 27 square miles of open space surrounding the manufacturing facility is home to nearly 300 species of wildlife. After the cleanup is complete, the property will become a permanent part of the National Wildlife Refuge System (EPA 2008b). For more detailed information about this example, see Appendix A.

Community Involvement Coordinators (CICs), as well as toxicologists; attorneys; and reuse, tribal, and environmental justice coordinators based in each regional office work closely with EPA headquarters staff to coordinate site-specific cleanup activities. For issues requiring specialized expertise, FFRRO also collaborates with related EPA headquarters offices on a project-specific basis. Additionally, FFRRO co-chairs the Federal Facilities Leadership Counsel (FFLC), a coordinating body within EPA that provides direction and leadership on federal facility cleanup efforts. The FFLC is a forum for addressing a wide spectrum of federal facility cleanup issues, including compliance, technical, enforcement, financial, budgeting, and legislative issues. The FFLC includes EPA regional federal facility program and project managers, regional counsels, and headquarters staff from FFRRO and FFEO.

Coordinating With Other Agencies. FFRRO's partners include governmental and non-governmental groups that are involved in federal facilities cleanup. FFRRO works directly with other federal agencies, primarily DoD and DOE, to coordinate initiatives related to cleanup of federal properties.

FFRRO partners also include state, local, and tribal governments; community groups; environmental justice communities; and advocacy organizations. Local stakeholders include individuals, community groups and any other entities that might be affected by contamination, cleanup activities, or both. FFRRO encourages early and meaningful community involvement at all federal facilities.

Tools and Resources. FFRRO provides a variety of information resources about its programs, policies, and partners. The following Web sites provide access and information about its resources:

Visit www.epa.gov/fedfac/info.htm for access to EPA FFRRO's publications, newsletters, information centers, and other information resources.

Visit www.epa.gov/swerffrr/policy.htm for access to federal facilities related laws, regulations, policies, and guidance.

Visit FFRRO's comprehensive, searchable library of resources related to federal facility restoration and reuse topics at http://cfpub.epa.gov/fdrl/index.cfm.

2.4 RCRA Corrective Action Facilities

EPA's ORCR regulates all household, industrial, and commercial solid and hazardous waste under RCRA, 1981, as amended. One important objective of EPA's RCRA Program is to protect the public from the management and disposal of hazardous wastes that RCRA facilities generate as part of normal operations. Examples of RCRA facilities include metal finishing operations, auto body repair shops, dry cleaners, chemical manufacturers, foundries, locomotive and railcar maintenance operations, and steelworks. In some cases, these facilities are no longer operational, have no significant activity, or are now vacant. Accidents or activities by hazardous waste generators or at hazardous waste treatment,

BP Former Refinery, Casper, Wyoming

Under a RCRA Corrective Action Consent Decree, BP and the Wyoming Department of Environmental Quality (DEQ) cleaned up this 4,000-acre former refinery located along the banks of the North Platte River and incorporated several ecological revitalization components, creating wildlife habitat and allowing recreational reuse of the facility. Soda Lake, which was once used to dispose of waste water from the refinery, has been revitalized. BP worked with local citizens and the Audubon Society to design a bird sanctuary and resting ground for migrating birds. The reuse plan also incorporated a wetland treatment system into the design of a golf course constructed on the facility. The team planted more than 2,000 a trees as part of phytoremediation approach for cleaning up of portions of the property (EPA 2007a). This facility is a good example of how ecological revitalization measures can be incorporated at a facility with ongoing manufacturing activities. For more detailed information about this facility, see Appendix A.

storage, and disposal facilities regulated under RCRA may release contaminants into the environment. The RCRA Corrective Action Program ensures that regulated facilities that accidentally or otherwise release hazardous waste investigate and clean up such hazardous releases. The RCRA Corrective Action Program differs from Superfund in several ways. First, RCRA facilities often have viable owners and operators and on-going operations. As such, how best to use/reuse the property is ultimately the decision of the property owner, including whether to incorporate ecological revitalization elements on the facility. Second, EPA has delegated the RCRA Program to 43 states and territories that directly manage and oversee the Corrective Action Program; EPA implements the program in other unauthorized states.

In 1998, EPA established the RCRA Reuse and Brownfields Prevention Initiative to encourage the reuse of facilities subject to corrective action under RCRA so that contaminated or otherwise under-used land

Figure 2-2: Before and after photographs of England Air Force Base in Louisiana where contaminated areas were excavated and became part of the Audubon Trail, providing habitat and a stopping point for migratory birds. See Appendix A for additional information. *Photographs courtesy of RCRA Corrective Action Program*.

transitions back into productive use or greenspace (EPA 2008a). Several activities under this initiative support the ecological revitalization of RCRA facilities. One such activity is a cooperative agreement between EPA and the Wildlife Habitat Council (WHC). Under this agreement, the WHC works with EPA and other stakeholders to incorporate ecological revitalization into the cleanup design for end uses, hence providing wildlife habitat (WHC 2008). For example, corrective action at the Ford Rouge Center in Dearborn, Michigan, included ecological components to minimize impacts to the Rouge River. The cleanup team restored or created new wildlife habitat, including hedgerow wildlife corridors and wetland and grassland restoration. In addition to wildlife habitat, the project included other sustainable elements, such as installing a vegetated roof, using pervious pavement, and including phytoremediation. Because many aspects of the project involved ecological enhancement activities, the Ford Motor Company funded most of the activities on the property, with some additional funding provided through a state grant (for a stormwater swale) and an EPA grant to the Dearborn Public Schools System under its Five Star Restoration Grants Program (to support wetlands restoration activities). See Appendix A for a case study regarding this facility.

DuPont-Remington Arms Facility, Lonoke, Arkansas

The DuPont-Remington Arms Facility continues to manufacture munitions on 385 acres of the 1,116-acre facility. The company manages the remaining 731 acres as a wildlife habitat. In cooperation with Ducks Unlimited, the cleanup team constructed a 20-acre moist soil impoundment for waterfowl habitat (EPA 2007b). See Appendix A for more detailed information about this facility.

EPA introduced RCRA Cleanup Reforms in 1999 (EPA 1999b) and additional Reforms in 2001 (EPA 2001) to more effectively meet the goals of the RCRA Corrective Action Program and speed up the pace of cleanups. One initiative of the 2001 Cleanup Reforms is capitalizing on the redevelopment potential of RCRA Corrective Action facilities. In addition, the RCRA program issued guidance to tailor cleanups to facility-specific end uses, including ecological end uses, while maintaining the ultimate goal of protecting human health and the environment. The “Guidance on Completion of Corrective Action Activities at RCRA Facilities” 68 FR 8757 (Feb 25, 2003) describes how corrective actions can be completed with contaminants remaining, using controls tailored to protection for a specific end use for the property (EPA 2005).

In most cases, facilities that are subject to RCRA corrective action continue their operations throughout the cleanup process. Although operations continue at these facilities, opportunities to incorporate ecological revitalization measures still may exist at parts of the property where there are no ongoing operations (see the DuPont-Remington Arms Facility text box). Facilities that are no longer continuing their current industrial or waste management operations may also provide opportunities for ecological revitalization. Some examples include the Ford Rouge Center in Michigan, the BP Oil facility in Lima, Ohio, and the Hopewell Plant (Honeywell) in Hopewell, Virginia. See Appendix A for additional information on these case studies. In

Reuse at RCRA Corrective Action Facilities

In Spring 2001, a survey to determine trends in reuse potential of the 155 RCRA federal lead corrective action facilities in EPA Region 5 identified that 32 percent of all facilities (a total of 49) have potential for habitat or natural area restoration as a sole option or in combination with other reuses (EPA 2002b). While current, nationwide data is not available for ecological reuse of RCRA facilities, at least two regions (EPA Regions 3 and 10) recently conducted studies regarding their RCRA facilities’ status and type of use. The results show that, even though most land use on RCRA facilities is industrial, as stakeholders reuse more RCRA facilities, a broader range of use is occurring. Visit the following Web site to review the results from EPA Region 3’s study: www.epa.gov/region03/revitalization/R3_land_use_final/data_results.pdf.

some cases, especially with large properties, parcels of the property may provide special reuse opportunities (for example, riverfront location, road or rail access, or community reuse interest). In particular, many large RCRA facilities are federal facilities that may include large tracts of land that could be suitable for ecological revitalization or conservation easements. Stakeholders may be able to reuse uncontaminated parcels or those parcels on a shorter cleanup schedule more quickly than the entire facility (EPA 2008e). For example, at the former England Air Force Base in Alexandria, Louisiana, areas excavated as part of a remedial action became part of the Audubon Trail, providing habitat and a stopping point for migratory birds (see **Figure 2-2**). See Appendix A for additional information on this case study.

Tools and Resources. ORCR provides a variety of information resources about its programs, policies, and partners. The following Web sites provide access and information about its resources:

Visit www.epa.gov/epawaste/hazard/correctiveaction/bfields.htm for information on the RCRA Brownfields Prevention Initiative and case study examples of successes under the initiative.

Visit www.epa.gov/epawaste/hazard/correctiveaction/resources/index.htm for guidance and other information about RCRA corrective action.

2.5 Brownfields Properties

EPA's OBLR manages the Brownfields Program under the authority of Small Business Liability Relief and Brownfields Revitalization Act of 2002 (the "Brownfields Law"). EPA designed its Brownfields Program to empower states, communities, and other stakeholders to work together in a timely manner to prevent, assess, safely clean up, and sustainably reuse brownfields properties.

Brownfields are real property[1], the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Included in the definition of Brownfields properties are sites contaminated with petroleum that represent a relatively low risk, including properties where the contamination resulted from an UST (Section 2.6 provides information on EPA's UST Program). An estimated 450,000 brownfields properties are located throughout the country (www.epa.gov/brownfields/about.htm). Cleaning up and reinvesting in these properties relieves development pressures on undeveloped, open land while both improving and protecting the environment.

The Brownfields Program is a grant-based program that promotes green, ecological, and open space uses as part of its competitive grants process. These grants support revitalization efforts by funding environmental assessment, cleanup, and job training activities. Brownfields funds can support sustainable remediation measures and planning for ecological revitalization (as the reuse of the property), but typically not actual revitalization or reuse activities. EPA's grant review process generally favors grant proposals that include ecological reuse as part or all of the ultimate reuse goals, especially with respect to greenspace and sustainable use criteria. The ultimate decision on

Sequim Bay Estuary,
Jamestown S'Klallam Tribe, Washington

The Jamestown S'Klallam Tribe used an EPA Brownfields Cleanup grant to clean up and restore estuary function to 82 acres of Sequim Bay. Cleanup activities included removing pilings, contaminated soil, and solid waste from the shoreline and riparian wetlands. The bay now provides clean sediment and habitat for shellfish, salmon, and other species. See Appendix A for more detailed information about this case study.

[1] "Real property" is a legal term indicating a property consisting of lands and of all appurtenances to lands, as buildings, crops, or mineral rights (distinguished from personal property).

Figure 2-3: Before and after photographs of the Grace Lease Property in Pennsylvania, where a former industrial area was revitalized to natural habitat. See Appendix A for additional information. *Photographs obtained courtesy of Office of Brownfields and Land Revitalization.*

whether a brownfields property will include ecological revitalization remains with the community receiving the grant. Although data specifically on the ecological revitalization of brownfields properties are not available, data reported by grantees on reuse measures for OBLR from fiscal year (FY) 2003 to FY2007 indicated that an estimated 4,756 acres were ready for reuse, and more than 507 acres of greenspace or open space were created (EPA 2008i). The Grace Lease property in Pennsylvania (see **Figure 2-3**) is an example of a restored Brownfields property, which had been dormant for nearly a century and was then converted into a natural habitat. A Brownfields Assessment Grant allowed stakeholders to study contaminant levels at the blighted property, remove uncertainties associated with property contamination, and transform the dormant property into usable greenspace for the community.

The Brownfields Program also encourages the incorporation of green infrastructure into brownfields redevelopment projects. Green infrastructure techniques, such as bioswales, green roofs, and rain gardens, present an opportunity to return land to functioning and sustainable habitat. Other green infrastructure practices can also retain, treat, and release stormwater without exposing it to contaminated soils. For more information about this effort, visit www.epa.gov/brownfields/publications/swdp0408.pdf.

Brownfields and Land Revitalization Technology Support Center (BTSC)

Coordinated through EPA's Technology Innovation Program, the BTSC ensures that Brownfields decision makers are aware of the full range of technologies available to make informed or "smart" technology decisions for their properties, including support for ecological revitalization. BTSC provides a readily accessible resource for unbiased assessments and supporting information on options relevant to specific properties, including a technology-oriented review process for investigation and clean-up plans for these properties. The BTSC also provides information about other available support activities, such as those conducted by the Technical Assistance to Brownfields (TAB) Program located at five regional Hazardous Substance Research Centers. Direct support is available to EPA regional staff, state staff, and local governments. For more information, visit www.brownfieldstsc.org.

The Brownfields Program also provides Training, Research, and Technical Assistance Grants to fund projects that explore innovative ideas in the areas of protection of human health and the environment, sustainable development, and equitable development. Each assistance project will receive between $100,000 and $150,000 in annual funding for up to five years. Recipients can use the grants to support a variety of projects including, ecological revitalization, sustainable uses of land, and green jobs in communities. For more information about these grants, visit www.epa.gov/brownfields/trta.htm.

Other initiatives under the Brownfields Program can also contribute to ecological revitalization of brownfields properties. For example, through its partnership with Groundwork USA and the National Park Service Rivers, Trails, and Conservation Assistance Program, OBLR works with communities to improve their environment, economy, and quality of life through local action. This partnership also results in the ecological reuse of brownfields properties through Groundwork Trusts. Visit www.groundworkusa.net/index.html for more information about the Groundwork USA network.

Under the Sustainable Sites Initiative, EPA is currently working with the U.S. Green Building Council to provide a framework for the green development of brownfields properties. The framework is similar to what the Leadership in Energy and Environmental Design (LEED) system has accomplished for green buildings. The framework includes considerations for cleaning or mitigating all hazardous substances from prior use, supporting sustainable landscape principles and practices, and preventing the creation of future brownfields. For more information, see the following document: www.sustainablesites.org/report/SSI_Guidelines_Draft_2008.pdf.

Tools and Resources. OBLR provides a variety of information resources about its programs, policies, and partners. The following Web sites provide access and information about these resources:

Visit www.brownfieldstsc.org for information on strategies, technologies, and technical assistance available to support the investigation and cleanup of brownfields properties.

Visit www.epa.gov/swerosps/bf/toolsandtech.htm for access to a variety of tools and technical resources available to support property reuse.

Visit www.epa.gov/swerosps/bf/initiatives.htm for information on the various EPA and related initiatives that may be applicable at brownfields properties.

Visit www.epa.gov/swerosps/bf/partnr.htm to learn more about the partnerships that EPA has entered in support of brownfields revitalization and reuse.

2.6 Underground Storage Tank Sites

EPA's OUST manages and oversees the UST Program, which seeks to prevent leaks or releases of petroleum or certain hazardous substances from USTs, and ensures that contamination from USTs is cleaned up. OUST manages the program under the authority of several statutes, including Subtitle I of RCRA, as amended by the 1984 Hazardous and Solid Waste Amendments, the 1986 Superfund Amendments and Reauthorization Act, and the Energy Policy Act of 2005. States and territories primarily implement the UST Program, while EPA implements the UST Program in Indian Country. OUST administers the Leaking UST Trust Fund, which provides money for (1) overseeing and enforcing corrective action taken by a responsible party, who is the owner or operator of the leaking UST; and (2) implementing cleanups at UST sites where the owner or operator is unknown, unwilling, or unable to respond, or which need emergency action.

A key provision of the 2002 Brownfields Law allocates 25 percent of funding each year to assess, cleanup, and make ready for reuse petroleum brownfields properties that are relatively low risk. Of the estimated 450,000 brownfields properties in the U.S., approximately half are affected by USTs or some type of petroleum contamination (EPA 2008f). OUST is responsible for promoting the cleanup of sites with leaking USTs and coordinates with OBLR to refine the implementation of the law's petroleum provisions to allow more sites to support appropriate reuse or revitalization (EPA 2008d).

To encourage the reuse of abandoned properties contaminated with petroleum from USTs, OUST created the USTfields Initiative in 2000. USTfields are abandoned or underused industrial and commercial properties where revitalization is complicated by real or perceived environmental contamination from USTs. The purpose of these pilots was to promote the importance of public-private partnerships; the critical role of the state as the primary implementing agency; and the leveraging of private funds to maximize cleanups. Although OUST will not award any new USTfields pilots beyond the original 50 pilots, sites may receive funding for similar assessment and cleanup projects through the Brownfields assessment, cleanup, and revolving loan fund grants and through the Leaking Underground Storage Tanks (LUST) Trust Fund.

Pocket Park at a Former Service Station, Chicago, Illinois

A former service station in Chicago was transformed into a small pocket park using native plantings. This pocket park initiative is a joint effort by BP, the City of Chicago, and the local community. The contaminants of concern at the site were benzene, toluene, xylenes, and ethylbenzene (BTEX) at levels above maximum contaminant levels (MCLs) but not at levels that would pose a risk to the surrounding community. Once the site received "no further remediation" letters and was considered cleaned up, the team planted native species to create pockets of habitat for wildlife, expand greenspace for the community, and reduce stormwater runoff by reducing paved surfaces. See Appendix A for more detailed information about this example; this document's cover also includes a photograph of this pocket park.

Coordinating with Other Agencies. A major component of OUST's efforts to support the revitalization of contaminated sites caused by leaking USTs is collaboration with federal, state, and local agencies, and tribal and private partners to foster the revitalization and reuse of petroleum-contaminated sites. OUST also works with numerous grant recipients to enhance their efforts to revitalize petroleum brownfields. For example, OUST collaborated with the Indiana Brownfields Trails and Parks Initiative, which uses EPA grant funding to provide environmental assessments to local governments and non-profits for brownfields properties (including petroleum brownfields) where parks, trails, or other green uses are planned (see www.in.gov/ifa/brownfields/files/TPI_Fact_Sheet_6-18-08.pdf for more information on this state program). OUST is also partnering with EPA's Office of Policy, Economics, and Innovation (OPEI) to utilize several assistance mechanisms, such as the SmartGrowth America National Vacant Properties campaign. This campaign provides local planners with the information needed to consider viable reuse options, such as green or open spaces, at abandoned or under-utilized service stations and other petroleum brownfields.

OUST entered into a cooperative agreement with the WHC to help maximize the ecological benefits of reusing petroleum brownfields. One goal of the agreement is to demonstrate how federal, state, and local governments, tribal partners, industry, and community groups can use ecological revitalization to facilitate the restoration of petroleum brownfields for a variety of uses, including wildlife habitat. Under the agreement, the WHC will demonstrate the use of the latest technologies for applying ecological enhancements to site cleanups. Specific objectives for the partnership include: (1) achieving greater regulatory flexibility and support for ecological enhancements; (2) developing a strategy for obtaining constructive and meaningful stakeholder involvement; (3) ensuring sound scientific and technical support for ecological enhancement practices; and (4) promoting the value of ecological enhancements through a broad range of communication tools. OUST works with the WHC to identify opportunities to include ecological enhancements in end use plans at petroleum-contaminated sites. The pocket park project highlighted in the text box on the previous page is one of several successes resulting from this collaboration. WHC documents and provides case studies on a variety of programs on the following WHC Web site: www.wildlifehc.org/brownfield_restoration/lust_pilots.cfm.

OUST collaborated across all levels of government and with private industry to develop a Petroleum Brownfields Action Plan that improves stakeholder communications; expands technical assistance to states, tribes, and local governments; explores potential policy changes; and builds upon existing successes by expanding partnerships and testing new and innovative approaches to petroleum brownfields revitalization (EPA 2008d). The Action Plan provides a comprehensive framework for enhancing revitalization efforts at petroleum brownfields and promoting information sharing from both public and private sector efforts to revitalize petroleum brownfields. Four initiatives outlined in the Action Plan cover broad areas and can further EPA's collective efforts to highlight all applicable reuse options. Tasks within three of those initiatives are applicable to ecological revitalization and include the following:

- **Action Item 1.3** provides a basis for developing a "petroleum reuse/options catalogue" that could help compile and update information on reuse options and associated partnerships, as well as provide insights for interested parties to consider when addressing comparable sites.
- **Action Item 2.3** provides a framework to help eligible entities develop voluntary inventories of petroleum brownfields that complement local end use planning efforts.
- **Action Item 4.2** promotes the use of greenspace or wildlife habitat through collaboration with wildlife habitat organizations and property owners (of abandoned oil fields or urban petroleum brownfields) to support converting these properties to wildlife habitats.

OUST does not currently track the indicators listed in **Table 1-1** related to the status and type of end use. However, OUST is committed to tracking the mandatory measures and has developed the OUST Cross-Program Measures commitment memorandum (EPA 2007e). Petroleum brownfields sites are difficult to track and coordinate because of their small size, scattered distribution, variable ownership, and associated uncertainties in cleanup costs and liability. Continued coordination with organizations, such as the WHC, could help to provide a consistent means of tracking site reuse. Revitalizing petroleum sites also remains a local endeavor, and by enhancing public-private coordination, OUST intends to promote the appropriate use of petroleum brownfields sites to help meet community, end user, and stakeholder needs. Ultimately, though, local organizations drive the end use of each site.

Tools and Resources. OUST provides a variety of information resources about its programs, policies, and partners. The following Web sites provide access and information about its resources:

Visit www.epa.gov/swerust1/pubs/index.htm for publications that support the investigation and cleanup of leaking USTs.

Visit www.epa.gov/swerust1/rags/ustfield.htm to learn more about the USTFields Initiative and to access case studies on the pilot projects for examples and lessons learned associated with the reuse of former UST properties.

More information about the issues and opportunities associated with petroleum or UST brownfields cleanups is also available at www.nemw.org/petroleum%20issue%20opportunity%20brief.pdf (Northeast-Midwest Institute 2007; EPA 2008e).

3.0 Technical Considerations for Ecological Revitalization

There are several technical considerations for implementing ecological revitalization while cleaning up a property that are common to each of the cleanup programs discussed in Section 2.0. The objectives of ecological revitalization and those of the cleanup process are best accomplished if they are coordinated carefully. This section summarizes technical considerations for common cleanup and revitalization technologies that stakeholders can use during planning and design with the intent to minimize ecological damage during cleanups. Specifically:

- Section 3.1 presents factors to consider when selecting cleanup technologies for ecological revitalization.
- Section 3.2 addresses issues that may occur when waste is left in place at a cleanup property, how they could affect ecological revitalization, and potential approaches to mitigate these issues.
- Section 3.3 identifies ways to minimize ecological disruptions during cleanups.

3.1 Considerations When Selecting Cleanup Technologies for Ecological Revitalization

When designing and implementing any cleanup action at a contaminated property, it is necessary to consider certain factors related to natural resources or ecological revitalization (see text box below). Numerous *in situ* cleanup technologies can be used to ensure that contaminated properties are managed in a manner that protects human health and the environment; complies with federal, state, and local cleanup requirements; and allows for safe ecological revitalization. These cleanup technologies can include source control treatment (for example, soil vapor extraction and bioremediation), source control containment (for example, caps and barriers), institutional controls, and monitored natural attenuation. For additional information on a variety of cleanup technologies, visit EPA's CLU-IN Web site (www.clu-in.org/techfocus) and the Annual Status Report (www.clu-in.org/asr). These cleanup technologies can affect ecosystems such as wetlands, streams, and upland areas such as meadows, prairies, and woodlands; therefore, it is important to consider their possible effects during ecological revitalization. While many of these effects are technology and property-specific, some general considerations apply, including the following:

- **Amendments**: Some *in situ* treatments involve adding amendments to the contaminated media. Project managers could evaluate their effects in the subsurface, their potential for eventual transport to surface waters, and their possible subsequent adverse effects on plant and animal communities. Some examples of soil amendments include organic matter additions such as biosolids, compost, manures, digestates, pulp sludges, yard wastes, and ethanol production by-products; lime; wood ash; coal combustion products; foundry sands; steel slag; dredged materials; and water treatment residuals. At the California Gulch Superfund Site in

When designing and implementing a cleanup action, it is important to consider the following:

- Physical and biological condition of the property and its location in relation to local and regional plant and animal species
- Regulatory requirements governing cleanup and protection or creation of ecologically significant areas
- Temporary and long-term ecological impacts
- Types of habitats that are to be protected, restored, or created at the property

Colorado, the remediation team applied lime and municipal biosolids to reduce the acidity of mine tailings and to reduce the bioavailability of heavy metals at the site (see **Figure 3-1**). For additional information on soil amendments, see the following document: www.clu-in.org/download/remed/epa-542-r-07-013.pdf.

- **Regulatory requirements**: Federal and state regulations may apply to organic amendments such as biosolids, manures, and pulp sludges. State and local regulations apply to pH-adjusting amendments such as lime and wood ash as well as mineral amendments, such as foundry sand and dredged materials. For additional information, see the following document: www.clu-in.org/download/remed/epa-542-r-07-013.pdf (EPA 2007d).

- **Attractive nuisance**: An attractive nuisance is an area, habitat, or feature that is attractive to wildlife, where waste or contaminants that have been left on site after a property is cleaned up that may be harmful to plants or animals. One objective of cleaning up such a property is to remove the pathway from a contaminant to a receptor. Some cleanup technologies, such as amended covers, are designed to prevent contact exposure, but they are not a barrier against burrowing animals. Preventing burrowing animals that could cause damage to a cleanup technology from entering the area, through fencing or other means, would help to keep the remedy intact, and protect the animals from coming in contact with the waste left on site. For additional information, see the following document: www.clu-in.org/s.focus/c/pub/i/1438.

- **Equipment and utility location**: Equipment generally needs periodic maintenance and monitoring. The cleanup team can maximize potential for habitat formation and biodiversity, and minimize disruption, by carefully considering the location of equipment. This might mean placing equipment near the edge, rather than in the middle, of a valuable habitat. For example, confining property disturbance to areas within 15 feet of roadways.

- **Hydrology and surface water management**: Cleanup technologies that could affect hydrology need to be designed carefully to avoid adverse effects on existing and anticipated habitat. For example, over pumping by ground water pump and treat (P&T) systems can cause dewatering of wetlands because over pumping lowers the water table (EPA 1993). Alternatively, discharging process water to surface waters and wetlands changes water depth, turbidity, circulation, and temperature. The use of settling basins and other such measures can help moderate discharges to wetlands and streams.

- **Surface vegetation**: Cleanup project managers are encouraged to consult technical experts to determine appropriate surface vegetation that will thrive but not interfere with the cleanup. For example, revegetation designed to emulate the native plant communities in the surrounding area would increase chances of success. However, vegetation growing near equipment related to a cleanup technology, such as a diversion wall, may prevent access to the equipment for maintenance and could cause performance issues. In addition, it is important to consider ecological succession when determining appropriate vegetation. Plant communities will naturally shift toward a climax community unless periodic maintenance is performed. When the cleanup technology, such as phytoremediation, employs vegetation, the plants selected to phytoremediate can also serve as a buffer to control runoff or stabilize soil or streambanks. Stakeholders can obtain technical assistance through a variety of sources, including EPA's regional BTAG (www.epa.gov/oswer/riskassessment/ecoup/pdf/v1no1.pdf), EPA's Emergency Response Team (www.ert.org), and EPA's Ecotools Web site (www.clu-in.org/ecotools).

The considerations mentioned above, in addition to others shown in **Table 3-1** at the end of this section, play a role in addressing cleanup planning and design issues when considering ecological revitalization at properties where waste is left in place.

Figure 3-1: Before and after photographs of the California Gulch Superfund Site in Colorado where site managers used high rates of lime amendment to neutralize the acidity of the mine tailings and applied municipal biosolids directly into the tailings along the Upper Arkansas River. See Appendix A for additional information. *Photographs courtesy of Michael Holmes, EPA Region 8.*

3.2 Cleanup Planning and Design Issues and Ecological Revitalization

The text box at the right outlines some general steps when planning and carrying out ecological revitalization projects during cleanup planning and implementation. However, a number of issues associated with the application of a cleanup technology can alter the effectiveness of the cleanup or the ecological revitalization of a property. **Table 3-1** at the end of this section presents several issues that may occur when waste is left in place at a cleanup property, how they could affect ecological revitalization, and potential approaches to mitigate these issues. By carefully accounting for these issues at the outset, cleanup project managers can ensure the long-term success of the cleanup and minimize the potential negative effects of the cleanup approach on future uses of the property.

General steps when planning and implementing an ecological revitalization project

- Determine pre-disturbance and reference conditions
- Conduct a property inventory
- Establish revitalization goals and objectives
- Evaluate revitalization alternatives
- Develop a property-specific ecological design
- Prepare specifications for construction contractors
- Construct habitat features
- Conduct maintenance and monitoring activities

3.3 Minimizing Ecological Damage During Cleanups

Cleanups that include excavation and require earthmoving equipment can disrupt the surface area of a property and cause considerable loss of existing habitat as well as erosion, sedimentation, and colonization by invasive plants. These disruptions may also cause sedimentation or otherwise adversely affect ground water and nearby surface waters. To minimize the effects on habitat and encourage successful ecological revitalization, cleanup project managers may take steps to minimize excavation and other surface disruptions, avoid erosion and sedimentation, and protect the existing flora and fauna, by considering the following approaches (EPA 1993; Natural Resources Council [NRC] 1992; Kent 1994):

Develop and Communicate Ecology Awareness and Procedures. The process of ecological revitalization begins in the assessment or investigation phase, not after the remedy has been designed and is underway. Contractors and construction engineers are often not cognizant of sensitive ecological areas or aware that they can minimize disturbance and protect the ecology. Cleanup project managers can articulate a preservation policy and distribute it to everyone involved with on-site activities. Cleanup project managers can also incorporate requirements to protect habitat or species into construction plans, specifications, and contracts, as appropriate.

Design a Property-Wide Work Zone and Traffic Plan. The cleanup project manager can delineate staging areas, work zones, and traffic patterns to minimize unnecessary disruption of sensitive areas and existing habitat on or near a property. The cleanup team can delineate areas not requiring surface disruption and areas off-limits to disturbance, such as steep slopes, sensitive habitats, and clean stream corridors, with fences, tape, or signs to avoid disturbance by property workers and equipment.

Minimize Excavation and Retain Existing Vegetation. Earthmoving can destroy the roots of trees and other plants as well as disturb vegetation in uncontaminated areas. In addition, compaction of soil is also damaging to roots. These activities can be restricted to areas essential for the cleanup and avoided in all other areas. Some areas with low contamination levels or immobile contaminants posing no unacceptable risk to human health or the environment may be better off left undisturbed, if the disruptive effects of excavation outweigh the benefits of further cleanup, especially in valuable habitats (EPA 1998). Treatment and monitoring technologies are less invasive cleanup measures than excavation.

Myers Property Superfund Site, New Jersey

At the Myers Property Superfund site in Hunterdon County, New Jersey, (see case study in Appendix A), RPMs are saving select trees in areas with low levels of contamination by hand digging around the roots to a level of six inches. Excavated soil will be replaced with clean topsoil from off site. The site will be monitored in case large trees fall and expose soils deeper than six inches.

Phase Site Work. Sometimes cleanup project managers can phase construction by stabilizing one area of the property before disturbing another. This approach can reduce total soil erosion for the entire property and allows for revegetation or redevelopment of some areas immediately after cleanup. The cleanup project manager can also schedule construction to minimize the area of soil exposed during periods of heavy or frequent rains, and avoid sensitive periods (breeding, nesting, etc.) of certain species. For example, project managers at the Rocky Mountain Arsenal site (see case study in Appendix A and a photograph on the cover of this document) suspended cleanup activities during certain seasons to avoid disturbing the nesting and breeding of the bald eagle and other sensitive species.

Consider Property Characteristics. During the ecological revitalization of a property and to increase chances of successful revitalization, it is important that ecologists consider the following property characteristics: property size, existing habitat, proximity to undisturbed areas, topography, natural water supply, access, biodiversity (preserved by establishing connections between habitats or enlarging habitats), contaminant bioaccumulation (assessed during an ERA [EPA 1998, 1999a]), health of

Rocky Mountain Arsenal, Colorado

At the Rocky Mountain Arsenal, project managers recognized that cleanup-related traffic and road building could have major effects on the existing habitat at the 27-square-mile property. To facilitate reuse of the property as a wildlife refuge, they developed a property-wide traffic plan that routed traffic around valuable habitat and sensitive areas, minimized the potential for erosion and sedimentation, and used existing roads wherever possible. See the Rocky Mountain Arsenal case study in Appendix A for additional details.

species and ecosystems, and threatened and endangered species (usually involves the assistance of a professional biologist or ecologist). Consider surrounding habitat when selecting native species for revegetation to increase chances of success. Urban properties pose additional challenges because they are typically small and may be subject to heavy runoff containing pollutants.

Protect On-Site Fauna. In some cases, the project team may temporarily relocate on-site fauna that is being protected. Relocation may involve humane trapping and release, but less disruptive techniques may also be effective. For example, to relocate beavers and alligators at the French Limited Superfund Site in Crosby, Texas (see case study in Appendix A), project managers reduced their food supply in areas to be treated and increased the food supply in other suitable areas of the property. To protect fauna such as snakes, turtles, and some nesting birds that prefer edge habitat, it is necessary to consider careful use and parking of construction equipment in sensitive areas. For example, using construction equipment on edge habitat, or even using it to store equipment or fill material can adversely affect these species.

Locate and Manage Waste and Soil Piles to Minimize Erosion. Property cleanup may include the creation of temporary waste or soil piles to store contaminated soil for treatment or to store treated soil before redeposition. To minimize disruption of the local habitat, the cleanup project manager can structure stockpiles to minimize runoff; locate them away from steep slopes, wetlands, streams, or other sensitive areas; place them away from tree root zones to avoid soil compaction; and cover or stabilize them to control erosion and dust.

Design Containment Systems with Habitat Considerations. Building containment systems usually removes existing biota but can greatly improve the habitat, especially if the contamination present has severely degraded the area. While revegetation over containment areas or treatment systems must not detract from the effectiveness of the cleanup, cleanup project managers can design the cleanup components with ecological revitalization in mind. Cleanup project managers may also want to consider the type of contaminants, their stability, the media through which they travel, and the anticipated future land use. In addition, they may choose to avoid features that could damage the containment system or create an attractive nuisance. Where feasible, plan to allow enough soil above the protective cover to support the root systems of the intended vegetation. The use of fencing, removing access to potential food sources, or providing sufficient soil cover over the contaminated material can discourage wildlife from coming into contact with the contaminated material or from damaging a containment area.

Reuse Indigenous Materials Whenever Practical. Reusing logs, rocks, brush, or other materials found on site can provide logistical and ecological advantages as well as cost savings. Topsoil from on-site sources is usually well suited to support native vegetation. Treated soil and other materials can also be used as backfill, reducing the need for borrow areas for clean fill. Green waste, such as logs and branches can be used on site, to a limited degree, to create structure within the new habitats. Excess woody material can be shredded, composted, and used as a soil amendment. For example, at Loring Air Force Base in Northeastern Maine (see case study in Appendix A), boulders and cobbles, larger than 15 centimeters in diameter, were removed from the streambed and nearby trees during cleanup and later used in stream reconstruction, after completion of cleanup activities. Reuse of native materials at this property significantly reduced the need for additional materials and thereby achieved cost savings.

Control Erosion and Sedimentation. Revitalization areas usually need erosion and sedimentation control measures to avoid disturbing sensitive areas, even when state or local regulations do not require them. These measures can include retaining sediment on the property and managing runoff using filters, such as compost or other organic materials.

Ensure that Borrow Areas Minimize Impact on Habitat. Borrow areas, locations where cleanup teams excavate clean soil for use elsewhere during a cleanup, may be located and used with ecological revitalization objectives in mind. For example, borrow areas can be located in low-value areas to create or improve habitat and be designed, contoured, and vegetated to meet aesthetic and habitat considerations. Based on consultations with the USFWS, project managers at the Rocky Mountain Arsenal (see case study in Appendix A and a photograph on the cover of this document) designed borrow areas to establish the habitat of a planned wildlife refuge.

Avoid Introducing New Sources of Contamination. If not properly managed, cleanup activities can introduce new sources of contamination that may affect habitat and ecological receptors. Contamination can result from materials used on the property, fugitive dust emissions, and operations of equipment and sanitation facilities. Materials that can cause contamination include pesticides, herbicides, fertilizers, petroleum products, treatment agents, and solid wastes. To avoid introducing these new sources, storage areas can be sheltered from the elements, lined with plastic sheeting, surrounded by berms, and regularly inspected for releases. In addition, equipment maintenance can be done in suitable staging areas and adequate sanitation facilities for property workers can be provided away from streams, wetlands, and other sensitive areas.

Prevent the Introduction of Undesirable Species. Non-native plant species can invade and destroy native species. To prevent introducing undesirable species, monitor barren and disturbed areas, which are susceptible to colonization by undesirable plants, and remove undesirable species where necessary. In addition, equipment operators can wash trucks and equipment before entering a property to avoid introducing invasive plant seeds. Clothing and shoes can also be managed to avoid introducing invasive plant seeds.

TABLE 3-1: Cleanup Planning and Design Issues When Waste is Left on Site and Other Considerations for Ecological Revitalization

Issue	Property Type[2]	Potential Impact	Solution/Consideration
Attractive Nuisance Issues: An area, habitat, or feature that is attractive to wildlife and has, or has the potential to have, waste or contaminants left on site that are harmful to plants or animals after a property is cleaned up	Landfill Mining Site Brownfield Military Installation Foundry Gas Station Metal Plating Facility Refinery Tannery	• Harm wildlife if (1) an exposure pathway exists from contaminants left on site that could directly harm wildlife or travel up the food chain; or (2) wildlife interfere with the cleanup, thereby creating an exposure pathway	• Consider potential ecological risks throughout the cleanup process • Conduct a thorough ecological risk assessment to avoid potential attractive nuisance issues • Carefully consider plant species and the type of animals that those species will attract; protect newly planted species until they are established • For additional information, refer to EPA's fact sheet titled "Ecological Revitalization and Attractive Nuisance Issues" (EPA 2007c)
Managing Gases: Depending on the waste composition, some containment sites have the potential to generate gas	Landfill	• Provide fuel for fire or explosions • Stress vegetation • Damage cover system • Infiltrate nests or other wildlife homes • Create other health or safety hazards	• Determine ability of waste to generate gas during planning stage (EPA 1991) • Build gas collection systems • Place components where they (1) do not interfere with planned uses, (2) minimize noise and odors, and (3) are not easily accessible to trespassers or wildlife • For additional information, refer to the EPA fact sheet "Reusing Cleaned Up Superfund Sites: Commercial Use Where Waste is Left On Site" (EPA 2002a) and "Landfill Gas Control Measures" (www.atsdr.cdc.gov/HAC/landfill/PDFs/Landfill_2001_ch5.pdf)
Restoring Soil: Soils, especially those found in urban, industrial, mining, and other disturbed areas suffer from soil toxicity, too high or too low pH, lack of sufficient organic matter, reduced water-holding capacity, etc.	Mining Site Manufacturing Facility Metal Plating Facility Brownfield Refinery Tannery	• Decrease ability to support vegetation, which can lead to increased erosion and offsite movement of contaminants by wind and water	• Consider appropriate soil amendments (inorganic, organic, or a mixture) to limit contaminant bioavailability and restore appropriate soil conditions for plant growth by balancing pH, adding organic matter, restoring soil microbial activity, increasing moisture retention, and reducing compaction

[2] See Table 2-1 for EPA Programs that can apply to each property type.

TABLE 3-1: Cleanup Planning and Design Issues When Waste is Left on Site and Other Considerations for Ecological Revitalization, Continued

Issue	Property Type[2]	Potential Impact	Solution/Consideration
Settlement: The consolidation of subsurface materials at closed-in-place sites due to compaction or degradation	Landfill	• Rate and magnitude of settlement may affect the type of habitats that will be successful • Damage containment systems, alter slopes, cause gullies to form, and disturb other property features • Municipal landfills can settle up to 30 percent of the landfill depth over 15 to 30 years	• Consult with geotechnical engineer during cleanup planning to estimate settlement magnitude, distribution, and rate • If necessary, delay ecological revitalization until settlement has largely ceased, but under long-term settlement scenarios, vegetation will likely adapt to the changing property conditions • Use a nurse crop like oats, to control erosion and provide greenspace • Use construction techniques, such as preloading, vibrocompaction, and dynamic compaction, to accelerate settlement (these approaches will not affect settlement caused by biodegradation); however, do not compact topsoil because over-compaction of topsoil will result in vegetative failure
Stabilizing Metals: Some property soils contain toxic levels of metals that can be harmful to plants or animals	Mining Site Metal Plating Facility Brownfield Refinery Tannery	• Metals taken up by plants which are eaten by animals causing a potential attractive nuisance • Metals leach into ground water	• Use soil amendments to chemically precipitate or sequester metals that are present in the soil; this can reduce metal availability to plants and metal leaching into water • Select plant species based not only on availability but also on their ability to establish and grow in a newly created root zone and the species' inability to uptake metals
Surface Vegetation: Used to limit soil erosion, promote evapotranspiration and surface water management, and, in some cases, may be a component of the cleanup (for example, phytoremediation)	Landfill Mining Site Brownfield Military Installation Foundry Gas Station Metal Plating Facility Refinery Tannery	• Not all plants are well-suited to property conditions • Roots can physically damage equipment for a cleanup treatment technology, such as a barrier or well	• For wetlands, study the proper hydrology, tidal elevation, and height of a newly constructed wetland profile; these factors are of great importance to allow the new wetland (both saline and fresh) to flourish • When selecting plants, consider Executive Order (EO) 13148, which promotes use of native species • Place equipment away from areas where deep-rooted vegetation will be planted • Choose native plants found in the surrounding natural areas because they have the most chance of success, require the least maintenance, and are the most cost-effective in the long term • Ensure the waste containment system is properly designed and implemented to maintain system integrity while supporting a variety of plants • For additional information, refer to EPA's fact sheet titled "Revegetating Landfills and Waste Containment Areas Fact Sheet" (EPA 2006d)

[2] See Table 2-1 for EPA Programs that can apply to each property type.

TABLE 3-1: Cleanup Planning and Design Issues When Waste is Left on Site and Other Considerations for Ecological Revitalization, Continued

Issue	Property Type[2]	Potential Impact	Solution/Consideration
Surface Water Management: Includes a variety of activities that protect the natural functions and beneficial uses of surface waters	Landfill Mining Site Brownfield Military Installation Foundry Gas Station Metal Plating Facility Refinery Tannery	• Affects nearby vegetation, streams, lakes, and wildlife migration routes through erosion or sedimentation • Runoff controls and water diversions implemented as part of a cleanup influence water tables and the rate of flow into streams or wetlands • Erodes the top layer of a cover system • Percolates into a cap	• Design protective caps to prevent precipitation from infiltrating into the subsurface and grade the cap to establish an effective slope (usually 3-5 percent) • Route runoff through settling basins to collect sediment to reduce impacts to property hydrology and construct runoff controls to reduce the volume and rate of runoff to low-lying areas, wetlands, or streams • Use rerouted runoff to create new wetland habitat or enhance existing habitat to provide natural controls and reduce contaminant transport • Build drainage channels and swales and design diversions where possible to minimize changes to natural drainage patterns or the quantity of surface water flows to wetlands or streams • For additional information, refer to EPA's fact sheet titled "Controlling the Impacts of Remediation Activities in or Around Wetlands" (EPA 1993)
Timing: The time at which ecological revitalization is considered during the remedial planning process	Landfill Mining Site Brownfield Military Installation Foundry Gas Station Metal Plating Facility Refinery Tannery	• The longer planning is delayed, the greater the possibility that fewer reuse options will be available	• Begin revitalization planning as early as possible • Begin developing a revitalization project on parts of a property before a cleanup is completed, if possible • Consider advice from a restoration ecologist to determine the proper season to plant grasses, shrubs, and trees • Consider breeding seasons and other timing issues to avoid affecting sensitive species when scheduling remedial or revitalization activities
Utilities: Can include sanitary sewers, water, telecommunications, natural gas, and electricity	Brownfield Landfill Manufacturing Facility Military Installation Foundry Gas Station Metal Plating Facility Refinery Tannery	• Act as a conduit for gas migration • Facilitate water infiltration into a waste containment area • Require excavation into a waste containment area and contaminated material if utility repairs are necessary • Increase the quantity of leachate generated if sewer lines below a waste containment area begin to leak • Can be damaged by settlement	• Include special provisions to ensure utilities do not hinder the effectiveness of the cleanup or ecosystem functions; for example, avoid burying a utility line in a protective cap or placing it in an area where trees will be planted • For additional information, refer to the following EPA report: "Reusing Cleaned Up Superfund Sites: Commercial Use Where Waste is Left On Site" (EPA 2002a)

[2] See Table 2-1 for EPA Programs that can apply to each property type.

4.0 Wetlands Cleanup and Restoration

Wetlands are of particular concern for cleanups because in addition to intercepting storm runoff and removing pollutants, they provide food, protection from predators, and other vital habitat factors for many of the nation's fish and wildlife species (EPA 2008g). Section 3.0 discusses the general considerations that apply during planning and design of a wetland cleanup and restoration. This section summarizes wetland cleanup and restoration, focusing on specific considerations during planning and design.

Whether a cleanup involves restoring an existing wetland or creating a new one, a cleanup project manager must typically take the following steps (EPA 1988; USFWS 1984):

- Evaluate the characteristics, ecological functions, and condition of wetlands related to the property
- Determine the type of wetland functions and structures that would be beneficial in the area after the cleanup
- Develop a wetland design that will achieve the stated ecological functions
- Design the cleanup and wetland features to ensure that cleanup activities have minimum effect on existing wetlands and other ecosystems and do not create an attractive nuisance (see **Table 3-1** for additional information on attractive nuisance issues)
- Specify and implement maintenance requirements

Once it has been determined that a cleanup will affect a wetland, several key factors need to be considered, including the following:

Wetland Characteristics. The cleanup project manager may wish to determine wetland characteristics to develop a thorough understanding of the role of the wetland in the overall ecosystem and the relationships between the various plant and animal species within the wetland. It is also important to determine if any endangered, sensitive, or commercially important wetland species are present.

Wetland Regulatory Requirements. Several regulatory requirements generally apply when a cleanup or reuse project affects wetlands, including Sections 401, 402, 403, and 404 of the Clean Water Act; Section 10 of the Rivers and Harbors Appropriation Act; and the Federal Agriculture Improvement and Reform Act, commonly known as the Farm Bill. Depending on the type of cleanup and the law under which action is taken, permits may be needed prior to conducting any cleanup activities.

Wetland Vegetation and Hydrology. Analyses of hydrologic and soil conditions help define the property's wetland vegetation associations (a known plant community type, uniform habitat conditions, and uniform appearance). Generally, restoring hydrology and re-establishing a previous vegetation association tends to lead to a successful wetland ecosystem. For properties where the historical native vegetation association cannot be determined, use nearby wetlands with similar soil and hydrology

Wetland Mitigation and Ecological Revitalization

Cleanup project managers may consider ecological revitalization part of wetland mitigation depending on the property-specific habitat. However, if the wetland mitigation is part of a contaminant treatment system and is not intended to provide habitat, it cannot be considered ecological revitalization. For additional information on wetland mitigation requirements, go to www.epa.gov/wetlandsmitigation. For additional information on wetlands in general, go to www.epa.gov/wetlands.

as a guide. See example in text box to the right and **Figure 4-1** at the end of this section. For additional information on reference wetlands, visit the Society for Ecological Restoration's Web site under Section 5 of the Ecological Restoration Primer: www.ser.org/content/ecological_restoration_primer.asp. Also, consider water availability and soil type when selecting and placing the vegetation. Where appropriate, seeded species that establish quickly may be planted first, followed by species that are more difficult to establish. Where available, a natural seed bank in existing wetland soils is often adequate for establishing wetland vegetation.

Use of Neighboring Wetlands as Reference at Naval Amphibious Base Little Creek, Virginia Beach, Virginia

After removing a 1.2-acre landfill, the Navy, in partnership with EPA and Virginia Department of Environmental Quality, constructed a tidal wetland in the Chesapeake Bay. The team achieved tidal wetland hydrology by constructing two connecting channels to the nearby Little Creek Cove. In addition, they used a neighboring marsh as a reference wetland to determine appropriate plants to place along designated elevations to establish tidal wetland vegetation. See Appendix A for additional information on this case study.

Wetland Wildlife. Wetlands provide valuable wildlife habitat. The ability of a wildlife species to thrive in a wetland is dependent upon a number of factors, including the minimum habitat area necessary for the species, the minimum viable population of the species, the species' tolerance for disturbance (for example, excavation or installation of ground water pumps), and the wetland ecosystem's functional relationship to adjacent water resources and ecosystems. Thus, three factors will play a major role in determining the effectiveness of a wetland for long-term wildlife use: (1) the size of the wetland, (2) the relationship of the wetland to other wetlands, and (3) the level and type of disturbance (Kent 1994; NRC 1992; EPA 1994).

Wetland Maintenance. A variety of wetland maintenance activities are needed to ensure long-term success, including weed control and management of aggressive exotic species, such as common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), water hyacinth (*Eichornia crassipes*), and salvinia (*Salvinia molesta*). In addition, installing wire screens or other barriers around the plants or the planted area to control deer, rabbit, or beaver grazing can help protect vegetation until the ecosystem becomes established. Periodic monitoring of the wetland for plant loss, erosion, insect or disease infestations, and litter or debris buildup is also important. For properties near populated areas, public education efforts can help reduce maintenance issues associated with litter or debris dumping, off-road vehicle use, or other human activities that may threaten the long-term success of a wetland project.

Treatment Wetlands. Wetlands created to treat contaminants have some additional considerations regarding ecological revitalization and attractive nuisance issues. Conducting an ERA and monitoring of the treatment wetland until it meets cleanup goals can help to identify any potential attractive nuisance issues. Cleanup project managers are employing this approach on a variety of cleanups. For example, a public-private partnership is installing a series of passive treatment systems, including treatment wetlands, to treat acid mine drainage from abandoned surface and underground coal mines in western Pennsylvania. After passing through a series of limestone-lined ponds to neutralize pH, the water is sent through an aerobic constructed wetland to remove iron hydroxides. The system can even recover metals removed from the water so recovered metal can be sold (see Appendix A for additional information on this case study).

Bunker Hill Superfund Site in the Coeur d'Alene River System in Kellogg, Idaho

At the West Page Swamp area of the Bunker Hill Superfund Site, EPA contractors spread a cap composed of compost and wood ash over the soil to reduce accessibility and bioavailability of the underlying tailings and to restore wetland function.

Figure 4-1: Before and after photographs of Naval Amphibious Base Little Creek in Virginia, where the remediation team converted a landfill into a tidal wetland. See Appendix A for additional information. *Photographs courtesy of Bruce Pluta, EPA Region 3*.

Treatment wetlands are also used as the final polishing treatment step of a remediation scheme. For example, stormwater or effluent from ground water treatment systems can be sent through restored or created wetlands before being released to nearby waterways. This step helps remove suspended solids and other pollutants from the stormwater or effluent.

Ideally, cleanup goals will be met when using a treatment wetland to assist in property cleanup. Once the property meets its cleanup goals, components of the remedy, including a wetland, may no longer be necessary for further treatment. At this stage, coordinating with co-regulatory partners to determine long-term maintenance and stewardship responsibility for the wetland is critical. Section 7.0 discusses long-term stewardship.

For additional information on treatment wetlands, visit the following Web site: www.epa.gov/owow/wetlands/watersheds/cwetlands.html.

5.0 Stream Cleanup and Restoration

Stream cleanup and restoration are important because streams serve as corridors for migratory birds and fish, and they provide habitat to many unique species of plants and animals (EPA 2008g). Cleaning up a stream corridor can be complicated, as cleanups often disrupt the stream flow and habitat. This section provides an overview of considerations for designing and implementing cleanups that facilitate ecological restoration of streams and stream corridors and mitigating adverse ecological impacts of constructing cleanup features. A successful stream cleanup, combined with appropriate restoration strategies can hasten the recovery of degraded stream corridors and begin the natural process of restoring their ecological functions (EPA 1995).

An important first step in cleaning up a stream corridor is to assess the possible sources of disturbance from cleanup activities. Baseline data can be gathered on existing species, in-stream and riparian habitat, soil characteristics, and stream function to characterize potential degradation. Other disturbances to characterize include stream channel alteration, water quality impairment, invasion by exotic species, loss of riparian vegetation, and compaction or undercutting of streambanks. Defining the conditions of the stream corridor prior to the disturbance can help to identify the cause of the disturbance. Another important step is to determine the type of ecosystem that can be established in the stream corridor. When historical records are unavailable, information on undisturbed, nearby stream corridors with similar physical characteristics can help determine the type of ecosystem that will likely be successful at the property. The following considerations are critical to a successful stream cleanup and restoration:

Importance of Stream Corridors

Healthy stream corridors can provide important habitat for fish populations; erosion and sedimentation control; high-quality water for wildlife, livestock, flora, and human consumption; opportunities for recreationists to fish, camp, picnic, and enjoy other outdoor activities; and support for diverse plant and wildlife species.

Stream Channel Restoration. Removing contaminated sediment and soil from stream channels and banks during a cleanup typically results in severe alteration of stream flow. In such instances, reconstruction of stream channels and banks is usually necessary. Decisions about stream channel width, depth, cross-section, slope, and alignment profoundly affect future hydrology (and the resulting ecology) of the stream system. Restoration design typically considers factors such as the physical aspects of the watershed, hydrology, sediment size distribution, average flood flows, and flood frequency. When designing a stream channel restoration, the cleanup project manager can try to anticipate the effects of future land uses on the watershed. For example, the restoration of riverbanks along the Poudre River was designed to accommodate heavy recreational use while providing ecological benefits (see case study in Appendix A). For additional information, refer to resources listed in Appendix B and the following publication at www.clu-in.org/download/newsltrs/tnandt1208.pdf.

Tidal Channels

Stream channel restoration can include tidal channels. After removing contaminated sediment at the Atlas Tack site in Fairhaven, Massachusetts, site managers used coconut coir fiber logs to stabilize the salt marsh tidal channels. See Appendix A for additional information on this case study.

Streambank Stabilization. Disturbed or reconstructed streambanks often need temporary stabilization to prevent erosion. Temporary stabilization can consist of natural materials such as logs, brush, and rocks, and property planners can design it so as not to hinder permanent revegetation. At the Cache La Poudre River Superfund Site, EPA incorporated boulders and snags into the cleanup to stabilize the streambank while providing habitat (see **Figure 5-1** and case study in Appendix A). In

Figure 5-1: Before and after photographs of the Cache La Poudre River Superfund Site in Colorado, where EPA implemented an ecological remedy to preserve the riverine habitat and restore the streambank. See Appendix A for additional information. *Photographs courtesy of Paul Peronard, EPA Region 8.*

some cases, geotextiles, natural fabrics, and bioengineering techniques may be necessary. Revegetating streambanks using seeding or bare root planting techniques will often fail if the stream floods before vegetation is fully established. Consequently, temporary vegetation for stabilizing streambanks may be more successful using anchored cuttings or pole plantings (that is, woody cuttings or poles inserted and anchored into the streambank) taken from species that sprout readily, such as willows. For additional information, refer to resources listed in Appendix B.

Streambank Vegetation. Wherever possible, it is important to protect existing native vegetation, especially mature trees, during cleanup and restoration activities; however, many properties will need some revegetation. Cleanup project managers may select species for revegetation for their ability to establish a long-lasting plant community rather than as quick fixes for erosion or sedimentation problems. For example, fast growing non-native species may quickly stabilize a denuded stream bank, but over the long term, they may end up invading the entire stream corridor to the detriment of desirable native species. Approaches that attempt to establish ecosystems similar to pre-disturbance conditions tend to have more long-term success and need less maintenance than more highly engineered solutions (for example, gabions or riprap) that reduce the amount of viable habitat. For additional information, refer to resources listed in Appendix B.

Watershed Management. The entire watershed ecosystem affects the health and condition of a water body. Therefore, cleanup and revitalization may need to address watershed processes that degrade ecosystems, such as sediment loading from road cuts or construction, increased runoff from impervious areas, and other point and nonpoint sources of

Fort Collins Stream Corridor Restoration

In Fort Collins, Colorado, soil and ground water contamination migrated to the Cache La Poudre River and contaminated the sediments of this wild and scenic river. Cleanup activities included temporarily re-routing the river and excavating the contaminated sediments. The remediated portion of the river was not channelized, and EPA made an effort to create an unobtrusive remedy by consulting ecological restoration experts to create natural stream characteristics. See Appendix A for additional information on this case study.

pollution. Effective watershed management could even eliminate the need for in-stream restoration approaches.

Bioengineering techniques have become an increasingly popular approach to streambank restoration and maintenance. Bioengineering refers to stabilizing the soil or streambank by establishing sustainable plant communities. Stabilization techniques may include using a combination of live or dormant plant materials, sometimes in conjunction with other materials such as rocks, logs, brush, geotextiles, or natural fabrics. Bioengineering techniques can be more labor intensive than traditional engineering solutions and sometimes take longer to control streambank erosion. Nevertheless, over the long term, they often have lower maintenance costs and create important habitat.

Finally, maintenance such as erosion control, reseeding, and soil amendments may be needed after evaluating the initial progress of stream corridor recovery. Allowing natural processes to shape the ecosystem in the stream corridor will generally lead to self-sustaining, long-term recovery of in-stream, riparian, and upland terrestrial habitats in the stream corridor. Because this process takes time, providing short-term riparian and upland habitats may hasten the return of wildlife to the disturbed area. Cleanup project managers may use engineered habitat structures such as weirs, dikes, randomly placed rocks, riffles and pools, fish passage structures, and off-channel pools to enhance in-stream habitat during the short term. Engineered habitat structures are most effective when installed as a complement to a long-term recovery strategy. For additional information on engineered habitat structures, see Section 8G of the Federal Interagency Stream Restoration Working Group's Stream Corridor Restoration Guide at www.nrcs.usda.gov/Technical/stream_restoration/newtofc.htm.

6.0 Terrestrial Ecosystems Cleanup and Revitalization

Grading or earthmoving operations at cleanup properties can seriously disturb terrestrial plant and animal life at properties. The cleanup process can denude some contaminated properties of all vegetation and topsoil. Establishing a plant community that will thrive with minimal maintenance is a critical step in developing a healthy terrestrial ecosystem on these properties. This section discusses factors to consider when planning terrestrial plant communities in disturbed areas. It addresses (1) general revegetation principles and factors to consider in the course of protecting or creating natural terrestrial ecosystems and (2) specific considerations when creating meadows or prairies and establishing vegetation on semi-arid or arid lands. Section 3.1 presents general cleanup planning and design issues that may also be applicable to the revitalization of terrestrial ecosystems.

Native Plantings at College Park Landfill

At the College Park Landfill in Beltsville, Maryland, cleanup project managers used recycled waste materials such as fly ash and animal and plant by-products as land cover as part of the landfill cap. In addition, the vegetative cover includes diverse native plantings. See Appendix A for additional case study information.

General Revegetation Principles.

While restoring terrestrial ecosystems, it is recommended that cleanup project managers consider soil type, plant selection, and timing.

Soil Type. Soil testing is generally necessary to evaluate whether the pH, nutrient availability, toxicity, salinity, and organic material content are appropriate for successful plant establishment. Several organizations provide assistance in soil testing, including U.S. Department of Agriculture (USDA)'s Natural Resources Conservation Service (NRCS) and the WHC. The soil can then be prepared or amended, as necessary, to ensure proper soil texture and conditions. Soil amendments, or residuals from other processes that have beneficial properties when added to soil, may be used in areas without adequate topsoil; if fertilizer is needed, it is important to choose a formulation that meets the growing needs of the selected species (EPA 2007d). The cleanup team may also have to stabilize the soil and apply compost to hold seed in place, aid in establishing plants, mitigate the effect of rainfall on newly seeded areas, preserve soil moisture, and control erosion. Soil stabilization methods include mulching with straw or wood-fiber product, or installing synthetic matting. Cleanup project managers may wish to select soil amendments and stabilization techniques for their ability to improve conditions for germination of the selected species. In addition, some types of soil amendments may help adjust the pH of the soil in preparation for seeding (EPA 2007d). Refer to the following document for more information on soil testing: www.nrcs.usda.gov/feature/backyard/pdf/nutrient.pdf.

Plant Selection. Seed mixtures and plants can be adjusted to suit the soil, climate, hydrology, exposure (to both sun and wind), and topography of an area. Local native populations of plant and seed usually result in higher survival rates and maintain the integrity of the local gene pool. As discussed in Section 3.0, cleanup project managers are encouraged to avoid using non-native species. These species can out-compete and displace native species, disrupt ecological processes, and significantly degrade entire plant communities, both on and off the property.

Amending Soils with Biosolids at a Refinery

In Lima, Ohio, a refinery undergoing RCRA Corrective Action is using biosolids to help create prairie habitat with native grasses, flowers, and trees over a soil cover. See Appendix A for additional case study information.

After seeding, cleanup project managers can protect the seeded areas from grazing animals, vehicles, and other disturbances until plants are well established. Techniques for protecting plantings include fencing, clearly marked access roads, animal repellants, trenches or berms to control run-on and runoff (if they are already part of stormwater control features at the cleanup property), and interim surface stabilization methods such as mulching or matting. Cleanup project managers may need to reseed the area within the planting season to replace damaged vegetation or to achieve the desired plant density. For additional information on seed mixtures and plant selection, visit EPA's GreenAcres Web site (www.epa.gov/greenacres), the Plant Conservation Alliance (PCA) Web site (www.nps.gov/plants), and the Bureau of Land Management's Seeds of Success Program (www.nps.gov/plants/sos).

Timing. It is important to seed during the optimum periods for plant establishment, which are property-specific and vary depending on the type of terrestrial habitat that is being restored. Information on seeding techniques and conditions for individual species is available from NRCS technical guides (www.nrcs.usda.gov), university extension offices, and seed suppliers. If planting cannot occur during optimum periods, cleanup project managers may use a nurse crop, such as annual rye or oats, as ground cover until the appropriate planting season.

Meadows and Prairies. A few additional considerations apply when restoring meadows or prairies. Generally, when seeding an area with native grass species, specialized planting equipment, such as a native grass drill, is needed to ensure good seed to soil contact. Seeds need to be certified and purchased on a pure live seed basis. Grass stands usually do not need fertilizer or irrigation. However, they may need periodic maintenance activities, such as controlled burning, mowing, and removing plant litter, to suppress woody growth and encourage vigorous new growth. To maximize benefits to wildlife, conduct these activities outside of the primary nesting season, preferably in late winter or early spring.

Semi-Arid and Arid Areas. Cleanup project managers may consider a number of additional factors when establishing vegetation in semi-arid and arid areas, including the following:

- **Soil treatment** is important because damage to soil structure and function is a common and serious problem in degraded semi-arid and arid areas. Arid soil, compacted soil, and nutrient-poor soil may need to be improved by adding organic amendments, such as leaf and litter compost, composted manure, biosolids, or mulch that is certified contaminant and weed-free. These amendments could help bind recalcitrant organic compounds and metals and increase the much-needed water holding capacity and fertility. Other measures to improve soil structure and function include soil surface treatments, such as creating pits in soil, to improve water retention in arid land and imprinting, to increase soil moisture and gully control to improve plant establishment.
- **Water availability** for plants may improve if the ground is shaped to collect and retain water. Transplanted seedlings may need limited irrigation to survive until established. Species selections can also be adapted to local hydrology. Too much irrigation may encourage invasive weeds, leave salts at the soil surface that kill plants, or cause infiltration into subsurface contaminated materials.
- **Seed selection** for arid areas is hampered by the limited availability of commercial stocks of dry land seeds. If possible, the project manager may hire a commercial seed collector to collect seed from the local area or an area with similar climate. The alternate collection area needs to be within a 100-mile radius and 500 feet of the altitude of the area to be planted; where the average rainfall is within two inches per year of the annual rainfall for the area; and have similar soil characteristics (Department of the Interior [DOI] 1995). Seed testing can help cleanup project managers ensure that the seeds are of high quality. Proper seed storage will also help maintain the seed's viability until sowing. Visit the Plant Conservation Alliance Web site for a directory of restoration experts and native seed suppliers (www.nps.gov/plants).
- **Planting techniques** primarily include direct seeding and transplanting. Direct seeding is generally less expensive. However, in dry areas this technique is more vulnerable to seed loss from exposure to wind, insects, and rodents, as well as declines in germination rates and plant growth because of insufficient rainfall in the months following planting. The installation of an erosion blanket consisting of straw or coco fiber with biodegradable netting can help prevent seed loss and retain moisture while plants are established. Cleanup project managers may also consider using collected seed to grow container plants for drier areas. If container plants are used, additional time will be necessary to allow the plants to germinate and achieve the desired growth in a greenhouse or nursery before planting. Using container plants can be costly and labor intensive. Because plant losses usually occur, it is prudent to budget for monitoring and replacement.

7.0 Long-Term Stewardship Considerations

Cleanups are risk-based and, when waste is left in place, long-term stewardship is necessary to ensure protectiveness of the remedy; therefore, long-term stewardship responsibilities are an integral part of the cleanup process. O&M activities through responsible stewardship protect the integrity of the cleanup and the functioning of the associated ecosystems after cleanup completion. For example, at the Woodlawn Landfill Superfund Site, WHC and Bridgestone Americas Holding, Inc. conducted ecological revitalization activities at the site to create wildlife habitat. Local volunteers manage the site. In addition, Chicago's pocket park project highlighted earlier in Section 2 incorporated (1) ICs and (2) community involvement in site planning and maintenance, which reduced costs and helped ensure the success of ecological revitalization. See Appendix A for case studies regarding these sites.

There are four major components for a successful O&M program:

- Plan early for long-term stewardship
- Identify and complement general O&M activities
- Establish a monitoring program
- Use ICs

Long-Term Stewardship. EPA's co-regulatory partners, including states, local governments, and tribes, have increasing responsibility and oversight for property assessment and cleanup planning. This property knowledge is particularly important for long-term stewardship as state voluntary cleanup programs and property owners typically have primary responsibility for carrying out maintenance of engineering controls and ICs for the long-term. Therefore, it is essential to prepare for safeguarding the effectiveness of the ecological revitalization activities as early in the cleanup planning process as possible. Regardless of who is responsible for O&M, stakeholders can make agreements to have general maintenance tasks as well as those specific to ecological revitalization implemented by property owners, a local government agency, Trustees, or the community. It may be practical to have the same organization undertake general O&M activities as well as those relating specifically to the ecosystem. For example, at the Silver Bow Creek/Warm Springs Ponds Superfund Site in Montana, the Montana Department of Fish, Wildlife, and Parks, a Trustee, conducts many general and specific monitoring and maintenance tasks (see case study in Appendix A).

Cleanup project managers can also enlist a local group or guardian to conduct long-term stewardship of a property. Such groups are committed to follow-through and have knowledge of local conditions. They can also monitor the ecological revitalization component and look for early signs of any emerging issues. Local government agencies can also provide expertise, equipment, supplies, or other resources to help the local community or group conduct long-term stewardship; this can reduce costs, provide interpretive educational benefits, and help encourage a sense of property ownership by the community.

Stakeholder Collaboration at a Former Refinery in Casper, Wyoming

Stakeholders are successfully achieving cleanup of a BP former refinery in Casper, Wyoming through a collaborative process. The group redeveloped the former refinery into a business park and golf course where the wetland treatment system also functions as a golf course water hazard. To reach agreement on the cleanup, BP worked closely with stakeholders, including the local Audubon Society and the community. The Audubon Society used its local expertise to help determine an appropriate shoreline elevation to maintain the wetlands and mud flats. See Appendix A for a case study regarding this site.

General O&M Activities. In some cases, appropriately designed ecosystem revitalization may be self-sustaining and need little or no maintenance after an initial establishment period. In most cases, however, O&M will be necessary. O&M activities depend on the type of cleanup as well as the ecological revitalization component and, depending on the situation, are often necessary for a long period of time (up to 20, 50, or 100 years). O&M for the overall cleanup typically includes inspection, sampling and analysis, routine maintenance and small repairs, and reporting, as necessary. Cleanup project managers can incorporate ecological revitalization measures into each of these tasks.

- **Inspection needs to occur on a regular basis.** Inspectors can also perform non-routine inspections after unusual events such as earthquakes or large storms. Typically, inspectors check for invasive species, erosion, and dead or dying vegetation, among other items, when assessing the ecological revitalization component of the cleanup. For properties with cover systems in place, inspectors also check for settling, burrowing animals, and pooling water. Cleanup project managers typically include performance standards to measure the success of the project, as well as a detailed description of how team members will conduct inspections, sampling, and maintenance activities.
- **Regular sampling and analysis** helps monitor habitat, ground water, and surface water quality. Monitoring habitat indicators such as plant species composition and percentage of cover helps to determine the success of the revitalization measures. In addition, making a determination of the amount of invasive plant species in the area helps to ensure that they are not overtaking the area. Sampling and analysis includes collecting and chemically analyzing water samples from surface water, wetlands, or ground water wells; soil samples may also be collected and analyzed to evaluate soil conditions. For properties with cover systems in place, sampling would include leachate formation and gas release concentrations. The frequency of sample collection can vary widely and needs to be determined on a property-specific basis.
- **Routine maintenance** may consist of simple activities such as burning, using herbicide, or mowing to control invasive species; maintaining a cover; or repairing perimeter fencing. On properties that have operating treatment plants, routine maintenance may be more complex and may need a full- or part-time plant operator. Typical activities include operating ground water and gas treatment systems, repairing erosion damage, and maintaining rainwater collection and diversion systems. Based on inspection results and plant species composition and cover at the revitalization area, reseeding or replanting may be necessary as well as periodic mowing or controlled burns. Manual or natural controls or herbicides or insecticides applications can also control invasive plants and undesirable insects and diseases. For additional information on maintaining a variety of habitat types, review ITRC's Planning and Promoting Ecological Land Reuse of Remediated Sites (ITRC 2006).
- **Reporting** requirements depend on the cleanup program, and cleanup project managers generally write and submit reports to regulatory authorities after both routine and non-routine inspections. The reports typically include information on the general condition of the cleanup measures, test results from samples collected, and operational data from treatment processes (for example, ground water extraction rate, gas flow rate).

Monitoring Program. A monitoring program, established as part of post-cleanup activities, evaluates the effectiveness of the cleanup in restoring ecological function and reducing ecological risks (EPA 1998, 1999a). Information from baseline surveys and ERAs conducted during the planning process can be the starting point for developing the monitoring program. For example, periodic monitoring of sediment contamination and benthic

Loring Air Force Base in Maine

Cleanup project managers for Loring Air Force Base consulted with the U.S. Fish and Wildlife Service (USFWS) to identify useful indicator species such as dragon fly nymphs, midge flies, dace minnow, and brook trout to monitor the recovery of the stream system after remedial activities. These species were selected because they are sensitive to contaminants and are quick to manifest symptoms of exposure. See Appendix A for additional case study information.

communities following the removal of contaminated sediment in a stream can provide indications of the protectiveness of the cleanup features as well as the ecosystem's recovery to a more natural condition. At the Revere Chemical Company Superfund Site in Pennsylvania, ground water and stream monitoring is used to evaluate the risks of heavy metals getting into the ground water and migrating off site. Cleanup project managers also use the monitoring program to help evaluate the recovery of important aquatic species. Monitoring habitat indicators such as plant species composition and percent cover could indicate the success of the revitalization measures. See Appendix A for a case study regarding this site.

Designing and Implementing Institutional Controls

Many factors may influence the design and implementation of ICs, such as state policies, whether the property is a federal facility, or whether regulatory authorities, such as RCRA or CERCLA, are involved. An EPA guide addresses many of these issues (EPA 2000). Visit the following Web site to view the guide: http://epa.gov/superfund/policy/ic/guide/guide.pdf

Institutional Controls. ICs are designed to limit land or resource use, and provide information to help modify or guide human behavior, and complement engineering controls. They can also protect ecological revitalization properties by restricting public access to parts of a property that are particularly sensitive to erosion or contain sensitive or establishing habitats; or to achieve human protectiveness or other revitalization goals. A key to success is to identify and evaluate as much information as possible about the needed ICs early in the planning process. Generally, major considerations with IC use at ecological revitalization properties include the following:

- **Consider what the IC is intended to accomplish and establish clear objectives.** A common IC objective for ecological purposes involves controlling human activities in a particular area that could potentially interfere with sensitive habitats or the ecosystem balance that supports the cleanup features.
- **Consider the appropriate types of ICs.** These can include governmental controls (zoning, building codes, and ground water use restrictions), proprietary controls (easements, covenants, and conservation trusts), enforcement tools (consent decrees and administrative orders), and informational devices (fishing advisories, deed notices, and state registries of contaminated properties). For example, a conservation easement for catch and release fishing and a local health department fishing advisory could accomplish the same IC objective to reduce fish consumption. For information about different types of ICs, see EPA's guide titled Institutional Controls: A Site Manager's Guide to Identifying, Evaluating, and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups at http://epa.gov/superfund/policy/ic/guide/guide.pdf (EPA 2000).
- **Ensure that the specified ICs are effective and remain in place over the long term** through proper implementation, monitoring, and enforcement. For example, at the Silver Bow Creek Superfund Site in Butte, Montana, the Montana Department of Fish, Wildlife, and Parks enforces a fish consumption prohibition. In addition, at the BP Former Refinery in Casper, Wyoming, project managers implemented several ICs including a "use control area" through a resolution to limit use on the property, a ground water restriction area, and a soil management overlay district. Within one of these defined areas, a constructing entity has to contact the state or BP if they have been issued a building permit. See Appendix A for additional information on these case studies.

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Appendices

Appendix A: Ecological Revitalization Case Studies

Appendix B: Additional Ecological Revitalization Resources

Appendix C: Acronyms

Appendix A: Ecological Revitalization Case Studies

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
REGION 1							
Atlas Tack Superfund Site, Fairhaven, MA	Superfund Manufacturing Facility	Ground water contaminated with cyanide and toluene that leached from the site lagoon and soils contaminated with VOCs, heavy metals, pesticides, PCBs, and PAHs were cleaned up by removing buildings, contaminated soil, and sediment.	The cleanup preserved as much of the wetland sediment as possible and provided the necessary mix of fresh and salt water sources to create a functioning wetland, in addition to protecting human health and the environment.	1) The original ROD contained sediment cleanup values that would require complete excavation of the entire marsh. 2) The initial remediation plan included lowering the ground water table to prevent it from flowing through residual contamination.	1) The bioavailability study showed that it was not necessary to remove all sediments, and therefore only necessary sediment was removed, thereby preserving the marsh to the extent possible. 2) The remediation approach was re-evaluated during wetland design, and risks from ground water flowing beneath the site were minimal.	Elaine Stanley, RPM EPA Region 1 1 Congress Street Suite 1100 Mail Code: HBO Boston, MA 02114-2023 617-918-1332 stanley.elainet@epa.gov	http://www.epa.gov/ne/superfund/sites/atlas/
Fort Devens: OU2 Devens Consolidation Landfill, Sudbury, MA	Superfund Military Base	Numerous small historical landfills were remediated and the waste was consolidated in a new state-of-the-art landfill. Soils and debris disposed at the Devens Consolidation Landfill included those contaminated with petroleum, pesticides, PCBs, PAHs, and asbestos. A total of approximately 365,000 cubic yards of waste was disposed of in the new landfill. The historic landfill sites were then backfilled and regraded to restore the sites to pre-construction conditions.	Three of the historic landfills had waste or debris in wetland areas. For these areas, the remedy included waste and debris removal, followed by wetland restoration. The wetlands were restored by backfilling with clean fill and manufactured wetland soil. Materials were stabilized with a custom wetland seed mix, in accordance with a Habitat Restoration Work Plan. The site was monitored and evaluated during the next three growing seasons to ensure it achieved restoration success measures.	Not specified	Not specified	Ginny Lombardo, RPM EPA Region 1 1 Congress Street Suite 1100 Mail Code: HBT Boston, MA 02114-2023 617-918-1754 lombardo.ginny@epa.gov	http://yosemite.epa.gov/r1/npl_pad.nsf/51dc4f173ceef51d85256adf004c7ec8/df7d910ff9a93fab8525691f0063f6c9!OpenDocument&Highlight=0,devens
Fort Devens: OU9 AOC 57, Sudbury, MA	Superfund Military Base	AOC 57 consists of 2 areas that were affected by stormwater runoff and wastes from vehicle maintenance activities at a historic storage yard upgradient of the site. The areas are sloped along Cold Spring Brook. Soils and ground water were contaminated with petroleum hydrocarbons, chlorinated VOCs, PCBs, and arsenic. Contaminated soils were removed and disposed off-site, and ground water will be remediated via MNA.	Soil excavation at one of the areas included excavation within delineated wetland areas along Cold Spring Brook. The remedy required that the wetland areas be restored in accordance with an appropriate mitigation and restoration plan and that the wetland restoration area be monitored for 5 years to ensure that restoration success measures were achieved.	Not specified	Not specified	Ginny Lombardo, RPM EPA Region 1 1 Congress Street Suite 1100 Mail Code: HBT Boston, MA 02114-2023 617-918-1754 lombardo.ginny@epa.gov	http://yosemite.epa.gov/r1/npl_pad.nsf/51dc4f173ceef51d85256adf004c7ec8/df7d910ff9a93fab8525691f0063f6c9!OpenDocument&Highlight=0,devens

* Links valid at time of publication.

Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
GE-Housatonic River, Pittsfield, MA	Superfund Manufacturing Facilities	Site remediation involved clean up of Housatonic River sediments and floodplain soils contaminated with PCBs and other hazardous substances. Remediation included excavating and disposing of sediment and soil and full-scale capping of Silver Lake.	GE is providing economic aid to the City of Pittsfield for 10 years and making upgrades to the Housatonic River, its floodplain, and Silver Lake that will have aesthetic value and enhance local habitat.	Issues relating to flood storage compensation are under discussion with EPA.	Not specified	Thomas Hickey, Jr. Pittsfield Economic Development Authority 81 Kellogg Street Pittsfield, MA 01201 413-494-7332 thickey@peda.cc	http://www.epa.gov/region1/ge/redevelopment.html
Industri-Plex Site, Woburn, MA	Superfund Manufacturing Facility	The remedy included remediating approximately 110 acres of soil contaminated with lead, arsenic, and chromium; demolishing onsite buildings; and constructing clay, soil, and synthetic layers, concrete foundations, and asphalt to cover contamination. In addition, gases at a hide pile were collected and treated, and wetlands and open spaces were created.	Wetlands and open space were created adjacent to redeveloped areas, which included a regional transportation center, highway interchange, and land developed for retail and commercial use.	None	None	Joseph LeMay, RPM EPA Region 1 1 Congress Street Suite 1100 Mail Code: HBO Boston, MA 02114-2023 617-918-1323 lemay.joe@epa.gov	http://yosemite.epa.gov/r1/npl_pad.nsf/f52fa5c31fa8f5c885256adc0050b631/1E8F7D6FFCD9B61B85256A0F00067136?OpenDocument
Iron Horse Park, North Billerica, MA	Superfund Manufacturing Facility Landfill	On-site ground water and surface water were contaminated with organic and inorganic chemicals, asbestos, and heavy metals. The soil at the site was contaminated with PCBs, petrochemicals, and heavy metals. Remediation activities included capping on-site landfills and excavating and removing contaminated soil and sediment.	Wetlands were restored.	Not specified	Not specified	Don McElroy EPA Region 1 1 Congress Street, Suite 1100 Mail Code: HBO Boston, MA 02114-2023 617-918-1326 mcelroy.don@epa.gov	http://yosemite.epa.gov/r1/npl_pad.nsf/51dc4f173ceef51d85256adf004c7ec8/e334fff032cee1e78525691f0063f6d0?OpenDocument
Jamaica Island Landfill OU3, Kittery, ME	Superfund Remedial Action Landfill	A variety of organic and inorganic constituents were detected in soil and ground water and included VOCs, SVOCs, PCBs, pesticides, metals, and petroleum hydrocarbons. Remediation included installation of a cap and shoreline erosion controls.	Wetlands were constructed.	Minimizing the effect on existing mudflats in the area and locating appropriate backfill to maximize the potential for success.	Not specified	Fred Evans, RPM Navy Portsmount Naval Shipyard Kittery, ME 03904 610-595-0567 ext.159 evansfj@efane.navfac.navy.mil	http://www.wildlifehc.org/ewebeditpro/items/O57F3078.pdf
Loring Air Force Base, Northeastern ME	Superfund Air Force Base	Ground water contaminated with VOCs and fuel-related compounds and surface water and sediment contaminated with VOCs, PCBs, and heavy metals were remediated. Activities included capping on-site landfills and excavating and removing contaminated soil and sediment.	Boulders and cobbles from the streambed and nearby trees larger than 15 centimeters in diameter that were removed during cleanup were later used in stream reconstruction, after completion of cleanup activities. Reuse of native materials significantly reduced the cost of restoration materials.	Not specified	Not specified	Mike Daly, RPM EPA Region 1 1 Congress Street Suite 1100 Mail Code: HBT Boston, MA 02114-2023 617-918-1386 daly.mike@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0101074

* Links valid at time of publication.

Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Materials Technology Laboratory, Watertown, MA	Superfund Arsenal	Remediation included removal and off-site disposal of contamination sources related to weapons and ammunition manufacture and storage, and demolition and cleanup of the nuclear reactor, including radiological contamination, PAHs, PCBs, and pesticides.	Wetlands restoration was completed adjacent to the redeveloped area. Fifty-five acres of the property have been used to build the Arsenal Mall, Harvard Community Health Center, Arsenal Apartments, a public park with walking and bike trails, and a playground.	Not specified	Not specified	Christine Williams, RPM EPA Region 1 1 Congress Street Suite 1100 Mail Code: HBT Boston, MA 02114-2023 617-918-1384 williams.christine@epa.gov	http://yosemite.epa.gov/r1/npl_pad.nsf/701b6886f189ceae85256bd20014e93d/d98829ad20e19d6f852568ff005adb08!OpenDocument
Pease Air Force Base, Portsmouth, NH	Superfund Air Force Base	Soils and ground water were contaminated with solvents and fuel.	A wildlife refuge was created in addition to a public airport.	Not specified	Not specified	Mike Daly, RPM EPA Region 1 1 Congress Street Suite 1100 Mail Code: HBT Boston, MA 02114-2023 617-918-1386 daly.mike@epa.gov	http://yosemite.epa.gov/r1/npl_pad.nsf/f52fa5c31fa8f5c885256adc0050b631/9E95FBAD0CEC73E0852568FF005ADB09?OpenDocument
Saco Municipal Landfill, Saco, ME	Superfund Landfill	Soil and ground water contaminated from landfill activities were remediated.	A portion of the site adjacent to the redeveloped area was reserved for a wetland. The site is ready for reuse and the City of Saco plans to develop a community recreation area for hiking, biking, ice skating, and soccer.	Not specified	Not specified	Ed Hathaway, RPM EPA Region 1 1 Congress Street Suite 1100 Boston, MA 02114-2023 617-918-1372 hathaway.ed@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0101010
Tibbetts Road Site, Barrington, NH	Superfund Rural/Farmland	Site soils and ground water were contaminated by chlorinated and non-chlorinated solvents. Remediation included source removal, building demolition, water supply extension, and phytoremediation.	The wooded phytoremediation area is providing increased biodiversity through new wildlife habitat for various birds and small mammals.	Not specified	Not specified	Jerome S. Amber, P.E. Ford Motor Company, retired 248-765-1044 jamber@comcast.net	http://www.wildlifehc.org/eweb editpro/items/O57F3072.pdf
REGION 2							
Asbestos Dump, Millington, NJ	Superfund Landfill	Asbestos from 4 sites was collected, consolidated, and treated on-site to prevent release of contaminants. A soil cover was then placed over the site.	A barn was converted into an environmental awareness center. Most of the property will be preserved and will help expand the Great Swamp National Wildlife Refuge.	Not specified	Not specified	Carla Struble, RPM EPA Region 2 290 Broadway New York, NY 10007-1866 212-637-4322 struble.carla@epa.gov	http://yosemite.epa.gov/opa/admpress.nsf/b853d6fe004acebf852572a000656840/3f082ae6d59bb9ac85257165006bc507!OpenDocument
DeRewal Chemical Co., Kingwood Township, NJ	Superfund Chemical Company	Contaminated soil and ground water from chemical spills was cleaned up through excavation and treatment of soil and extraction and treatment of ground water.	The site now contains walking, canoe, and biking trails, and bird watching opportunities. The Kingwood Township also plans to convert a house on the site into a historical, environmental, and recreational center.	Not specified	Not specified	EPA Region 2 290 Broadway New York, NY 10007-1866	http://www.epa.gov/region02/superfund/npl/0200792c.pdf

* Links valid at time of publication.

Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Lipari Landfill, Pitman, NJ	Superfund Landfill	A slurry wall and cap were constructed for the landfill, which accepted wastes contaminated with VOCs and heavy metals. A ground water and leachate P&T system was installed, and contaminated soil and sediment were excavated and treated.	Revitalization included recreational use of a park and lake as well as development of streams and marshes.	In the ROD for OU2, changes in the remedy flow rates, equipment sizes, and estimated costs in design were made to the on-site containment facilities. The ROD for OU3 included changes to the soil and sediment volumes handled and methods for removing sediment.	Changes in the ROD did not change the functionality of the remedies.	Melissa Friedland EPA HQ Ariel Rios Building 1200 Pennsylvania Avenue Mail Code: 5204P Washington, DC 20460 703-603-8864 friedland.melissa@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0200557
Marathon Battery, Cold Spring, NY	Superfund Manufacturing Facilities	The factory and surrounding soils, a nearby marsh, and adjacent river sediments were contaminated with heavy metals. Remediation included excavating, capping, and restoring the marsh; excavating contaminated soils; dredging cove and river sediments; and demolishing the plant.	The marsh is now used for recreational and educational purposes, and the factory grounds are ready for redevelopment.	Difficulties included experienced goose predation, destructive ice flows, invasive plant species, and bare areas due to differential settlement within the marsh.	Each problem was dealt with individually. Some areas were replanted, coir logs were used to encourage natural plant coverage and sediment build-up in bare areas, and beetles were used to retard the growth of invasive species.	Pam Tames, RPM EPA Region 2 290 Broadway New York, NY 10007-1866 212-637-4255 tames.pam@epa.gov	http://www.epa.gov/Region2/superfund/npl/0201491c.pdf
Myers Property Superfund Site, Hunterdon County, NJ	Superfund Manufacturing Facility	Soil and ground water contaminated with VOCs, pesticides, semiVOCs, metals, and dioxins were cleaned up by excavating contaminated soil and sediment, treating soil, and extracting and treating ground water.	RPMs are saving existing trees above a certain size in areas with low levels of contamination by hand digging around the roots to a depth of six inches. Excavated soil will be replaced with clean topsoil from off site.	Subsurface soil contamination remains, so if a tree falls, contaminated soil could be exposed.	The property will be monitored in case large trees fall and expose soils deeper than six inches.	Stephanie Vaughn, RPM EPA Region 2 290 Broadway, 19th Floor New York, NY 10007-1866 212-637-3914 vaughn.stephanie@epa.gov	http://www.epa.gov/region02/superfund/npl/0200774c.pdf
REGION 3							
Army Creek Landfill, DE	Superfund Landfill	Remediation of soil and ground water contaminated with VOCs, chromium, and mercury included a multi-layer protective cover over a municipal and industrial landfill and a ground water treatment system. Army Creek was also contaminated with cadmium, chromium, mercury, iron, and zinc.	Native vegetation was planted to create a bird and wildlife habitat. In addition, discharge pipes from the ground water treatment system were routed to create wetlands to help prevent flooding and create additional habitat.	Not specified	Not specified	Deb Rossi, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS23 Philadelphia, PA 19103-2029 215-814-3228 rossi.debra@epa.gov	http://www.epa.gov/superfund/programs/recycle/live/casestudy_armycreek.html

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Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Avtex Fibers, Front Royal, VA	Superfund Manufacturing Facilities	The principle contaminants found in the ground water were carbon disulfide, ammonia, arsenic, antimony, phenol, and high pH. Arsenic, lead, and PCBs have been identified in soils. PCBs associated with the plant were also detected in the Shenandoah River. Remediation was completed by demolishing or decontaminating onsite buildings, removing and treating onsite hazardous and nonhazardous chemical waste, excavating contaminated soil and debris, and constructing a low-flow wastewater treatment system.	The site was used to create a river conservancy park, active recreation park, and an eco-business park.	Not specified	Not specified	Bonnie Gross, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS23 Philadelphia, PA 19103-2029 215-814-3229 gross.bonnie@epa.gov	http://www.epa.gov/superfund/accomp/success/avtex.htm
Berks Landfill, Berks County, PA	Superfund Landfill	Ground water was contaminated with VOCs and metals. The remedy included ICs, long-term monitoring of ground water, operation and maintenance of the leachate system, and repair to the landfill cap.	The former residential property at the site is being reused as open green space with trees and vegetation. ICs were implemented in order to prevent on-site ground water use and to protect the landfill cap.	Not specified.	Not specified	Kristine Matzko EPA Region 3 1650 Arch Street Mail Code: 3HS21 Philadelphia, PA 19103-2029 215-814-5719 matzko.kristine@epa.gov	http://www.epa.gov/superfund/sites/fiveyear/f05-03018.pdf
Butz Landfill, Monroe County, PA	Superfund Landfill	A former municipal dump contaminated the ground water with a solvent, TCE, and other organic compounds. Nearly 82,720,000 gallons of water were treated using a P&T system.	Revitalization involved creating wetlands to mitigate potential loss of wetlands caused by the P&T system.	Not specified	Not specified	Romuald A. Roman, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS22 Philadelphia, PA 19103-2029 215-814-3212 roman.romuald@epa.gov	http://www.epa.gov/reg3hscd/super/sites/PAD981034705/
Chisman Creek, York County, VA	Superfund Mining site	Ground water and surface water were contaminated with heavy metals from the disposal of fly ash. The cleanup plan eliminated contact with the fly ash and contaminated water, restored ground water, and protected nearby wetlands.	The site is being reused as a recreational complex, including ponds and the County Memorial Tree Grove. The site cleanup also protects nearby ponds, a creek, and an estuary, and it is part of a large water quality improvement that has led to the reopening of the Chisman Creek estuary for private and commercial fishing.	Not specified	Not specified	Andrew C. Palestini EPA Region 3 1650 Arch Street Mail Code: 3HS23 Philadelphia, PA 19103-2029 215-814-3233 palestini.andrew@epa.gov	http://www.epa.gov/superfund/programs/recycle/live/casestudy_chisman.html
College Park Landfill, Beltsville, MD	Superfund Landfill	Remediation included installing a cap over a landfill that accepted household trash, as well as commercial, industrial and some agricultural and research waste.	The vegetative cover will include diverse native plantings.	The stakeholders were concerned about whether the vegetation would be killed by methane from the landfill, and if the vegetation would be able to adequately prevent leachate generation.	A pilot study is being conducted to ensure these concerns are addressed.	Karen Zhang, PhD, PE, RPM USDA 10300 Baltimore Avenue Bldg. 003, Rm. 117 Beltsville, MD 20705 301-504-5557 zhangk@ba.ars.usda.gov	http://www.wildlifehc.org/ewebeditpro/items/O57F3070.pdf

* Links valid at time of publication.

Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Craig Farm Drum, Parker, PA	Superfund Landfill	Ground water and soil were contaminated with resorcinol and VOCs, such as benzene and toluene. Site remediation consisted of excavating and stabilizing contaminated soils onsite from two former waste disposal pits.	Wetlands were built on site to replace a smaller area of wetlands lost during construction of the on-site landfill.	Not specified	Not specified	John Epps EPA Region 3 1650 Arch Street Mail Code: 3HS33 Philadelphia, PA 19103-2029 215-814-3144 epps.john@epa.gov	http://www.epa.gov/reg3hscd/super/sites/PAD980508527/
DeSale Restoration, Butler County, PA	Pennsylvania Department of Environmental Protection Mining Site	A passive treatment system was used to capture and treat acid mine drainage and included an anoxic collection system, vertical flow ponds, a settling pond and wetland complex, and horizontal flow limestone bed.	In addition to creating a treatment wetland complex, 11 miles of streams that were once devoid of life because of acid mine drainage are now teeming with fish.	Not specified	Not specified	Scott Roberts Pennsylvania Deparament of Environmental Protection Office of Mineral Resources P.O. Box 2063 Harrisburg, PA 17105-2063 717-783-5338 jayroberts@state.pa.us	http://www.srwc.org/projects/desale.php
E.I. DuPont Nemours & Co., Inc. (Newport Pigment Plant Landfill), Newport, DE	Superfund Landfill	Soils, sediments, ground water, and surface water were contaminated with various metals. Contaminated sediments were excavated, the two landfills were capped, and soil at the ballpark was removed.	The cleanup is protecting Delaware's natural resources and wildlife habitat. Over 35 acres of wetlands and wildlife habitat have been restored as part of the site's overall cleanup.	Ground water appeared to be seeping over the sheet pile wall in several areas of the north landfill. This created a concern regarding possible vapor intrusion into structures above the contaminated ground water plume.	Evaluation of vapor intrusion potential and appropriate mitigation steps was conducted. Ground water table elevation at the north landfill was continuously monitored; water, soil and/or sediment sampling was conducted; and the need for more recovery wells was evaluated.	Randy Sturgeon EPA Region 3 1650 Arch Street Mail Code: 3HS23 Philadelphia, PA 19103-2029 215-814-3227 sturgeon.randy@epa.gov	http://www.epa.gov/superfund/sites/fiveyear/f0503006.pdf
Former Elf Atochem North America (Bensalem Redevelopment), Cornwell Heights, PA	RCRA Corrective Action Manufacturing Facility Refinery	Site soils and ground water are contaminated with chlorinated organics, PAHs, PCBs, pesticides, and arsenic. Remediation included removing contaminated soil and reusing concrete from demolished buildings as fill for basement areas in buildings that had been razed.	The site is planned to be redeveloped as a mixed-use area with greenspace for passive and active recreation along the Delaware River waterfront.	The property is in an area where many industries have downsized or discontinued operations over the last 20 years. Unemployment rates in the area are among the highest in Bucks County.	The redevelopment authority received a grant and loan from the Brownfields Program to help with the cost of the cleanup. A mixed-use area is planned for the site.	Andrew Clibanoff EPA Region 3 1650 Arch Street Mail Code: 3WC22 Philadelphia, PA 19103-2029 215-814-3391 clibanoff.andrew@epa.gov	http://www.epa.gov/reg3wcmd/ca/pdf/elf_atochem.pdf
Grace Lease Property, Lancaster County, PA	Brownfields	A Phase II Environmental Site Assessment found that no contaminants were present at levels above state standards, so cleanup was not necessary.	The area, previously abandoned and unused, now provides natural habitat and recreational greenspace with hiking trails, picnic grounds, and a scenic overlook of the Susquehanna River. In addition, Bald Eagle nesting sites have reemerged on the land.	Site remediation was not necessary.	Not applicable	Andrew Kreider EPA Region 3 1650 Arch Street Mail Code: 3HS51 Philadelphia, PA 19103-2029 215-814-3301 kreider.andrew@epa.gov	http://www.epa.gov/region03/revitalization/newsletter/spring07/Lorax.html

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
GSA Southeast Federal Center, Washington D.C.	RCRA Corrective Action Manufacturing Facility	Contamination resulted from shipbuilding and ordnance production activities. Eleven of the 14 buildings were decontaminated and demolished; the remaining buildings will be renovated and reused. Contaminated soil was removed, and ground water is being treated to break down gasoline constituents.	Revitalization includes developing a waterfront park that includes wildlife habitat.	Not specified	Not specified	Barbara Smith EPA Region 3 1650 Arch Street Mail Code: 3LC20 Philadelphia, PA 19103-2029 215-814-5786 smith.barbara@epa.gov	http://www.epa.gov/reg3wcmd/ca/dc/pdf/dc8470090004.pdf
Honeywell (Formerly Allied Signal) Baltimore Works Facility, Baltimore, MD	RCRA Corrective Action Industrial Facility	Manufacturing buildings and associated hazardous waste were removed. The containment area was surrounded by a slurry wall and capped, and ground water is being pumped and treated off site. Chromium and PAH-contaminated soil was removed.	A waterfront park will be constructed and is planned to include wildlife habitat.	Not specified	Not specified	Russell Fish EPA Region 3 1650 Arch Street Mail Code: 3LC20 Philadelphia, PA 19103-2029 215-814-3226 fish.russell@epa.gov	http://www.epa.gov/reg3wcmd/ca/md/pdf/mdd069396711.pdf
Jacks Creek/ Sitkin Smelting & Refining, Inc, Maitland, PA	Superfund Metals Reclamation Facility	The former smelting and precious metals reclamation facility contained several buildings, waste piles, and large areas of soil contaminated with lead, copper, zinc, cadmium, and PCBs. Floodplain wetlands on site and Jacks Creek sediment near the site were contaminated with runoff from the waste piles and soil. The cleanup involved dredging contaminated sediment from the adjacent Jacks Creek, excavating contaminated soil, and removing USTss and drums. Contaminated soil, sediment, and waste piles were consolidated and capped. Drums and waste were removed from the site.	The floodplain remediation required removing vegetation in a segment of the riparian corridor of the creek. Because soil excavation affected existing wetlands on site, wetlands were recreated in the riparian corridor along Jacks Creek. RPMs created vernal pools, placed woody debris in the wetland as invertebrate habitat, and used a wet meadow seed mix. A monitoring plan will help document the effectiveness of the created wetland.	Not specified	Not specified	Rashmi Mathur, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS22 Philadelphia, PA 19103-2029 215-814-5234 mathur.rashmi@epa.gov	http://www.epa.gov/reg3hwmd/risk/eco/restoration/cs/JacksCreek.htm
Hopewell Plant (Honeywell), Hopewell, VA	RCRA Corrective Action Manufacturing Facility	This industrial chemical and fertilizer manufacturing facility is being cleaned up to control ground water releases and current human and ecological exposure to contaminated media.	A portion of the facility has been converted to a wildlife habitat area and has been certified as such by the Wildlife Habitat Council.	Not specified	Not specified	Russell Fish EPA Region 3 1650 Arch Street Mail Code: 3LC20 Philadelphia, PA 19103-2029 215-814-3226 fish.russell@epa.gov	http://www.wildlifehc.org/Registry_CertifiedSites/cert_sites_detail2.cfm?LinkAdvID=95327

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Mill Creek Dump, Erie, PA	Superfund Landfill	A former freshwater wetland that was used as a landfill for foundry sands, solvents, waste oils, and other industrial and municipal waste was capped and flatter slopes were created.	The former landfill is now a golf course. Eight acres of wetlands were constructed adjacent to the course.	Not specified	Not specified	Romuald A. Roman, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS22 Philadelphia, PA 19103-2029 215-814-3212 roman.romuald@epa.gov	http://www.epa.gov/reg3hscd/npl/PAD980231690.htm
Morgantown Ordnance Works Disposal Area - OU1, Monongalia County, WV	Superfund Chemical Production Facility Landfill	Remediation activities included constructing a cap, removing soil and sediment contaminated with heavy metals and PAHs, and constructing three wetlands.	Wetlands were constructed and provided leachate treatment.	Contaminated sediment and soil were intended to be cleaned through bioremediation. However, bioremediation did not meet the clean up standards within a reasonable time frame and was not cost effective.	Three consecutive treatment wetlands were constructed to treat landfill leachate. Monitoring was implemented to ensure the effectiveness of wetlands.	Mr. Hilary Thornton, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS23 Philadelphia, PA 19103-2029 215-814-3323 thornton.hilary@epa.gov	http://epa.gov/reg3hwmd/npl/WVD000850404.htm
Naval Amphibious Base Little Creek, Virginia Beach, VA	Superfund Landfill	Approximately 29,000 tons of non-hazardous soil and debris were removed from the landfill and 6,300 cubic yards of clean fill were imported.	The landfill was converted to a tidal wetland. Two connecting channels were constructed to allow tidal inundation into the site from Little Creek Cove. Plants were placed along designated elevations to establish tidal wetland vegetation, using the neighboring marsh as a reference.	Not specified	Not specified	Bruce Pluta EPA Region 3 1650 Arch Street Mail Code: 3HS41 Philadelphia, PA 19103-2029 215-814-2380 pluta.bruce@epa.gov	http://public.lantops-ir.org/sites/public/nablc/Site%20Files/IRhistory.aspx#Site%208
Ohio River Park, Neville Island, PA	Superfund Landfill	A previous municipal landfill operating from the 1930s until the 1950s was capped with a protective cover.	The site will be transformed into a sports complex, with areas of habitat for wildlife; visitors will also be able to enjoy numerous walking, hiking, and biking trails.	Not specified	Not specified	Romuald A. Roman, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS22 Philadelphia, PA 19103-2029 215-814-3212 roman.romuald@epa.gov	http://www.epa.gov/superfund/programs/recycle/live/casestudy_ohioriver.html

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Palmerton Zinc Pile Superfund Site, Palmerton, PA	Superfund Mining Site	Former smelting operations resulted in soil and shallow ground water contamination by heavy metals, such as lead, cadmium, and zinc, and created a defoliated area on the adjacent Blue Mountain, a cinder bank, and additional defoliation along Stoney Ridge. Heavy metals were being transported to nearby stream segments through erosion. Biosolids were applied to accelerate revegetation of the defoliated areas, to stabilize the area, reduce soil erosion caused by wind and surface water, and increase evapotranspiration to prevent percolation of water and contaminants to the ground water. In addition, a system was installed to divert surface water around the cinder bank and treat leachate before discharge to the creek.	For the Blue Mountain revegetation, site managers constructed a self-sustaining meadowland because of minimum metal uptake from the plants. Also, ree species with high metal uptake were removed. For the cinder bank revegetation, the team used a grass seed mixture that included a nitrogen-fixing legume to maintain nitrogen fertility without the need for fertilizer.	Attempting to establish forestland at the site was extremely challenging because of competition from grasses, animal grazing, and insects. Some grass species were not desirable because of metals uptake. Use of sludge as a soil amendment caused a negative public perception.	Forestland was ultimately abandoned in favor of meadowland. The types of grass seeds were replaced with those having minimal metals uptake. Sludge application was replaced with mushroom compost.	Charlie Root, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS21 Philadelphia, PA 19103-2029 215-814-3193 root.charlie@epa.gov	http://costperformance.org/pdf/20070522_396.pdf
Resin Disposal, Jefferson Borough, PA	Superfund Landfill	The landfill, which accepted industrial waste including benzene and toluene, was covered with multi-layer cap. Leachate was collected and separated, and oil was recycled as fuel for a nearby plant.	The site now contains native wild flowers and is habitat to migratory birds.	Not specified	Not specified	Rashmi Mathur, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS22 Philadelphia, PA 19103-2029 215-814-5234 mathur.rashmi@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0301042
Revere Chemical, Nockamixon Township, PA	Superfund Waste Processing Facility	The site was contaminated with benzoic acid, VOCs, solvents, and PAHs. Remediation included disposing of debris and solid wastes off-site, cleaning VOC-contaminated soil by vacuum extraction, and installing a slurry wall and cap over an area contaminated with hazardous waste associated with an acid and metal-plating waste processing facility.	Revitalization activities included planting wildflowers and other foliage to attract migratory birds and other wildlife.	Treatment of VOC-contaminated soil by in situ vacuum extraction did not meet requirements of the Pennsylvania Land Recycling and Remediation Standards Act.	Protective levels of contaminant concentrations in ground water were established usingthe Synthetic Precipitation Leaching Procedure to determine the extent of capping. Soil contaminated with VOCs was treated by ex situ vacuum extraction.	Melissa Friedland EPA HQ Ariel Rios Building 1200 Pennsylvania Avenue Mail Code: 5204P Washington, DC 20460 703-603-8864 friedland.melissa@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0300982
Saltville Waste Disposal Ponds, Saltville, VA	Superfund Manufacturing Facility	Elevated mercury levels were present in soil and ground water in the area beneath the former chlorine plant. Remediation activities included constructing a water treatment plant and capping the ponds.	A wildlife habitat area was created on the former disposal ponds.	Not specified	Not specified	Eric Newman 1650 Arch Street Mail Code: 3HS23 Philadelphia, PA 19103-2029 215-814-3237 newman.eric@epa.gov	http://www.epa.gov/reg3hscd/super/sites/VAD003127578/

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Seaford Nylon Plant, Seaford, DE	RCRA Corrective Action Site Manufacturing Facility	Wastes include fly ash, corrosives, ignitables, spent halogenated solvents, and discarded commercial chemical products. Ground water contains low levels of metals and VOCs and low pH. Remediation included MNA of ground water with ICs as well as installing a protective cover over solid waste. Fly ash from the site was used as fill at an adjacent golf course.	Reuse includes expansion of the neighboring golf course.	There was concern that the fly ash placed at the golf course may cause a ground water problem.	Evaluations of the ground water at the golf course indicated that the fly ash did not impact the ground water.	Douglas Zeiters Delaware Department of Natural Resources and Environmental Control 89 Kings Highway Dover, DE 19901 302-739-9403 douglas.zeiters@state.de.us	http://www.epa.gov/reg3wcmd/ca/de/pdf/ded002348845.pdf
Site 46 Landfill A, Stump Dump Road, Dahlgren, VA	Superfund Landfill	Ground water and surface water contained contaminants such as cadmium, lead, mercury, and PCBs from municipal waste at the site. Contaminated waste from the site was removed to an appropriate off-site landfill.	The remedial design includes the integration and establishment of tidal wetlands in the low areas of the site.	Uncovering UXO caused a safety issue at the site.	EOD support and screening at all times was required.	Neal Parker 1314 Harwood St., SE Washington Navy Yard Washington, D.C. 20374 202-685-3281 parkernm@efaches.navfac.navy.mil	http://www.wildlifehc.org/ewebeditpro/items/O57F3079.pdf
Tybouts Corner Landfill, New Castle, DE	Superfund Landfill	Remediation activities included installing water lines for residents in the area and installing a protective cap over the landfill, which accepted municipal and household waste.	Revitalization included planting wildflowers and other vegetation on the cap to stabilize the ground and prevent erosion.	Not specified	Not specified	Katherine Lose, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS23 Philadelphia, PA 19103-2029 215-814-3240 lose.kate@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0300035
Walsh Landfill, PA	Superfund Landfill	Residential well water off-site was contaminated with chloromethane, chloroform, xylenes, and other VOCs, as well as lead, mercury, and zinc. Remediation included removing waste and installing an evapotranspiration cover system to protect against migration of on site ground water contaminated with mercury, toluene, and other VOCs from former disposal practices.	Revitalization included replanting a vegetative layer of a variety of native hardwood and coniferous trees.	The site was planned for reuse originally. However, because both the site owner and community were unresponsive, the team installed an evapotranspiration cover with trees as an integral part of the remedy. Therefore, reuse options are minimal.	Trees planted as the vegetative layer of the evapotranspiration cover have provided excellent habitat for birds and small mammals. Current plans are for the site to remain as is.	Frank Klanchar, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS22 Philadelphia, PA 19103-2029 215-814-3218 klanchar.frank@epa.gov	http://www.epa.gov/reg3hwmd/super/sites/PAD980829527/index.htm
Wildcat Landfill, Dover, DE	Superfund Landfill	Contaminated soil and ground water from the previous landfill were capped with a protective cover.	A mixture of native plants and wildflowers were planted on the cap, and Kent County is evaluating plans to allocate a part of the site as a greenway, which is an open space for recreational purposes.	Not specified	Not specified	Hilary Thornton EPA Region 3 1650 Arch Street Mail Code: 3HS23 Philadelphia, PA 19103-2029 215-814-3323 thornton.hilary@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0300101

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Woodlawn County Landfill, MD	Superfund Landfill	The ground water is contaminated with VOCs, primarily vinyl chloride and 1,2-dichloroethane, and with PAHs, pesticides, and metals, primarily manganese. Initially RPMs installed an impermeable cap and ground water P&T system. Later they replaced the cap with a vegetative soil cap to help sustain naturally occurring bacteria in the soil that degrade the contaminants. In addition to P&T, the remedy included MNA with monitoring of the ground water and the vegetative soil cover. The team planted wildlife enhancements such as trees and native wildflowers after installing the vegetative cap.	The closed landfill was used to create wildlife habitat called "New Beginnings, the Woodlawn Wildlife Habitat Area." It is currently used as a nature and science study area by local schools and as an area for projects by the Boy Scouts and Girls Scouts of America.	Analyses showed contamination of on-site and off-site ground water, soil, and sediment and surface water of a stream that crosses the site. MNA posed a difficulty due the scarcity of its use at the time.	The original remedy included extraction and treatment of contaminated ground water. However, continued monitoring showed that MNA effectively removed or immobilized contaminants from ground water. Two remedial designs were completed in parallel in case the MNA process failed to perform as expected.	James J. Feeney, RPM EPA Region 3 1650 Arch Street Mail Code: 3HS22 Philadelphia, PA 19103-2029 215-814-3190 feeney.jim@epa.gov	http://www.wildlifehc.org/brownfields/woodlawn.cfm
REGION 4							
Black Warrior-Cahaba Rivers Land Trust, AL	Brownfields Mining Site	Soils contaminated with lead and heavy metals. Remediation included a recreational park and community stream cleanup events.	Transformed a former industrial region into a 27-mile greenway with parks and paths along the Five-Mile Creek.	It could take 20 years to complete the entire greenway project.	Many of the targeted former industrial areas have been cleaned up and made available to communities as natural and recreational land.	EPA Region 4 Brownfields Team 61 Forsyth Street, S.W. Atlanta, GA 30303-8960 404-562-8493 www.epa.gov/region4/waste/bf/index.htm	http://www.epa.gov/brownfields/success/fultondale_al_BRAG.pdf
Milan Army Ammunition Plant, Milan, TN	Superfund Ammunitions Plant	Two wetland systems were created, a subsurface flow ground-bed wetland and a surface flow lagoon wetland, to degrade explosives and their byproducts. Specifically, ground water was contaminated with explosives constituents including TNT, RDX, HMX, 2,4-DNT and 2,6-DNT.	Revitalization included creation of wetlands and use of phytoremediation as a remedial technology.	Weather was an obstacle because it affects the efficiency of phytoremediation.	Not specified	Laurie Haines U.S. Army Environmental Center 2511 Jefferson Davis Highway Taylor Building NC3- Arlington, VA 22202-3926 703-601-1590 laurie.haines@us.army.mil	http://www.wildlifehc.org/ewebeditpro/items/O57F3081.pdf
Northwest 58th Street Landfill, Miami, FL	Superfund Landfill	Ground water contaminated with heavy metals and toxic chemicals from previous landfill activities was cleaned up through remediation and closure of the landfill.	Through careful design, a lake was constructed at the site for wading birds; trails were created with lookout centers.	Not specified	Not specified	Bill Denman EPA Region 4 61 Forsyth Street, SW Atlanta, GA 30303 404-562-8939 denman.bill@epa.gov	http://www.epa.gov/region4/waste/reuse/fl/nw58reuse.pdf
Solitron Microwave, Port Salerno, FL	Superfund Manufacturing Facility	Ground water contaminants consist of PCE and its breakdown products. Remediation activities include water line extensions, soil removal, *in situ* chemical oxidation, and natural attenuation.	Six acres at the site have been reserved for wetland areas, an upland preserve for native plant habitat, and a 50-foot natural buffer between the site and surrounding residential areas.	Not specified	Not specified	Bill Denman EPA Region 4 61 Forsyth Street, SW Atlanta, GA 30303 404-562-8939 denman.bill@epa.gov	http://www.epa.gov/Region4/waste/npl/nplfls/solmicfl.htm

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REGION 5							
Allied Chemical & Ironton Coke, Ironton, OH	Superfund Chemical and Tar Manufacturing Facility	Solid wastes and wastewater including crude tar and ammonia contaminated the ground water at this site. Remediation activities included excavating and disposing of contaminated soil, installing containment systems, and constructing a water treatment plant.	This area is being converted into a wetlands system, taking advantage of its natural flooding conditions and predisposition to wetlands-type vegetation.	Not specified	Not specified	Syed Quadri EPA Region 5 77 West Jackson Boulevard Mail Code: SR-6J Chicago, IL 60604-3507 312-886-5736 quadri.syed@epa.gov	http://www.epa.gov/region5/sites/alliedchemical/pdfs/allied-chemical-5yr-review-200409-report.pdf
Bowers Landfill, Circleville, OH	Superfund Landfill	Soil, ground water, and surface water contaminated with VOCs and PCBs. Remediation included removing debris and installing a clay cap.	Wetlands were created around the site to protect the cap from flooding.	The nearby Scioto River was prone to flooding, which could affect the landfill cap.	Wetlands were created in the area between the landfill and river, where clay was taken to create the cap, to control flooding.	Sirtaj Ahmed, RPM EPA Region 5 77 West Jackson Boulevard Chicago, IL 60604-3507 312-886-4445 ahmed.sirtaj@epa.gov	http://www.epa.gov/superfund/programs/recycle/live/casestudy_bowers.html
Calumet Container Site, Hammond, IN	Superfund Industrial Facility	Remediation consisted of cleaning up soil contamination caused by previous drum and pail reconditioning operations at the site.	The area will be restored as a native habitat area with opportunities for passive recreation, including walking trails, and increasing biological diversity of native plants for prairie and wetland habitats.	Not specified	Not specified	Thomas Bloom EPA Region 5 77 West Jackson Boulevard Mail Code: SE-4J Chicago, IL 60604-3507 312-886-1967 bloom.thomas@epa.gov	http://www.epa.gov/region5superfund/redevelop/pdf/Calumet.pdf
Broverman Landfill, Christian County, IL	Illinois EPA Corrective Action Landfill	Cleanup included repair of the protective cap placed over an abandoned municipal landfill.	Prairie plants were seeded to stabilize the soil cover and reduce maintenance requirements.	Deep gullies were eroding down the landfill's sparsely vegetated sides and low areas were holding pools of stagnant water.	The cleanup team filled in large surface irregularities, added rip-rap in drainage ways to deter future erosion, installed vegetation mats, and seeded the area with native grasses and wildflowers. The remedy was cost-effective because nitrogen and phosphorous did not have to be added to the soil, additional topsoil and tilling was not required, and maintenance only included occasional prescribed burns.	Jody Kershaw Illinois EPA 1021 North Grand Avenue East P.O. Box 19276 Springfield, Illinois 62794-9276 217-524-3285 jody.kershaw@epa.state.il.us	http://www.epa.state.il.us/environmental-progress/v25/n1/abandoned-landfill.html
Dupage County Landfill, IL	Superfund Landfill	Ground water contamination associated with the landfill was cleaned up.	The site is now being used as a recreational area with picnic and camping areas, trails, and a lake. The previous landfill is used for sledding during the winter months.	Not specified	Not specified	Thomas Williams, RPM EPA Region 5 77 West Jackson Boulevard Mail Code: SR-6J Chicago, IL 60604-3507 312-886-6157 williams.thomas@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0500606
E-Pond Solid Waste Management Unit, Lima, OH	RCRA Corrective Action Refinery Landfill	Synthetic root barrier and soil cover will be placed over the site, which is contaminated with chromium, antimony, thallium, PCB-1248, benzo(a)pyrene, and dibenz(a,h)anthracene.	Prairie habitat constructed with native plants. Interpretive areas and educational opportunities will be created.	Not specified	Not specified	Thomas Matheson, RPM EPA Region 5 77 West Jackson Boulevard Mail Code: DM-7J Chicago, IL 60604-3507 312-886-7569 matheson.thomas@epa.gov	http://www.epa.gov/epaoswer/hazwaste/ca/curriculum/download/eco-rec.pdf

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Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Fernald, Southwest OH	Superfund Uranium Metal Production	Remediation and closure project addressing uranium contamination in soil and ground water. Remediation included treatment and disposal through an on-site disposal facility and off-site disposal. The treated silos and waste pit materials were all disposed of off-site. The on-site disposal facility contains primarily contaminated soil and building debris.	End use of the entire 1,000-acre site is an educational park focusing on site history and ecology. Deep excavations are being converted to wetland and open water habitat. Excavations into the subsoil are being converted to native grasslands.	The primary problems have been invasive species control, geese and deer browsing, and germination success.	Invasive control was initially implemented through mechanical removal. Selective use of herbicides provides on-going control. Deer exclosures have been installed to fence the deer out of new restoration areas where woody plants were installed. Goose fencing, flagged twine, and coyote decoys have been used to discourage geese. Germination success is being evaluated and in some cases has required reseeding.	Thomas A. Schneider Ohio EPA, Office of Federal Facility 401 East Fifth Street Dayton, OH 45402-2911 937-285-6466 tom.schneider@epa.state.oh.us	http://www.wildlifehc.org/ewebeditpro/items/O57F3069.pdf
Ford Rouge Center, Dearborn, MI	MDEQ/ RCRA Corrective Action Automobile Manufacturing Complex	Remediation included removal of soils contaminated with SVOCs, PCBs, metals, and organics as well as containment strategies.	Ecological enhancements include a vegetated roof, pervious pavement, vegetated drainage swales, hedgerow wildlife corridors, wetland restoration, sunflower plantings, and grassland restoration. When it was built, this was the world's largest green roof at 10 acres in size. Honey bee hives have been added to enhance pollination for new plantings.	Issues encountered included coordinating remediation with ongoing plant expansion activities.	Early negotiations with MDEQ helped the process go smoothly.	Dan Ballnik Ford Motor Company One American Road Dearborn, MI 48126 313-248-8606 dballni1@ford.com	http://www.wildlifehc.org/ewebeditpro/items/O57F3071.pdf
Former Brass Foundry and Eljer Park, Marysville, OH	RCRA Corrective Action Foundry	Remediation included removing soil and stream sediments contaminated with VOCs and metals, demolishing buildings, capping residual areas, and improving site drainage to prevent erosion.	Revitalization included creating a park with athletic fields, playground equipment, a walking trail, and a wetlands area.	Not specified	Not specified	Jan J. Chizzonite, Managing Executive Partner Environmental Strategies Consulting LLC 11911 Freedom Drive Reston, VA 20190 703-709-6500 jan.chizzonite@wspgroup.com	http://www.epa.gov/ne/nationalcaconf/docs/Chizzonite.pdf
Former Ford Michigan Casting Center Landfill, Flat Rock, MI	Brownfields Landfill	A wooded leachate collection/management system was used to treat contaminated soil and ground water.	Wooded phytoremediation area providing increased biodiversity via creation of wildlife habitat for various birds and small mammals.	Not specified	Not specified	Jeff Hartlund Ford Motor Company One American Road Dearborn, MI 48126 313-322-0700 jhartlun@ford.com	http://www.wildlifehc.org/ewebeditpro/items/O57F3059.pdf
Former Gulf Refinery Site, Hooven, OH	RCRA Corrective Action Refinery	Phytoremediation consisting of a vegetative cap was used to treat soil contaminated with a mixture of petroleum hydrocarbons, including PAHs.	Activities at the site include constructing a wetland habitat for wildlife and extending the park planned for the adjacent area by providing community access.	Not specified	Not specified	Lucinda Jackson ChevronTexaco Corporation 100 Chevron Way P.O. Box 1627 Richmond, CA 94802-0627 510-242-1047 luaj@chevron.com	http://www.wildlifehc.org/ewebeditpro/items/O57F3061.pdf
Ilada Energy Company, East Cape Girardeau, IL	Superfund Waste Oil Reclamation Facility	Water and soil were contaminated with VOCs, PCBs, and heavy metals. Remediation activities included the removal of 1,742 cubic yards of soil and 865,700 gallons of water. Oil and sludge were incinerated.	The site is part of an ecological preservation area. The Land Conservancy bought land around the site and planted bottomwood trees adjacent to the site.	Not specified	Not specified	Sam Chummar EPA Region 5 77 West Jackson Boulevard Mail Code: SR-6J Chicago, IL 60604-3507 312-886-1434 chummar.sam@epa.gov	http://www.epa.gov/region5superfund/npl/illinois/ILD980996789.htm

* Links valid at time of publication.

Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Industrial Excess Landfill (IEL), Uniontown, OH	Superfund Landfill	Remediation activities such as extraction and treatment, capping the landfill, and installing a landfill gas extraction system were used to treat ground water contaminated by VOCs.	The site's remedy involves enhancing wildlife habitat and creating greenspace. Almost 10,000 native trees and shrubs were planted.	Not specified	Not specified	Timothy Fischer, RPM EPA Region 5 77 West Jackson Boulevard Mail Code: SR-6J Chicago, IL 60604-3507 312-886-5787 fischer.timothy@epa.gov	http://www.epa.gov/superfund/sites/fiveyear/f2006050001133.pdf
Joliet Army Ammunition Plant, Joliet, IL	Superfund Ammunitions Plant	Remediation included excavation and off-site disposal of soils contaminated with metals and on-site bioremediation of explosives-contaminated soils.	Midewin National Tall Grass Prairie was created for recreational, educational, and agricultural benefits to the public. Also, revitalization activities included restoring native wildlife populations and habitat.	Remediation goals were questioned as possibly not protecting ecological resources of the Midewin National Tall Grass Prairie due to the uncertainty of the risk posed by chemical constituents.	Site representatives are still working to establish proper remediation goals and costs.	Laurie Haines U.S. Army Environmental Center 2511 Jefferson Davis Highway Taylor Building NC3- Arlington, VA 22202-3926 703-601-1590 laurie.haines@hqda.army.mil	http://www.epa.gov/R5Super/npl/illinois/IL0210090049.htm
Petersen Sand and Gravel, Libertyville, IL	Superfund Quarry	The former Petersen quarry was used during the 1950s as a dumping ground for solvents and paints causing extensive contamination. Cleanup activities included removing drums, paint cans, and contaminated soil and surface water.	The cleanup enabled Independence Grove Forest Preserve to create a 115-acre lake and establish an education center at the site.	Not specified	Not specified	David Seeley, RPM EPA Region 5 77 West Jackson Boulevard Mail Code: SR-6J Chicago, IL 60604-3507 312-886-7058 seely.david@epa.gov	http://www.epa.gov/region5superfund/npl/illinois/ILD003817137.htm
Pocket Parks at Former Service Stations, Chicago, IL	IEPA Corrective Action Former Service Station	The sites were contaminated with BTEX, and contaminated soil was removed. Each of the sites received "No Further Remediation" letters through IEPA's Voluntary Cleanup Program.	Greenspace was created to reduce paved areas, which decreased the amount of stormwater that reaches the combined storm sewers.	Local politics favored commercial use over recreational use.	Multiple meetings with community groups helped to achieve consensus.	Kelly Kennoy City of Chicago 30 North Lasalle Street, 25th Floor Chicago, IL 60602-2575 312-744-8692 kkennoy@cityofchicago.org	http://www.wildlifehc.org/ewebeditpro/items/O57F3057.pdf
REGION 6							
AMAX Metals Recovery (Freeport McMoRan), Braithwaite, LA	RCRA Corrective Action Metals Recovery Facility	A UST and waste pile area was cleaned up and designated "ready for reuse."	A water retention pond was dewatered to form a wetland that provided a home to alligators relocated due to Hurricane Katrina in 2005.	Not specified	Not specified	U.S. EPA Region 6 1445 Ross Avenue Suite 1200 Dallas, TX 75202-2733 Louisiana Department of Environmental Quality Galvez Building 602 North Fifth Street Baton Rouge, LA 70802	http://findarticles.com/p/articles/mi_qn4200/is_20080604/ai_n25483065?tag=artBody;col1
Brooks City-Base, San Antonio, TX	RCRA Corrective Action Former Medical Research and Development Facility	A portion of the base was cleaned up by installing soil vapor extraction and ground water P&T systems, removing and installing a cover over garbage and construction debris, excavating contaminated soil, and incorporating ICs.	The former air force base was issued a "ready for reuse" determination, which was the first of its kind issued in Texas and the first for a federal facility nationwide. The remedial process incorporated ecological revitalization into the cleanup plan.	Not specified	Not specified	Jeanne Schulze EPA Region 6 1445 Ross Avenue, Suite 1200 Mail Code: 6PD-F Dallas, TX 75202-2733 214-665-7254 schulze.jeanne@epa.gov	http://enviro.blr.com/display.cfm/id/25919

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
DuPont Remington Arms Facility, Lonoke, AK	RCRA Corrective Action Manufacturing Facility	Remediation included excavation and treatment of approximately 6,080 cubic yards of contaminated soils.	Remington Arms continues to manufacture ammunition at the facility. The remaining 731 acres are managed as a wildlife habitat. Ecological revitalization efforts include construction of a 20-acre moist soil impoundment for waterfowl habitat in cooperation with Ducks Unlimited.	Not specified	Not specified	Jeanne Schulze EPA Region 6 1445 Ross Avenue, Suite 1200 Mail Code: 6PD-F Dallas, TX 75202-2733 214-665-7254 schulze.jeanne@epa.gov	http://www.epa.gov/epaoswer/hazwaste/ca/success/rem11-07.pdf
England Air Force Base, LA	RCRA Corrective Action Air Force Base	A portion of the former air force base was cleaned up by removing contaminated soil, incorporating ICs, and instituting MNA of contaminated ground water. The site was designated "ready for reuse."	Areas excavated as part of a remedial action became part of the Audubon Trail, providing habitat and a stopping point for migratory birds, and an expanded 18-hole golf course.	Not specified	Not specified	Louisiana Department of Environmental Quality Public Records Center Galvez Building, Room 127 602 N. Fifth Street Baton Rouge, LA 70802	http://www.epa.gov/region6/ready4reuse/england_rfr.pdf
French, Ltd., Crosby, TX	Superfund Industrial Waste Storage	Remediation included treating soil and ground water contaminated with VOCs and heavy metals and creating 23 acres of new wetlands.	Wetlands and surrounding habitat can be used as recreation for outdoor enthusiasts and as habitat for vegetation and wildlife.	Not specified	Not specified	Ernest Franke, RPM EPA Region 6 1445 Ross Avenue Suite 1200 Mail Code: 6SFRA Dallas, TX 75202-2733 214-665-8521 franke.ernest@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0602498
Heifer International New World Headquarters, Little Rock, AR	Brownfields Industrial Facility	Petroleum contaminated soil was removed from the site.	Activities at the site included the creation of retention ponds and a wetland habitat.	The primary issue at this site was funding.	Support from federal, state, and local sources, along with existing funds allowed cleanup.	Gerald Cound Director of Facilities Management Heifer International 1 World Avenue Little Rock, AR 72202 501-907-2965 gerald.cound@heifer.org	http://www.wildlifehc.org/ewebeditpro/items/O57F5385.pdf
REGION 7							
3-D Investments, Inc., Alda, NE	RCRA Brownfields and Superfund Former Gas Station, Battery Cracking and Lead Recovery Facility	The 3.65-acre site was investigated under RCRA authority. The facility went bankrupt and cleanup costs exceeded monies in the facility's trust fund, so EPA RCRA referred the facility to Region 7 EPA Superfund. Region 7 Superfund evaluated the site and conducted removal activities of lead-contaminated soils. The site was cleaned up to residential or near residential standards.	EPA sent a letter stating the facility was cleaned up, and the property was deeded to the Crane Meadows Nature Center, a nonprofit organization dedicated to natural resource education and the preservation of Sandhill cranes.	During the cleanup response, EPA discovered areas of contamination that were previously unknown. Neighbors and Crane Meadows Nature Center also had a concern regarding excess tree removal.	EPA Region 7 RCRA received a RCRA Brownfields Prevention Initiative Targeted Site Effort grant to assist with characterization, public involvement and other activities. EPA worked with neighbors and Crane Meadows Nature Center to alleviate their concerns about removing perimeter trees. Crane Meadows Nature Center wanted perimeter trees to remain to serve as a wind-break. EPA obliged this request. Mulch from some of the trees was also left onsite.	Andrea R. Stone EPA Region 7 901 North Fifth Street Mail Code: ARTDRCAP Kansas City, KS 66101 913-551-7662 stone.andrear@epa.gov	http://www.epa.gov/swerosps/rcrabf/html-doc/tsefac03.htm

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Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Cherokee County, Galena, KS	Superfund Mining Site	Remediation consisted of burying surface mine wastes contaminated with lead, mercury, and cadmium in abandoned mine pits, subsidence areas, and mine shafts on site; diverting streams away from waste piles; recontouring land surface; and revegetating with native prairie grasses to control runoff and erosion.	Native prairie grassland habitat encouraged the return of wildlife.	Potential for cave-in of filled mine shafts after heavy rain or freezing and thawing cycles.	Avoided development in the areas with potential for cave-in or collapse.	David Drake, RPM EPA Region 7 901 North Fifth Street Mail Code: SUPRFFSE Kansas City, KS 66101 913-551-7626 drake.dave@epa.gov	http://www.epa.gov/superfund/programs/recycle/live/casestudy_cherokee.html
Times Beach, Times Beach, MO	Superfund Contaminated Urban Area	A temporary incinerator was installed to burn soil contaminated with dioxin. The waste ash from the treated soil was buried on site. People were relocated and all homes and businesses were demolished.	A state park now exists on the site and acts as a bird sanctuary.	Numerous problems and issues resulted from this contentious Superfund site. See the Web site provided under "Notes/Links" for more information.	See the Web site provided under "Notes/Links" for more information.	Bob Feild, RPM EPA Region 7 901 North Fifth Street Mail Code: SUPRMOKS Kansas City, KS 66101 913-551-7697 feild.robert@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0701237
Wheeling Disposal Service Co, Inc. Landfill, Amazonio, MO	Superfund Landfill	Soil contaminated with municipal and industrial wastes was remediated by upgrading the existing landfill cap with a clay and soil cover. Ground and surface water were monitored.	During the cleanup, the owner dug a pond and planted native wild grasses and other foliage that would attract birds and wildlife.	Not specified	Not specified	Amer Safadi, RPM EPA Region 7 901 North Fifth Street Mail Code: SUPRMOKS Kansas City, KS 66101 913-551-7825 safadi.amer@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0700780
REGION 8							
BP Former Refinery, Platte River Commons, Casper, WY	RCRA Corrective Action Former Petroleum Refinery	Cleanup included removal of trash and waste from the river to contain the flow of contaminated ground water, excavation of contaminated soils, addition of P&T wells and construction of a wetland treatment system. Nearly 2,000 trees were planted to assist with phytoremediation.	After the river was cleaned up, a recreational kayak course was created. A portion of the site was used to create an 18-hole golf course. Wetlands were incorporated into the golf course design to assist in treating contaminated ground water. Trees were planted for phytoremediation.	Not specified	Not specified	Vickie Meredith WDEQ Solid & Hazardous Waste Division, Hazardous Waste Permitting and Corrective Action Program 250 Lincoln Street Lander, WY 82520 vmered@state.wy.us 307-332-6924 Tom Aalto, EPA Region 8 1595 Wynkoop Street Mail Code: 8P-HW Denver, CO 80202-1129 aalto.tom@epa.gov 303-312-6949	http://www.epa.gov/waste/hazard/correctiveaction/pdfs/casper11-07.pdf

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Cache La Poudre River Superfund Site, Fort Collins, CO	Superfund	Soil and sediments in the Poudre River, and ground water were contaminated with gasoline mixed with coal tar. Cleanup activities included sediment excavation and temporary re-routing of the Poudre River, a vertical sheet pile barrier to stop ground water flow, and ground water treatment.	EPA completed an intact but unobtrusive remedy of the Poudre River to preserve the riverine habitat.	Beavers ate about half of the tree plantings.	Site managers used wire on the first 6 to 8 feet of tree plantings, and painted the wire to be easily visible.	Paul Peronard, OSC EPA Region 8 1595 Wynkoop Street Mail Code: 8EPR-SR Denver, CO 80202-1129 303-312-6808 peronard.paul@epa.gov	http://www.clu-in.org/conf/tio/ecocasestudies_080207/
California Gulch Superfund Site, Upper Arkansas River Operable Unit, Leadville, CO	Superfund Mining Site	The mining district's soil, surface water, and sediments were heavily contaminated with lead, zinc, and other heavy metals from mine tailings. Biosolids and lime were applied directly to the tailings along Upper Arkansas River.	The area along the river has been restored and supports vegetation and wildlife, and is available for agricultural use and recreational use such as hiking and fishing.	Tailings could not be excavated because of the risk of tailings entering the river and the difficulty of finding a repository for the contaminated soil. Also, replacement of topsoil would be costly. Mobilizing materials to the site was difficult due to the elevation of the site. Water was also scarce due to low rainfall and high elevation.	Biosolids were spread over the tailings, reducing the potential for tailings to migrate to the river.	Rebecca Thomas, RPM EPA Region 8 1595 Wynkoop Street Denver, CO 80202-1129 303-312-6552 thomas.rebecca@epa.gov Mike Holmes, RPM EPA Region 8 1595 Wynkoop Street Denver, CO 80202-1129 303-312-6607 holmes.michael@epa.gov	http://www.epa.gov/superfund/programs/recycle/pdf/cal_gulch.pdf
East Helena Site, Helena, MT	Superfund Smelting Site	Ground water, surface water, and soil contamination from decades of lead smelting activities was cleaned up by removing waste, treating soil, and capping the area.	In addition to mixed commercial and residential use, portions of the site are being used for a neighborhood park, a baseball field, and some wetlands redevelopment.	Not specified	Not specified	Scott Brown EPA Region 8 Montana Operations Office Federal Building 10 West 15th Street Suite 3200 Mail Code: 8MO Helena, MT 59626 406-457-5035 brown.scott@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0800377
Kennecott North and South Zone Sites, Salt Lake County, UT	Superfund Mining Site	Soil and ground water were contaminated with mining wastes, including sulfates and heavy metals. Soil was removed, and ground water was pumped and treated in the mine's tailings slurry line.	Open space, wetlands, and wildlife habitat were created. A residential area was also created.	Not specified	Not specified	Rebecca Thomas, RPM EPA Region 8 1595 Wynkoop Street Mail Code: 8EPR-SR Denver, CO 80202-1129 303-312-6552 thomas.rebecca@epa.gov	http://www.epa.gov/superfund/programs/aml/tech/kennecott.pdf
Milltown Reservoir Sediments, Milltown, MT	Superfund Mining Site	Six million cubic yards of mining waste that had piled up at the base of the Milltown Dam was poisoning the reservoir and affecting drinking water. A new drinking water system was installed at the site.	In addition to adding a new drinking water system, 2.5 miles was added to existing hiking trails in Missoula to complete a loop around the University of Montana and Missoula's waterfront.	Not specified	Not specified	Scott Brown EPA Region 8 Montana Operations Office Federal Building 10 West 15th Street Suite 3200 Mail Code: 8MO Helena, MT 59626 406-457-5035 brown.scott@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0800445

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Monticello Mill Superfund Site, Monticello, UT	Superfund Former DOE Processing Facility	A cover system was constructed to contain radioactive material removed from the site. The cover design mimics and enhances the natural ground water balance and uses a capillary barrier. Native vegetation was planted to maximize evapotranspiration.	The native vegetation chosen was designed to emulate the structure, function, diversity, and dynamics of native plant communities in the area.	Not specified	Not specified	Mark Aguilar EPA Region 8 1595 Wynkoop Street Mail Code: 8EPR-F Denver, CO 80202-1129 303-312-6251 aguilar.mark@epa.gov	http://www.clu-in.org/PRODUCTS/NEWSLTRS/ttrend/view.cfm?issue=tt0500.htm
Rocky Flats Plant, Golden, CO	Superfund Former DOE Weapons Facility	At one time the site stored more than 14 tons of plutonium. All special nuclear materials were packaged and shipped to licensed repositories. Over 800 structures were cleaned up, as necessary, and removed. 690 tanks were decontaminated and removed, and onsite landfills were covered. Three contaminated ground water plume barriers and passive treatment systems were installed. Finally, wastes and contaminated soils were removed and shipped to permitted facilities.	Part of the site that has been remediated has been transferred from DOE to DOI and the USFWS to manage as a National Wildlife Refuge.	Not specified	Not specified	Mark Aguilar EPA Region 8 1595 Wynkoop Street Mail Code: 8EPR-F Denver, CO 80202-1129 303-312-6251 aguilar.mark@epa.gov	http://www.epa.gov/region8/superfund/co/rkyflatsplant/index.html
Rocky Mountain Arsenal, Commerce City, CO	Superfund Army-Lead Remedial Action Ammunition Plant	P&T systems were installed to remediate ground water contaminated with wastes from production of chemical warfare agents, industrial and agricultural chemicals, and pesticides.	Congress passed the Rocky Mountain Arsenal National Wildlife Refuge Act, requiring the site to become part of the national wildlife refuge system once cleanup is complete.	Not specified	Not specified	Greg Hargreaves, RPM EPA Region 8 1595 Wynkoop Street Mail Code: 8EPR-F Denver, CO 80202-1129 303-312-6661 hargreaves.greg@epa.gov	http://www.rma.army.mil/cleanup/clnfrm.html
Silver Bow Creek and Warm Springs Ponds, Butte, MT	Superfund Mining Site	Remediation included excavating sediment contaminated by copper mining activities and installing a water treatment system.	Extensive wetlands are now home to a variety of wildlife. Nesting platforms were built to protect birds. The wetlands are also used for recreation such as fishing, hiking, and biking.	Not specified	Not specified	Ron Bertram, RPM EPA Region 8 1595 Wynkoop Street Mail Code: 8EPR-F Denver, CO 80202-1129 406-441-1150 bertram.ron@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0800416

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Summitville Mine, CO	Superfund Mining Site	Gold mining released cyanide and acidic mine water to the Alamosa River. Cleanup activities include permanently stabilizing the site and reversing the effects of mining on the river.	The Alamosa River and tributaries flow through wetlands, forested and agricultural land, and into the Terrace Reservoir, which supplies irrigation water to livestock and farms. The site has been revegetated with grasses that promote the recolonization of native plants. The river, which was void of life because of contamination, now supports some types of aquatic life.	Not specified	Not specified	Victor Ketellapper, RPM EPA Region 8 1595 Wynkoop Street Mail Code: 8EPR-F Denver, CO 80202-1129 303-312-6578 ketellapper.victor@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0801194
REGION 9							
Atlas Asbestos Mine, Fresno County, CA	Superfund Mining Site	The remedy included the removal of contaminated material, stabilization of erosion-prone areas, and structural improvements to clean up the asbestos contaminated soil and water.	The site is a wildlife sanctuary and a popular recreational area for hikers, campers, and hunters.	At the Atlas Mine Area, the road to the Rover Pit/Channel A is likely to fail sometime in the future due to an active landslide. In addition, the road to Pond A may also fail in the future due to erosion.	Alternate access roads to the Rover Pit/Channel A and to Pond A will be identified prior to failure of the existing roads.	Anna Lynn Suer EPA Region 9 75 Hawthorne Street Mail Code: WTR-2 San Francisco, CA 94105 415-972-3148 suer.lynn@epa.gov	http://www.epa.gov/superfund/sites/fiveyear/f2006090001092.pdf
A West Coast Refinery, Location not provided	EPA Research Technology Development Forum Site Refinery Effluent Treatment System	A phytoremediation demonstration was conducted at the site, which was contaminated with hydrocarbons. The remediation also included enhancing and planting wetlands, and installing a vegetation cap.	The site includes a clean stormwater holding basin. Natural vegetation was planted over the 90-acre vegetation cap.	Selenium was identified on site and in bird eggs, which can be harmful to the wildlife, especially bird embryos.	The site was turned into a treatment zone and habitat zone. Birds were discouraged from the treatment zone where selenium was to be removed. After testing, selenium was found to be greatly reduced in bird eggs.	Kim Beman Chevron 6001 Bollinger Canyon Road San Ramon, CA 94583, KBGS@chevron.com	http://www.wildlifehc.org/ewebeditpro/items/O57F3055.pdf
Alameda Naval Air Station, Alameda, CA	Superfund Landfill, Lagoon	Remediation included using dredged sediment from the lagoon as part of a landfill cap for parts of the site that were contaminated with PCBs, heavy metals, and PAHs.	A golf course is being planned in the landfill area, and a marina will be constructed in the lagoon area.	Not specified	Not specified	Anna Marie Cook EPA Region 9 75 Hawthorne Street Mail Code: SFD-8-3 San Francisco, CA 94105 415-972-3029 cook.anna-marie@epa.gov	http://www.epa.gov/oerrpage/superfund/programs/recycle_old/pilot/facts/r9_38.htm
REGION 10							
American Crossarm & Conduit Co., Chehalis, WA	Superfund Wood Treatment Facility	Remediation activities include removing contaminated site material, disposing of the site facilities, removing lagoon sediment, and excavating soil. The contaminants of concern are carcinogenic polyaromatic hydrocarbons, PCP, and dioxin/furans.	Wetlands restoration.	Not specified	Not specified	Anne McCauley EPA Region 10 1200 Sixth Avenue Mail Code: ECL-113 Seattle, WA 98101 206-553-4689 mccauley.anne@epa.gov	http://www.epa.gov/superfund/sites/fiveyear/f04-10004.pdf

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Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Commencement Bay, Tacoma, WA	Superfund Industrial Activities	Industrial activities resulting in hazardous waste contamination of the waterways within Commencement Bay were addressed.	In addition to navigational improvements to the port, nine acres of wetlands were restored as a result of the cleanup. EPA also worked with Washington Department of Environment to create seven acres of essential mud flats habitat where fish, birds, wildlife, and plant species thrive.	Not specified	Not specified	Chris Bellovary EPA Region 10 1200 Sixth Avenue Mail Code: ECL-111 Seattle, WA 98101 206-553-2723 bellovary.chris@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=1000981
Harmony Mine and Mill, Baker, ID	Superfund Mining Site	A diversion ditch was created and pipes laid to divert Withington Creek from tailings piles. After they were dry, 10,000 cubic yards of tailings were excavated and hauled to a repository location. A sedimentation pond was also constructed below the tailings pile to catch any runoff that occurred. Tailings were then capped with a 2-foot layer of compacted rock followed by a one-foot layer of uncompacted rock.	Where the tailings were removed, the area was graded, a stable creek bed with the ability to withstand large debris flow was constructed, and disturbed areas were seeded. Withington Creek is a designated cold water community and salmonid spawning habitat for the endangered chinook salmon.	Not specified	Not specified	Greg Weigel EPA Region 10, Idaho Operations Office 1435 North Orchard Street Boise, ID 83706 208-378-5773 weigel.greg@epa.gov	http://epaosc.net/site_profile.asp?site_id=10BN
Hoquarton Natural Interpretive Trail, Tillamook, OR	Brownfields Lumber Mill	Using an EPA Revolving Loan Fund, contaminated soil was excavated and treated.	The former lumber mill was transformed into a recreational and educational greenspace. Volunteers removed weeds and invasive plants, disposed of over two tons of trash, and planted over 2,000 native plants in riparian areas. A trail was also installed to provide walking and bird watching opportunities.	It was unclear how long-term maintenance of the park would be achieved.	Long-term maintenance of the park was supported by school groups and other volunteers.	Mike Slater EPA Region 10 805 SW Broadway Mail Code: OOO Portland, OR 97205 503-326-5872 slater.mike@epa.gov	http://www.landcurrent.com/contemporary/landscape_design.php?in=Hoquarton&work=public
Old Jensen Texaco Station, Rosalia, WA	OUST Abandoned Gas Station	Through the USTFields Pilot Program, this abandoned gas station site was remediated by removing five USTs and contaminated soil to make the site ready for future reuse. Contaminated soil treated and disposed of off-site. Additional contamination is being addressed through ground water monitoring and possible MNA.	Stakeholders plan to convert the former gas station site into a visitor and community center with green infrastructure. They plan to incorporate native plant communities that are part of the the distinctive Palouse ecosystem, including grasslands, scrub thickets, ridges, and slope communities. The community center could be used to educate visitors about the unique geology and ecology of the region.	Additional contamination could not be removed without destroying the historic building this project was intended to restore. *In situ* treatment options have been considered but will not be pursued until additional ground water data is evaluated. MNA of the remaining contamination may prove to be an adequate and appropriate cleanup alternative.	Not specified	Wildlife Habitat Council 8737 Colesville Road, Suite 800 Silver Spring, MD 20910 301-588-8994 whc@wildlifehc.org	http://www.wildlifehc.org/ewebeditpro/items/O57F7008.pdf

* Links valid at time of publication.

Appendix A: Ecological Revitalization Case Studies, continued

Property Name and Location	Property Type	Cleanup Type	Revitalization/Reuse Component	Problems/Issues	Solutions	Point of Contact	Notes/Links*
Port Hadlock Detachment, Jefferson County, WA	Superfund Landfill	Soil, ground water, sediment, and shellfish were contaminated with heavy metals, PCBs, and pesticides. As part of the remediation, the portion of the landfill that had leaked into the surrounding beaches was contained and capped.	Beaches and tribal fishing grounds were re-opened.	None	None	Nancy Harney, RPM EPA Region 10 1200 Sixth Avenue Mail Code: ECL-115 Seattle, WA 98101 206-553-6635 harney.nancy@epa.gov	http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=1001117
SeQuential Biofuels, Eugene, OR	OUST Fueling Station	USTs from the closed fueling station were removed and contaminated soil was excavated. A Brownfields grant assisted in cleaning up the remainder of the site and getting it ready for reuse.	The new station is bordered with grassy bioswales that help to contain stormwater runoff from the site, remediate contamination biologically before it leaves the site, and slow the flow of stormwater into the storm-sewer system. In addition, green building technologies were used including a vegetated roof, solar panels, purchased wind energy, and use of available natural light through window design to reduce the need for heating and cooling.	Not specified	Not specified	Jim Glass Oregon Department of Environmental Quality 750 Front Street NE, Suite 120 Salem, OR 97301-1039 503-378-5044 glass.jim@deq.state.or.us	http://www.neiwpcc.org/lustline/lustline_pdf/lustline_55.pdf
Sequim Bay Estuary, Clallam County, WA	Brownfields	Cleanup activities involved removing 99 creosote-treated pilings from the estuary and removing 350 tons of contaminated soil and 600 tons of solid waste from an adjacent shoreline and riparian wetlands.	The bay water now provides clean sediment and habitat for shellfish, salmon, and other natural species. The project also has the economic benefits for the Jamestown S'Klallam Tribe with increased revenue from the sale of fish and an expanded tourist area for kayaking and bird watching.	Not specified	Not specified	EPA Region 10 Brownfields Team 1200 Sixth Avenue Seattle, WA 98101 206-553-2100	http://www.epa.gov/brownfields/03grants/sequim.htm
West Page Swamp (Bunker Hill NPL Site), Shoshone County, ID	Superfund Mining Site	Remediation included constructing a cap over soil contaminated with lead and zinc tailings. The cap consisted of biosolids compost and wood ash.	Wetland is now habitat to wildlife.	Stakeholders were concerned that remediation is only a short-term solution because contaminants were not completely removed from site.	Ground water and surface water wells were installed and are being monitored quarterly or annually.	Harry Compton EPA Facilities Rariton Depot 2890 Woodbridge Avenue Mail Code: 101MS101 Edison, NJ 08837-3679 732-321-6751 compton.harry@epa.gov	http://www.wildlifehc.org/ewebeditpro/items/O57F3063.pdf
Wyckoff-Eagle Harbor, Puget Sound, WA	Superfund Wood Treatment Facility	EPA worked with USACE to obtain clean silt to cap contaminated sediments from a previous wood treatment facility and shipyard to stop further release of toxins into Puget Sound. EPA also removed on-site buildings and polluted sediments from the harbor.	After contaminated sediment was removed, EPA and state officials lined the area with gravel to attract mussels and barnacles and created a 2-acre estuarine habitat.	Not specified	Not specified	Ken Marcy EPA Region 10 1200 Sixth Avenue Mail Code: ECL-112 Seattle, WA 98101 206-553-2782 marcy.ken@epa.gov	http://www.epa.gov/superfund/programs/recycle/live/casestudy_wyckoff.html

* Links valid at time of publication.

Appendix B: Additional Ecological Revitalization Resources

Section 1: Introduction

Interstate Technology & Regulatory Council (ITRC): www.itrcweb.org

Land Revitalization Initiative: www.epa.gov/oswer/landrevitalization/basicinformation.htm

U.S. Environmental Protection Agency (EPA) Hazardous Waste Cleanup Information (CLU-IN). Tools for Ecological Land Reuse: www.cluin.org/ecotools

EPA One Cleanup Program Initiative: www.epa.gov/oswer/onecleanupprogram

Section 2: Ecological Revitalization Under EPA Cleanup Programs

Atlas Tack Superfund Site Information: www.epa.gov/ne/superfund/sites/atlas

Brownfields Green Infrastructure Fact Sheet: www.epa.gov/brownfields/publications/swdp0408.pdf

Biological Technical Assistance Groups (BTAG) Regional Web sites:
- EPA Region 3: www.epa.gov/reg3hwmd/risk/eco/index.htm
- EPA Region 4: www.epa.gov/region4/waste/ots/index.htm
- EPA Region 5: www.epa.gov/region5superfund/ecology/index.html
- EPA Region 8: www.epa.gov/region8/r8risk/eco.html

Cross Program Revitalization Guidance:
www.epa.gov/superfund/programs/recycle/pdf/cprm_guidance.pdf

Emergency Response Team: www.ert.org

EPA CLU-IN Publications Search Web site: www.clu-in.org/pub1.cfm

EPA CLU-IN Tools for Ecological Land Reuse: www.cluin.org/ecotools

EPA Guidelines for Ecological Risk Assessment:
http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=12460

EPA Land Revitalization Web site: www.epa.gov/landrevitalization/index.htm

EPA Office of Superfund Remediation and Technology Innovation: www.epa.gov/tio

EPA Region 3—Hazardous Waste Cleanup Sites Land Use & Reuse Assessment, Data Results:
www.epa.gov/region03/revitalization/R3_land_use_final/data_results.pdf

EPA Office of Solid Waste and Emergency Response (OSWER). 1991. ECO Update—The Role of Biological Technical Assistance Groups (BTAG) in Ecological Assessment. Publication number 9345.0-051. September. www.epa.gov/oswer/riskassessment/ecoup/pdf/v1no1.pdf

EPA OSWER. 2008. Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminates Sites. www.clu-in.org/download/remed/Green-Remediation-Primer.pdf

Federal Facilities Restoration and Reuse Office (FFRRO) Web site: www.epa.gov/fedfac/about_ffrro.htm

Interim Guidance for OSWER Cross-Program Revitalization Measures:
www.epa.gov/landrevitalization/docs/cprmguidance-10-20-06covermemo.pdf

Local native plant societies: www.michbotclub.org/links/native_plant_society.htm

National Oceanic and Atmospheric Administration (NOAA): http://response.restoration.noaa.gov

Superfund Sitewide Ready-for-Reuse Performance Measure:
www.epa.gov/superfund/programs/recycle/pdf/sitewide_a.pdf

Underground Storage Tank (UST) Brownfields Cleanups:
www.nemw.org/petroleum%20issue%20opportunity%20brief.pdf

U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS):
www.nrcs.usda.gov

Wildlife Habitat Council (WHC) Leaking Underground Storage Tank (LUST) Cleanups Web site:
www.wildlifehc.org/brownfield_restoration/lust_pilots.cfm

Section 3: Technical Considerations for Ecological Revitalization

EPA CLU-IN. The Use of Soil Amendments for Remediation, Revitalization, and Reuse:
www.clu-in.org/download/remed/epa-542-r-07-013.pdf

EPA Tech Trends. Fort Wainwright:
www.clu-in.org/PRODUCTS/NEWSLTRS/ttrend/view.cfm?issue=tt0500.htm

Section 4: Wetlands Cleanup and Restoration

EPA, Office of Water, Office of Wetlands, Oceans, and Watersheds: www.epa.gov/OWOW/wetlands

EPA OSWER. Considering Wetlands at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Sites (EPA 540/R-94/019, 1994):
www.epa.gov/superfund/policy/remedy/pdfs/540r-94019-s.pdf

EPA OSWER. Environmental Fact Sheet: Controlling the Impacts of Remediation Activities in or Around Wetlands (EPA 530-F-93-020).

Society of Wetland Scientists (SWS), Wetlands Journal: www.sws.org/wetlands

U.S. Department of Interior (DOI), U.S. Fish and Wildlife Service. National Wetlands Inventory:
www.nwi.fws.gov

U.S. Geological Survey (USGS), National Wetlands Research Center: www.nwrc.gov

Wetlands Research Program and Wetlands Research Technology Center:
http://el.erdc.usace.army.mil/wetlands

Wetland Science Institute, Natural Resources Conservation Service, U.S. Department of Agriculture:
www.wli.nrcs.usda.gov

Section 5: Stream Cleanup and Restoration

EPA Office of Water. River Corridor and Wetland Restoration Web site: www.epa.gov/owow/wetlands/restore

EPA Office of Water and OSWER. Integrating Water and Waste Programs to Restore Watersheds: www.epa.gov/superfund/resources/integrating.htm

EPA OSWER. Contaminated Sediment Remediation Guidance: www.epa.gov/superfund/health/conmedia/sediment/guidance.htm

Federal Interagency Stream Corridor Restoration Guide: www.nrcs.usda.gov/technical/stream_restoration/newgra.html

University of Nebraska-Lincoln: www.ianr.unl.edu/pubs/Soil/g1307.htm

Section 6: Terrestrial Ecosystems Cleanup and Revitalization

Clemants, Stephen. 2002. Is Biodiversity Sustainable in the New York Metropolitan Area? University Seminar on Legal, Social, and Economic Environmental Issues, Columbia University, December 2002.

EPA OSWER. 2008. Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminates Sites. www.clu-in.org/download/remed/Green-Remediation-Primer.pdf

Handel, Steven N., G.R. Robinson, WFJ Parsons, and J.H. Mattei. 1997. Restoration of Woody Plants to Capped Landfills: Root Dynamics in an Engineered Soil, Restoration Ecology, 5:178-186.

North Carolina Cooperative Extension Service: www.ces.ncsu.edu/depts/hort/hil/hil-645.html

Plant Conservation Alliance: www.nps.gov/plants

Robinson, G.R. and S.N. Handel. 1993. Forest Restoration on a Closed Landfill: Rapid Addition of New Species by Bird Dispersion, Conservation Biology, 7: 271-278.

Society for Ecological Restoration. Ecological Restoration Reading Resources: www.ser.org/reading_resources.asp

USDA, NRCS. Plant Materials Program: http://plant-materials.nrcs.usda.gov

USDA, NRCS. PLANTS Database: http://plants.usda.gov

Weed Science Society of America: www.wssa.net

Section 7: Long-Term Stewardship Considerations

EPA. Superfund – Operation and Maintenance Web site: http://epa.gov/superfund/cleanup/postconstruction/operate.htm

EPA OSWER. 2005. Long Term Stewardship Task Force Report and the Development of Implementation Options for the Task Force Recommendations. www.epa.gov/LANDREVITALIZATION/docs/lts-report-sept2005.pdf.

Institutional Controls: A Site Manager's Guide to Identifying, Evaluating, and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups, available at http://epa.gov/superfund/policy/ic/guide/guide.pdf

Appendix C: Acronyms

ACRES	Assessment, Cleanup, and Redevelopment Exchange System
AOC	Area of Concern
BMP	Best Management Practices
BP	British Petroleum
BRAC	Base Realignment and Closure
BTAG	Biological Technical Assistance Group
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
BTSC	Brownfields and Land Revitalization Technology Support Center
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CIC	Community Involvement Coordinator
CLU-IN	Hazardous Waste Clean-up Information
CPRM	Cross-Program Revitalization Measure
DARRP	Damage Assessment, Remediation and Restoration Program
DEQ	Department of Environmental Quality
DNT	Dinitrotoluene
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
EO	Executive Order
EOD	Explosives Ordnance Disposal
EPA	U.S. Environmental Protection Agency
ER3	Environmentally Responsible Redevelopment and Reuse
ERA	Ecological Risk Assessment
FFEO	Federal Facilities Enforcement Office
FFLC	Federal Facilities Leadership Council
FFRRO	Federal Facilities Restoration and Reuse Office
FS	Feasibility Study
FY	Fiscal Year
GPRA	Government Performance and Results Act
HE EI	Human Exposures Under Control Environmental Indicator
HMX	High Melting Explosive (or Cyclotetramethylenetetranitramine)
IC	Institutional Control
IEPA	Illinois Environmental Protection Agency
ITRC	Interstate Technology & Regulatory Council
JOAAP	Joliet Army Ammunition Plant
LEED	Leadership in Energy and Environment Design
LUST	Leaking Underground Storage Tank
MCL	Maximum Contaminant Level
MDEQ	Michigan Department of Environmental Quality
MNA	Monitored Natural Attenuation
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRDA	Natural Resource Damage Assessment
O&M	Operation and Maintenance
OBLR	Office of Brownfields and Land Revitalization
OPEI	Office of Policy, Economics, and Innovation
ORCR	Office of Resource Conservation and Recovery
OSC	On-Scene Coordinator
OSRTI	Office of Superfund Remediation and Technology Innovation

OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
OUST	Office of Underground Storage Tanks
P&T	Pump and Treat
PAH	Polycyclic Aromatic Hydrocarbon
PCA	Plant Conservation Alliance
PCB	Polychlorinated Biphenyl
PCE	Perchloroethylene (or Tetrachloroethene)
PDF	Portable Document Format
PFP	Protective For People
RAU	Ready for Anticipated Use
RCRA	Resource Conservation and Recovery Act
RDX	Royal Demolition Explosive (or Cyclotrimethylenetrinitramine)
RI	Remedial Investigation
RMA	Rocky Mountain Arsenal
ROD	Record of Decision
RI/FS	Remedial Investigation/Feasibility Study
RPM	Remedial Project Manager
RTU	Return To Use
SRI	Superfund Redevelopment Initiative
SVOC	Semi-Volatile Organic Compound
SWS	Society of Wetland Scientists
TAB	Technical Assistance to Brownfields
TCE	Trichloroethylene
TNT	Trinitrotoluene
TPM	Technical Performance Measure
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	Underground Storage Tank
UXO	Unexploded Ordnance
VOC	Volatile Organic Compound
WHC	Wildlife Habitat Council

Ecological Revitalization:
Turning Contaminated Properties
Into Community Assets

Office of Solid Waste and
Emergency Response

EPA-542-R-08-003
February 2009
www.epa.gov/tio
http://clu-in.org

United States
Environmental Protection Agency
(5203P)
Washington, D.C. 20460

Official Business
Penalty for Private Use $300

Frequently Asked Questions About Ecological Revitalization of Superfund Sites

Ecological revitalization provides habitat for wildlife and is not considered beautification or enhancement; therefore it can be incorporated into site remediation plans.

Fact Sheets on Ecological Revitalization

- This fact sheet is the first in a series of fact sheets on ecological revitalization.
- The second fact sheet "Revegetation of landfills and waste containment areas", EPA 542-F-06-001, can be found at http://cluin.org/ecorevitalization.
- Look for our third fact sheet "Ecological Revitalization and Attractive Nuisance Issues", EPA 542-F-06-003.

Introduction

Damaged land does not have to be abandoned land. Ecological revitalization can return damaged land to a state of health, vitality, and diversity. This fact sheet, the first in a series on ecological revitalization, addresses many frequently asked questions about ecological revitalization and revegetation of Superfund sites.

Through the Superfund, Brownfields, and Federal Facilities programs, the U.S. Environmental Protection Agency (EPA), states, tribes, or potentially responsible parties (PRP) clean up sites that pose real or potential threats to human health or the environment. Part of the cleanup process may include ecological revitalization – a cost-effective way to either create habitat or incorporate it as a natural remediation technology for Superfund sites while increasing the ecological value of the land. As those responsible for site cleanups learn more about ecological revitalization, its use at Superfund sites increases. In fact, in March 2006, EPA announced that it is helping communities reuse cleaned up sites through the Superfund Redevelopment Initiative (http://www.epa.gov/superfund/programs/recycle/), and several of those Superfund sites have a planned recreational end use that will incorporate ecological revitalization.

The information in this fact sheet is intended for EPA site managers, state agency site managers, consultants, and others interested in restoring disturbed sites. Various information sources used to prepare this fact sheet are listed at the end.

What is ecological revitalization?

Ecological revitalization of a Superfund site is the process of returning a site to a functioning and sustainable use. Ecological revitalization re-establishes a site to a natural state, thus increasing or improving habitat for plants and animals without impairing the remediation activities that ensure the protection of human health and the environment. Although ecological revitalization can be used to create habitat as a specific goal, it also can be used to complement or enhance a traditional cleanup method; as a green remediation technology to remove or stabilize contaminants; or reduce erosion while providing valuable wildlife habitat. Ecological revitalization also can be used adjacent to areas redeveloped for commercial use, such as for riparian zones, and in conjunction with recreational features such as hiking and biking trails or bird-watching lookout stations.

Selected Benefits of Ecological Revitalization

- Removes stigma associated with prior waste sites
- Repairs damaged land
- Enhances property values
- Provides recreational uses for local residents
- Improves soil health and supports diverse vegetation
- Creates wildlife habitat
- Contributes to a green corridor
- Can reduce erosion, sequester carbon, and control landfill leachate
- Protects surface and groundwater from potential contamination

Why should I consider ecological revitalization? What are the benefits?

Ecological revitalization provides a variety of environmental, economic, and public relations benefits. When the end use of a site is considered, those responsible should discuss all future use alternatives with the community, including ecological revitalization. The EPA Environmental Response Team (ERT) can assist in facilitating public outreach.

Environmental Benefits:

- **Biodiversity** In addition to providing areas that are more aesthetically pleasing than mowed grass or pavement, ecological revitalization provides important habitat that attracts and sustains wildlife, such as migratory birds. Areas with a variety of native plant species are less impacted by disease, provide habitat for a variety of wildlife species, and may be vital links to other habitat areas on critical migration routes.
- **Contaminant remediation** Ecological revitalization can include natural remediation technologies that can help biodegrade environmental contaminants, sequester carbon to make it unavailable as a greenhouse gas, improve groundwater recharge, and control landfill leachate.
- **Soil stability** Ecological revitalization provides rooted vegetation to stabilize the soil and can reduce the need to excavate or import soil. This in turn can limit dust, reduce erosion, and slow down and filter storm water runoff.
- **Education** Ecological revitalization provides educational, interpretive, and stewardship opportunities for students and the local community.

Economic Benefits:

- **Cost** Not only is ecological revitalization cost-competitive with other remediation technologies, but the reduced maintenance requirements often make it less expensive than many other end uses. Conservation easements, environmental offsets, and an increased tax base can also provide additional economic benefits.
- **Aesthetic value** Ecological revitalization can provide recreational areas that increase local property values or provide revenue. In addition, aesthetically pleasing commercial greenscaping or residential areas attract more customers and can be marketed to create a competitive advantage.

Public Relations Benefits:

- **Improved community image** Ecologically revitalized sites improve the aesthetics of a community and may increase recreational use and tourism.
- **Improved agency image** Site owners and regulatory agencies may gain an enhanced reputation, "green" image, external validation, and sustainable operations.

Additional information on the benefits of ecological revitalization is available through the Interstate Technology and Regulatory Council (ITRC 2004 and 2006). See the information resources listed at the end of this fact sheet.

What types of sites can be ecologically revitalized? Are small or industrial sites eligible?

Ecological revitalization can be implemented to some degree at any site; however, the benefits will be strongly influenced by the surrounding area. Ecological revitalization can most easily be incorporated for a site that is already located within a larger beneficial habitat or ecosystem. Sites that are somewhat isolated, but are along a corridor or riparian or transition zone and linked to more extensive habitat, are also suitable for revitalization. Sites that are completely isolated within industrial or residential development may also be candidates for ecological improvements and community recreational opportunities.

Small or industrial sites within an urban or suburban setting may appear to contribute less to the ecosystem, but they can be important habitats, reservoirs, or sanctuaries, and provide excellent opportunities for public education or recreation. In many cases, these sites provide valuable opportunities for restoring rare or unique habitat types and provide beneficial recreational assets such as soccer fields, golf courses, playgrounds, or parks with a green element. In many situations, ecological revitalization should be considered as part of a "green landscaping" approach to site development. These sites can provide a sense of ownership and opportunities for stewardship among the residents and public.

Should I use native vegetation for ecological revitalization?

Native vegetation should be used for ecological revitalization whenever possible. Executive Order 13148 refers to a presidential memorandum regarding beneficial landscape practices on grounds landscaped with federal dollars (http://www.epa.gov/greenacres/EO13148.pdf). The memorandum requires the use of regional native vegetation in landscaping when possible. Native vegetation prefers native (unfertilized) soils, and does not require soil amendments, such as fertilizer. Appropriate site and soil analyses should be performed during predesign stages of the project. On many Superfund sites, the soil characteristics are different than characteristics of native soil (for example, soil may have a lower pH or higher salt concentration). Soil amendments may be necessary in these cases to remediate contamination, and certain native vegetation may not thrive in the resulting environment. Therefore, it is not always possible to revegetate a site strictly using regional native vegetation. A restoration practitioner should be consulted to aid in proper selection of the vegetation and to increase the chance of planting success. The restoration practitioner can specify analyses that help match appropriate species of vegetation with site and soil conditions. Some minimal care should be incorporated during implementation, and a plan could be developed to cover such items as watering and any need for pest control, including control of invasive plant species. Longer term

Site managers should work with the local community when deciding to include ecological revitalization as a cleanup component for a site. Active participation by the local community enhances the value and acceptance of the final restoration effort. EPS's ERT (http://www.ert.org) can help to foster community partnership by outreach, public meetings, and providing technical information.

Site Types and Case Studies Related to Ecological Revitalization

- **Mining:** Cherokee County Galena Subsite (OU5) (native prairie grassland with potential for grazing or light industry development) - http://www.epa.gov/superfund/programs/recycle/success/casestud/chercsi.htm
- **Foundries:** Abex Corporation (playground in addition to a fire department and police station) - http://www.epa.gov/superfund/programs/recycle/success/briefs
- **Manufacturing facilities:** Industri-Plex (open space and wetlands preserve in addition to expanded roads and retail space) - http://www.epa.gov/superfund/programs/recycle/success/casestud/iplexcsi.htm
- **Avtex Fibers:** (open space in addition to a recreational park and an eco-business park) - http://www.epa.gov/superfund/accomp/success/avtex.htm
- **Refineries:** Alameda Naval Air Station (golf course and marina) - http://www.epa.gov/superfund/programs/recycle/pilot/facts/r9_38.htm
- **Landfills:** Lipari Landfill (open space with nature trail in addition to recreational fields, a parking lot and recreation building) - http://www.epa.gov/superfund/programs/recycle/success/1-pagers/lipari.htm
- **Military Installations:** Pease Air Force Base (wildlife refuge in addition to a public airport)- http://www.epa.gov/superfund/programs/recycle/success/briefs
- **Metal Plating:** Revere Chemical (native wildflower habitat) - http://www.epa.gov/superfund/programs/recycle/success/briefs/pa_brief.htm#pa_14
- **Tannery:** A.C. Lawrence Leather site in New England - contact ERT for more information

For more cases studies, visit the Wildlife Habitat Council website at http://www.wildlifehc.org/brownfield_restoration/case_studies.cfm.

Leadville, CO – Before ecological restoration
(Source: Dr. Sally Brown, University of Washington)

Leadville, CO – After ecological restoration
(Source: Dr. Sally Brown, University of Washington)

maintenance options, if allowed and appropriate, should also be established for the site.

Early in the process, site managers should incorporate funding in the budget for implementing ecological revitalization. While native plant seeds can be expensive and more difficult to sow, the reduced operation and maintenance (O&M) costs make native plants a more economical long-term option than non-native plants. Native plants can be used to establish a self-sustaining ecosystem, usually within 3 to 4 years, if properly selected and planted.

What kind of habitat should be considered for ecological revitalization?

Any site has the potential for ecological restoration, regardless of its size or location. While a variety of habitats can be considered for ecological revitalization, the habitat type in the surrounding area would likely have the greatest chance of success. In any case, site managers should always work with the community to determine the preferred beneficial reuse for the site, and thus habitat type.

Ecological revitalization can be managed for a variety of habitats such as meadow, prairie, riparian buffers and forest, and for wildlife such as nongame species, birds, and migratory butterflies. When planning for a specific habitat type, a restoration practitioner can provide valuable recommendations to maximize a habitat's potential for success. In addition to determining appropriate species and management techniques, the restoration practitioner can provide recommendations for adding nesting boxes, preserving snags, considering pollinators, and adding other habitat features to help attract and sustain wildlife populations.

Can you effectively predict and control the type of vegetation that will develop on a site when applying ecological revitalization?

Various types of Superfund sites, such as mined areas, hazardous waste spills, and landfills may require very different treatment technologies and different approaches to ecological revitalization. Initially, a planting will typically consist of a mixture of seeds or plants, native when possible, used to revitalize the habitat. However, the diversity will change because some plants will be better adapted to the site-specific conditions than others. If the vegetation is not maintained at the same stage as when it was planted, the plant community will naturally progress toward a more mature state or climax community. For example, if a native grass planting is not mowed in some regions, shrubs and trees will eventually take root and grassland will progress toward woodland. It is most

West Page Swamp, Bunker Hill, ID – Before ecological restoration (Source: Dr. Sally Brown, University of Washington)

West Page Swamp, Bunker Hill, ID – After ecological restoration (Source: Dr. Sally Brown, University of Washington) important to maintain native species that are functional based on the surrounding native vegetation.

At any revitalized site, invasive species should be controlled to allow native species to become established. Invasive species can quickly spread and invade disturbed land, especially in areas that contain bare soil. An invasive species management plan should be developed to prescribe methods for effectively controlling invasive species, such as burning, where allowed, or the use of chemical, biological, or hand-pulling techniques.

Will implementing an ecological revitalization project impair site remediation or development?

Site remediation activities are protective of human health, and ecological revitalization modifies a site to increase or improve habitat for plants and animals without impairing site remediation or development. Furthermore, an effective revitalization design can (1) reduce or eliminate exposure through the use of amendments for capping and soil cover or (2) reduce the bioavailability of contaminants through the use of organic amendments. Ecological revitalization measures incorporated for beneficial end use need to be planned early to maximize the use of native vegetation or to focus on opportunities for passive recreation and environmental education during site development. In addition, an ecological risk assessment should be completed to ensure that the revitalization and other cleanup components effectively protect the environment, thereby improving the protection of human health as well.

What is the definition of "attractive nuisance"?

For the purposes of the Superfund Program, an attractive nuisance is the potential for wildlife to be harmed from waste left on a site after a remedial action has been completed and a revegetation effort undertaken. One example is an abandoned mining site that is barren and void of life. After lime-treated biosolids are incorporated to complex the metals of concern, the health of the soil (fertility and general suitability to support root growth) is improved to permit revegetation with native plants and promote a self-sustaining ecosystem as habitat for nongame species. Once the plants are established, animal life becomes re-established. Because the metals remain in the soil, they could move through the food chain to adversely affect raptors at the top of the food chain. Thus, because no animals were present on the site prior to its revitalization, a potential attractive nuisance is created.

Jasper County, MO – Before ecological restoration
(Source: Dr. Sally Brown, University of Washington)

Jasper County, MO – After ecological restoration
(Source: Dr. Sally Brown, University of Washington)

Will ecological revitalization at sites where waste remains cause an attractive nuisance?

While ecological revitalization improves habitat for plants and animals, the primary goal of remediation is to protect human health and the environment. Therefore, if the potential for an attractive nuisance exists, an ecological risk assessment could be conducted to demonstrate that contaminants of concern are not present or will not accumulate to levels that might be toxic to wildlife attracted by the revitalized habitat. The risk assessment or a monitoring program would evaluate the potential risks to the environment, and the remediation and ecological revitalization would address any concerns. In addition, when an ecological revitalization project is implemented, the protection of public health may correspondingly improve. The ERT has conducted various evaluations concerning attractive nuisance over the past 6 years and can provide technical support in addressing this issue at a particular site. Additional information is provided in a separate fact sheet on ecological revitalization and attractive nuisance issues.

Can land application of biosolids cause contaminants to enter the food chain and result in harm?

Generally no. Biosolids are applied (with other soil amendments) to sites with disturbed soil as part of an in situ remediation approach or to provide soil nutrients. These are usually sites with metal-contaminated soils, where it is impractical to extract or remove the contaminants. Components within biosolids help to complex certain contaminants, minimizing or reducing their bioavailability. Iron, lignins, and other organic material can bind contaminants of concern, immobilizing them and rendering them biologically unavailable.

Specifically, the issue of attractive nuisance has been a concern at some Superfund remediation sites involving biosolids application. The concern pertained to lead moving through the vermiform pathway (for example, earthworms to shrews to raptors). Various regulatory agencies have requested studies to address the potential for contaminants to move up the food chain through this pathway. The contaminants are still present in the soil and can be extracted with strong acids. The key question is whether the bioavailability has been reduced to the point where harm or risk is acceptable under normal environmental conditions. Different studies have been conducted to answer this question. For example, treated soils have been fed to pigs, and small mammal trapping with follow-on pathology studies have been performed. To date, no evidence suggests that the contaminants are not adequately complexed. This reduction in bioavailability is encouraging, but has not been evaluated over long periods of time. EPA is currently working on a technical performance measures (TPM) paper to address the types of tests that should be applied to monitor and evaluate the efficacy and safety of applying biosolids during remediation efforts.

Some examples of Superfund sites that used biosolids during restoration include Bunker Hill in Idaho; California Gulch in Leadville, Colorado; and the Jasper County Site in Joplin, Missouri.

For additional information on land application of biosolids and compost, go to http://www.epa.gov/compost and http://www.epa.gov/own/mtb/biosolids/.

How does wetland mitigation compare to ecological revitalization?

Wetland mitigation involves creating new wetland habitat to compensate for impacts to existing wetlands. Ecological revitalization can be considered part of wetland mitigation depending on the site-specific habitat. However, if the wetland mitigation is part of a contaminant treatment system, it cannot be considered part of ecological revitalization. Such a wetland could be a cost-effective alternative to conventional technology, such as groundwater pump and treat. For example, at the Silver Bow Creek/ Warm Springs Ponds Superfund site in Montana, the PRP decided to fund the revitalization of a copper mining area after cleanup activities were completed; the effort included creating 400 acres of wetlands (http://www.epa.gov/superfund/programs/recycle/success/1-pagers/bowcrk.htm).

For additional information on wetland mitigation requirements, go to http://www.epa.gov/wetlandsmitigation/.

Mitigation ratios vary depending on the type and quality of the wetland that will be lost and the predicted time until functions are revitalized at the mitigation wetland. Even impacts to man-made wetlands can require mitigation because the characteristics and functional value of a wetland – and not the origin – are the primary factors in determining whether mitigation is required. Treatment wetlands constructed to remove contamination from surface water or leachate do not meet mitigation requirements, primarily because of their structure and function. Properly designed treatment wetlands need to be densely planted with an aggressive plant species to minimize exposure to contaminants that may collect in the sediment. These wetlands are not designed to attract wildlife or replicate the habitat and functional values of wetlands.

If plants are introduced for phytoremediation, does that qualify as revitalization?

In some cases, phytoremediation can be a cost-effective alternative for surface soil or water treatment and can help revitalize species diversity through habitat creation or expansion. Phytoremediation encompasses a broad range of designs. Some designs rely on plantation-style grids of non-native species that have negligible ecological value or use mass plantings of hyperaccumulating species that are harvested and disposed of off site; however, these crop systems do not constitute ecological revitalization. Other phytoremediation approaches use a mix of plant species to provide long-term revitalization, reduce bioavailability, and provide valuable habitat. These approaches, when designed to maximize ecological value, would be considered ecological revitalization or revegetation using native species.

Native plantings planned for early in the design process are a cost-effective consideration. However, cost savings realized through phytoremediation are site-specific and depend on the techniques applied. Savings can include the difference between soil removal and disposal versus the cost of the plants and the labor for planting. Savings could be achieved for groundwater contamination by replacing pump-and-treat technology required over many years with deep-rooted plants that extract water and transpire volatile contaminants.

For additional information on phytoremediation, go to http:// www.itrcweb.org/Documents/PHYTO-2ExecSum.pdf or http://www.cluin.org/techfocus and choose phytoremediation.

Do caps or soil covers over residual contamination have to be planted with fescue or is ecological revitalization appropriate?

Ecological revitalization is appropriate at these sites. Many caps and soil covers have been planted with fescue because it is easy to establish. In addition, some site managers are concerned that native plantings are more expensive and that the deeper roots of native species might compromise the cap.

Although caps planted with fescue are easy to establish, they do not provide useful habitat and require routine maintenance, which increases long-term O&M costs. The native seeds and plants themselves are more expensive than lawn grass seed mixes; however, O&M costs over many years are significantly lower for native plantings because of their hardiness to poor conditions, longevity, and self-seeding potential. Ecological revitalization that incorporates mixed native plant species also provides beneficial wildlife habitat.

If a cap is properly designed, roots of native species will not compromise the cap. Root growth depends on the soil characteristics, and the presence of a clay liner or geomembrane influences their growth. Research at the Brookfield Sanitary Landfill in New York showed that roots, including taproots, grow laterally once they reach the clay cap. No significant damage to the clay cap was observed as a result (Robinson and Handel 1995). For additional information, please see the fact sheet on revegetating landfills and waste containment areas (EPA 542-F-06-002, http://www.cluin.org/ecorevitalization) and review the references by Steven Handel listed at the end of this fact sheet.

Caps or soil covers that already have established fescue can be converted to native plants. An effective conversion method is to burn the existing fescue, if possible, and follow up with applications of a broad spectrum herbicide registered for the establishment of native warm season grasses and forbs. As the native grasses and forbs are establishing, follow-up herbicide treatments may be necessary to control the fescue. While areas can be converted from fescue to native plants, the conversion must be carefully planned and should be conducted by a restoration practitioner to increase the likelihood of success.

Ecologically revitalized areas are not necessarily off limits to the public. Recreational uses such as trails, athletic fields, and wildlife mixed use are compatible with ecological revitalization and revegetation using native species. In fact, kiosks and public viewing areas often can be included in ecological revitalization plans.

A separate fact sheet on revegetation of landfills and waste containment areas will provide additional information (http://www.cluin.org/ecorevitalization).

What maintenance and repair activities should I expect when supporting ecological revitalization?

All cover-type remedies require some level of maintenance. O&M costs will be lower for ecological revitalization because, while there is some cost for weed control, there is minimal to no cost for mowing.

- **Short-term requirements** When plants are establishing on the site, short-term monitoring and maintenance will consist primarily of weed control and irrigation, when necessary and possible, and reseeding to ensure the health of the native plants. Various methods can be used to control weeds, including mowing, hand pulling, prescribed burning, or use of EPA-registered pesticides; the most appropriate method depends on the final use of the site. An invasive species management plan that specifies short- and long-term activities should be developed early in the process by a restoration practitioner. If necessary in the management plan, guidelines for mowing to control weeds will need to be developed and followed, particularly because forbs and young trees will be eliminated if they are inadvertently mowed.

- **Long-term requirements** Long-term maintenance activities vary depending on the site. Some sites do not require any long-term maintenance because the native plants create a self-sustaining habitat. If the goal is to create a specific setting to attract a particular type of wildlife, such as butterflies, then tree removal and occasional mowing might be necessary. In general, long-term maintenance depends on the long-term objective of the site and should be determined by a restoration practitioner. If the objective requires intervention with the natural progression of the site, then some minimal long-term maintenance would be required.

Considering that native species typically take longer to become fully established (as compared to commercial erosion control seed mixes), how do I provide for appropriate vegetative cover during the establishment period?

Various agencies and organizations, including the Natural Resources Conservation Service (http://www.nrcs.usda.gov/), state native plant societies (such as in California [http://www.cnps.org] and Texas [http://www.npsot.org/]), or local Soil Conservation Service centers (http://offices.sc.egov.usda.gov/locator/app), can identify the best planting time for specific areas and species and can provide additional information to ensure appropriate vegetative cover during the establishment period. Some simple treatment might be required to improve the survival of planted species, such as soil surface cultivation and the use of nurse species (for example, sterile rye grass or non-sterile legumes). A fast-growing sterile nurse species grows quickly and then dies, providing soil protection and increased nutrients. Sterile annual rye grasses that germinate and grow quickly are often added to native seed mixes

For additional information on monitoring and evaluation of a revitalized site, go to http://www.ser.org/content ecological revitalization primer.asp#8.

to control erosion. In addition, fast-growing shrubs can be planted to stabilize stream banks, allowing time for slower-growing trees to mature and overtop the shrubs. Small groups of trees can be planted over a remediated area to attract birds and other animals that will naturally disperse seeds and expand the forested area over time.

Ecological revitalization is considered accomplished once a revitalization practitioner is no longer needed to ensure long-term sustainability of the ecosystem (typically after 3 to 5 years). However, long-term management may be required to prevent recurrent degradation of revitalized ecosystems. For trees and shrubs, contracts often require 90 percent survival after the first year of planting. Reseeding of bare spots and poor growth areas is often necessary for grasses and herbaceous plants.

Who is financially responsible for ecological revitalization, and are there any legal requirements?

The financial responsibility and legal requirements associated with ecological revitalization of a Superfund site are site-specific. Although EPA strives to get PRPs to fund the cleanup of a Superfund site, Superfund money can be used for the cleanup if the PRP cannot be found, is not viable, or refuses to cooperate. Whether a site is funded by the PRP or with Superfund money, ecological revitalization activities can be incorporated into the site reuse plan because they are not considered beautification or enhancement. Such activities are considered beneficial reuse and fall within EPA's policies, initiatives, and priorities.

The cost of native seeds can be high, so it is important to decide on the use of native plants early in the process and incorporate the associated costs into the remediation budget. When incorporating beneficial reuse into the site plan and remediation budget, one rule of thumb is to budget 5 to 10 percent of the remediation budget for beneficial reuse. For a removal site, ecological revitalization can be included in the action memorandum; for a remedial site, it can be included in the record of decision. If an ecological revitalization component is included in the selected remedy, completion of the revitalization can be required in a consent decree. If revitalization is not included in the site reuse plan, site managers can work with PRPs to explain the benefits of ecological reuse and encourage voluntary revitalization activities. However, unwilling PRPs cannot be forced to complete revitalization activities if those activities are not included in the site reuse plan.

Additional Information and Resources

Handel, S.N. et al. 1994.
"Biodiversity Resources for Restoration Ecology."
Restoration Ecology.
Volume 2, Number 4. Pages 230 through 241.

Interdisciplinary Training for Ecosystem Restoration.
On-Line Address:
http://www.epa.gov/owow/watershed/wacademy/training/bkley6.html

Internet Seminars on Ecological Restoration.
On-Line Address:
http://www.clu-in.org/studio/seminar.cfm

ITRC. Planning and Promoting Ecological Land Reuse at Remediated Sites. 2006.
On-Line Address:
http://www.itrcweb.org

Plant Conservation Alliance.
On-Line Address:
http://www.nps.gov/plants

Robinson, G.R., and S.N. Handel. 1993.
"Forest Restoration on a Closed Landfill: Rapid Addition of New Species by Bird Dispersal."
Conservation Biology. Volume 7, Number 2.
Pages 271 through 278.

Robinson, G.R., and S.N. Handel. 1995. "Woody Plant Roots Fail to Penetrate a Clay-Lined Landfill: Management Implications." *Environmental Management*. Volume 19, Number 1. Pages 57 through 64.

Society for Ecological Restoration (SER) International: Guidelines for Developing and Managing Ecological Restoration Projects, 2nd Edition. Andre Clewell, John Rieger, and John Munro. December 2005. On-Line Address: http://www.ser.org

U.S. EPA Revegatation of Landfills and Waste Contaminant Areas Fact Sheet" EPA 542 F-06-001. On-Line Address: http://www.cluin.org/ecorevitalization

U.S. EPA. Green Landscaping with Native Plants: Greenacres. On-Line Address: http://www.epa.gov/greenacres/

U.S. EPA Greenscape Program. On-Line Address: http://www.epa.gov/greenscapes/

U.S. EPA. An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement. On-Line Address: http://www.epa.gov/owow/wetlands/pdf/restdocfinal.pdf

U.S. EPA Land Revitalization Offices and Programs. On-Line Address: http://www.epa.gov/swerrims/landrevitalization/index.htm

U.S. EPA National Association of Remedial Project Managers (NARPM) Training Conference. On-Line Address: http://www.epanarpm.org

U.S. EPA Reusing Cleaned Up Superfund Sites: Golf Facilities Where Waste is Left On Site. On-Line Address: http://www.epa.gov/superfund/programs/recycle/pdfs/golf-103103-c.pdf

U.S. Department of Agriculture, Natural Resource Conservation Service. On-Line Address: http://soils.usda.gov/survey/printed_surveys/

U.S. EPA Superfund Redevelopment Program. On-Line Address: http://www.epa.gov/superfund/programs/recycle/index.htm

Wildlife Habitat Council. On-Line Address: http://wildlifehc/org

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Revegetating Landfills and Waste Containment Areas Fact Sheet

This Fact Sheet Discusses the Following:

- It is possible to plant on landfill surfaces
- Native plants are recommended when revegetating sites
- Technical factors to consider when revegetating
- References and additional resources

Keys to Success when Revegetating Landfill Surfaces:

- Ensure proper planning, design, and funding
- Provide adequate soil quality and depth
- Determine appropriate target habitat and native plant selection
- Allow for appropriate planting and establishment
- Conduct routine monitoring and management

Introduction

The U.S. Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI) is developing a series of fact sheets on ecological restoration and revegetation of contaminated sites. Former landfills, abandoned dumps, mines, and other contaminated sites throughout the U.S. - once thought to be of limited or no value - are being reclaimed for a variety of productive uses. These new uses include revegetation of land where plants and animals can once again flourish. For example, as of 2005, thousands of acres of land on Brownfields, Superfund, and Resource Conservation and Recovery Act (RCRA) sites have been assessed or cleaned up and revegetated. In particular, more than 50 Superfund sites have been cleaned up and returned to ecological use. Aesthetic and final land use considerations are becoming more common during cover design. Some increasingly common end uses include parks, hiking trails, wildlife habitat, sports fields, and golf courses. This fact sheet provides information on revegetation of landfill surfaces for EPA site managers, consultants, and others interested in the revegetation of landfill surfaces.

Contaminated material may be left on the property in containment systems designed to protect people and the environment from exposure and prevent contaminant migration. In deciding how to support the revegetation of these sites, however, there are questions about whether it is appropriate to plant on the landfill surface. Grasses are typically used to help stabilize the landfill surface and prevent runoff, but shrubs and trees are selected less frequently because of concerns that the root systems could damage the surface. Based on the location of the containment area, site-specific approaches should be used and a general approach has been discussed in this fact sheet. Former landfills, abandoned dumps, mines, and other waste containment areas will be referred to as landfill surfaces throughout the fact sheet.

Is it Possible to Plant on Landfill Surfaces?

Yes, it is possible to plant trees, shrubs, and other types of vegetation on the containment system at many sites without affecting its integrity and protectiveness. In fact, many sites have been revegetated with a variety of plants on a containment system. For example, grains, wildflowers, and other carefully selected flora were planted at the Army Creek Landfill in Delaware to create a meadow to attract migratory birds (http://www.epa.gov/superfund/programs/recycle/success/casestud/armycsi.htm).

The primary concern in planting on landfill surfaces is ensuring the integrity of the containment system, particularly the potential for roots to penetrate and physically damage the cap, thereby creating entry points for water, or to open fissures in the protective barrier by excessive moisture reduction. However, ongoing research and a growing body of experience indicate that, if it is properly designed and implemented, the integrity of the landfill surface can be maintained while it supports a variety of plants. Root growth depends on the characteristics of the soil, and the presence of a clay liner or geomembrane influences its growth. Research at the Brookfield Sanitary Landfill in New York showed that roots, including taproots, grow laterally once they reach the clay cap. No significant damage to the clay cap was observed as a result (Robinson and Handel 1995). The key factors that affect the feasibility of planting on a containment system include the characteristics of the landfill surface (such as soil depth and soil quality), the desired plant habitat, and the physical setting of the site (for example, topography and climate).

Why Use Native Plants?

- Native plants provide a beautiful, hardy, low maintenance, and drought resistant landscape
- Native plants can develop into a self-sustaining ecosystem, eliminating the need for fertilizers, pesticides, and water

Can Native Plants be Used on a Landfill Surface?

Although a variety of plant species can be used on a landfill surface, native plants are recommended when possible. While each project is site-specific, plants are typically selected based on the design of the landfill surface, the role of the vegetative cover, the depth of plant roots, irrigation and drainage requirements, geographic and atmospheric conditions, long-term maintenance requirements, and costs to acquire and install materials and plants. A single species of grass has commonly been planted as a monoculture to control erosion of landfill surfaces, but the species

For more information on the design of landfill caps, please visit the following Web sites:

- http://www.epa.gov/ORD/NRMRL/pubs/600r02099/600R02099.pdf
- http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/techman/subpartf.txt

may or may not be indigenous to the surrounding habitat and are more vulnerable to disturbance (Harper 1987). However, planting native species that have been selected over thousands of years in that area are best adapted to disturbances and climate change (Waugh 1994). Species diversity helps reduce disease dispersal or blights and encourages wider biological diversity in the restored habitat, making it more like a natural ecosystem, in turn reducing long-term operation and maintenance (O&M) and promoting a self-sustaining ecosystem (Handel et al 1994).

Even sites that currently support monocultures can be converted to diverse native plant communities through careful planning and monitoring. The site can be prepared for native seeding or planting by prescribed burning, using herbicide, or removing a thin layer of soil along with the monoculture vegetation. Native plants can even be seeded through existing cover with a no-till drill; periodic burning would also be beneficial in controlling the monoculture vegetation. For example, the Christian County Landfill was converted from a sparse monoculture with eroding areas to a thriving native prairie (http://www.epa.state.il.us/environmental-progress/v25/n1/abandoned-landfill.html).

A major consideration when selecting plants for a site is Executive Order (EO) 13148, which promotes use of native species on revegetated sites. EPA defines native plants as plants that have evolved over thousands of years in a specific region and that have adapted to the geography, hydrology, and climate (see http://www.epa.gov/greenacres/). Native plants found in the surrounding natural areas will have the most chance of success, require the least maintenance, and are the most cost-effective in the long term. Ideally, revegetation of a site will create natural conditions that encourage re-population by native animal

Native Plants – Ecological Values

- Native plants do not require fertilizers
- Native plants do not require pesticides
- Native plants require less water (no watering once established) than turf grass (lawns)
- Native plants provide shelter and food for wildlife
- Native plants are critical to a diverse number of pollinators
- Native plants reduce air pollution
- Native plants provide biodiversity and stewardship of our natural heritage
- Native plants save money
- Native plants can offer economic values (medicinal, herbals, landscaping and food)

For more information on plant types, please visit the following Web site: http://www.ciwmb.ca.gov/LEACentral/Closure/Revegetate/.

To identify the type of general land use in your area, please visit the following Web site: http://www.nrcs.usda.gov/technical/land/cover_use.html.

For examples of natural habitat restoration on landfills, please see page 63 of the following Web site: http://www.epa.gov/tio/tsp/download/dctechnical.pdf.

Native Plants - Ecosystem Integrity

- Native plants support a complex web of life, and provide a critical component to ensure balance in our ecosystems
- Only native plants can provide long-term sustainability of the landscape

Yet:

- more than 200 plants have become extinct since the early 1800's
- nearly 5,000 native plants are "at risk"
- one in ten plants face extinction

species and that are consistent with the surrounding land. Furthermore, using non-native plants located close to native plant environments could displace the native plants; therefore, it is important to check the invasive nature of the proposed plants (EO 13112). Plant succession may occur; for example, the original species planted may not survive due to predation or drought. However, local wildlife, such as birds, may aid in the dispersion of appropriate plant species and in the overall revegetation of the site (Robinson and Handel 1993).

Landfills in arid environments pose additional challenges because soil must be stabilized with sparse vegetation. A variety of options are available, however, to increase the likelihood of successful restoration in these areas, including adding compost blankets or other organic amendments to the soil to increase water-holding capacity and fertility, shaping the ground to collect and retain water, and using locally collected seeds of native species.

The species that are appropriate for local habitat conditions can be selected with support from EPA's regional Biological Technical Assistance Groups, EPA's Environmental Response Team (http://www.ert.org), the Natural Resources Conservation Service (NRCS) (http://www.nrcs.usda.gov), and local native plant societies, such as the following: http://michbotclub.org/links/native_plant_society.htm.

What Types of Plants Can be Used on a Landfill Surface?

Each project has site-specific considerations, and the plant types listed below are not applicable to every site.

- **Grasses and Wildflowers** are generally herbaceous and are limited to prairie-like habitats or appearances, with wildflowers providing a broad selection of plant heights, root depths, and aesthetic choices. Considerations when selecting these plants include the seeding cycle and whether they require re-seeding, as well as life span, resistance to invasive species, and root depth.

- **Shrubs** are woody perennials that range from several inches to several feet high. Considerations in selecting shrubs include their size when fully grown (and the resulting potential to obstruct gas vents, wells, or cap maintenance), root depths, irrigation requirements, and competition with other desired plants (such as saplings).

- **Trees** are the longest-lived plant group and can have the greatest influence on overall design of the vegetation. Considerations for selecting trees include root depths, size, irrigation requirements, competition with other vegetation, and debris.

What are the Key Considerations When Planting on Landfill Surfaces?

Each project is site-specific and depends on a variety of factors based on its individual requirements, including its location. There are eight distinct Level I eco-regions in the U.S., including Eastern Temperate Forests, Great Plains, and North American Deserts (http://www.epa.gov/wed/pages/ecoregions/na_eco.htm#Level%20I). Specific approaches for planting on landfill surfaces should be based on the particular eco-region. Information on planting in arid areas such as California can be found at http://www.ciwmb.ca.gov/LEACentral/closure/revegetate/. However, in general, the final cover (erosion or vegetative layer) should provide adequate soil depth to support the desired plant habitat to properly implement the revegetation of a site and help ensure survival. In addition, soil conditions and topographic features may be created that closely duplicate the surrounding soil types and geography. A revegetated site should duplicate the local native plant profile in terms of species selected and distribution of these species across the site. General factors to consider include:

- **Soil and Root Depth**. Soil and root depth are key determinants for whether and how a landfill surface can be revegetated. In general, the high density, low permeability, and poor aeration of the landfill surface provide an effective barrier to penetration by tree roots. Roots might penetrate a small distance into the landfill surface, but penetration through the entire landfill surface is prevented by the slow upward diffusion of landfill gases, which lowers the oxygen potential of the soil and can be toxic to plants (Flower et al 1981; Robinson and Handel 1995). Nonetheless, sufficient soil depth (18 to 24 inches optimum) is recommended to support the habitat selected. Several approaches can be taken in considering trees and shrubs with substantial root systems, such as building up berms or hillocks as areas for large vegetation. Simply providing a thicker erosion layer, even in small areas on the landfill, will improve the options for "naturalizing" the vegetation selected and the location of plants on the final landfill surface. Engineered soil and/or organic soil amendments, such as biosolids, can be used if sufficient amount of suitable soil is not available. Some examples of Superfund sites that used biosolids during restoration include Bunker Hill in Idaho; California Gulch in Leadville, Colorado; the Jasper County site in Joplin, Missouri; Palmerton Zinc in Palmerton, Pennsylvania; and the Lead Remediation Project in East St. Louis, Illinois. Another approach to support planting saplings in relatively shallow soil layers involves trimming the taproot, which encourages lateral root development. The lateral roots, up to three times the tree's canopy width, will provide ample anchorage and nutrient absorption for the tree. Indigenous tree species that lack a taproot also can be selected.

The following link provides additional information on tree planting and soil depth at the Fresh Kills Landfill in New York: http://www.sierraclub.org/sierra/200511/tr2.asp

For additional information on land application of biosolids, please visit the following Web sites:

- http://www.epa.gov/owm/mtb/land_application.pdf
- http://faculty.washington.edu/clh/newwet/summary.pdf

- **Soil Quality and Treatment**. The greatest cause of failure in revegetation, particularly with trees, is poor soil quality through factors such as soil compaction, water logging, drought, and insufficient rooting depth (Dobson and Moffat 1993; Watson and Hack 2000). Soil is an essential medium for plant growth, providing physical support for plants as well as access to water; soil also is the main source for nutrients that are necessary for plant growth. Soil needs to: (1) have a healthy layer near the surface, roughly equivalent to topsoil; (2) be tested as necessary for pH, nitrogen, phosphorus, conductivity, bulk density, organic matter, and other nutrients; and (3) be treated as necessary. (Soils with an acidic pH could be treated with lime before they are spread over the landfill surface.) Soils could be amended by incorporating lime or organic material into the top 6 inches of soil from one to several weeks before planting. The final soil surface should be loosely distributed during landscaping and should not be compacted with heavy equipment (Wong and Bradshaw 2002).

- **Terrain and Slope**. Although the landfill ideally could be contoured to match the topography of the surrounding area, it often is mound-shaped with steep slopes that can impair plant establishment. Biosolids with site-specific amendments can be used on steeper slopes to help prevent the surface soil from drying out and hold the seed until it germinates and establishes a vegetated surface. In addition, compost berms, blankets, and socks can be used to slow the rate of storm water as well as reduce erosion along steep slopes. The compost retains water, aiding in revegetation and filters the water, improving water quality as it flows off-site.

- **Moisture and Irrigation**. Water logging and drought stress are major factors that limit plant growth and revegetation on landfill sites and can occur on the same site at different times of the year in areas with low and erratic rainfall (Wong and Bradshaw 2002). Trees and shrubs can remove large quantities of water from soil quickly and efficiently, which can mitigate water logging (Robinson and Handel 1995). In addition, landfill surface material typically includes a geomembrane or clay layer that requires moisture in the soil to safeguard against desiccation. The need for moisture is seasonal and depends on annual precipitation and climate; moisture, however, also is beneficial to support vegetative surface. The moisture level must be monitored to avoid compromising the surface layer with saturated soils and must account for the season and volume of annual rainfall, the type of clay material used in the barrier, and the plant community to be grown.

- **Landfill Gas**. Landfill gases can create a hostile environment where vegetation cannot survive because of the lack of oxygen in the root zone. Gas collection systems can both alleviate or aggravate this problem. Exposure of vegetation to high gas concentrations can lead to stunted

For additional information about planting on steep slopes, please visit the following Web sites:

- http://www.nrcs.usda.gov/feature/backyard/grndcovsl.html
- http://cfpub.epa.gov/npdes/stormwater/menuofbmps/idex.cfm

Search by keywords: Compost blanket, compost filter sock, and compost filter berm.

growth, defoliation, or death, so that the existing plant community requires removal and replanting (Flower et al 1981). Methanotrophic bacteria in soil may consume landfill gas; these bacteria thrive symbiotically with plant roots, existing in concentrations 10 to 100 times higher than in unplanted soils. A well-established root zone can consume vast quantities of landfill gas, even when the plants are dormant.

- **Pests and Invasive Species**. The federal government promotes management of invasive plant species during revegetation, as detailed in EO 13112. This order states that, to the extent possible, federal agencies must prevent the introduction of invasive species, monitor and control existing populations, and restore native species and habitat of ecosystems in invaded areas. Invasive plant species can quickly disperse and invade disturbed land. Close monitoring of the habitat during establishment and control of invasive species will be required. A variety of methods can be used to control invasive species, including prescribed burning, chemical (herbicides) or biological (such as the purple loosestrife beetle) methods, and hand pulling. Careful plant selection can reduce the potential for disease from insects, molds, and fungi, as well as from burrowing animals such as gophers, moles, and other rodents. Judgment may be exercised in cleanup on a containment system because removal of too much material can jeopardize the nutritive regeneration qualities of ground litter and can remove an added means of soil protection and moisture retention in the natural soil surface.

- **Windthrow and surface integrity**. Windthrow (blowdown) of trees is a potential problem on landfill sites because it may jeopardize the integrity of the landfill surface should the roots peel away the soil layer with the toppled tree. Still, the risk of windthrow should be no greater than for conventional forested sites if there is an adequate depth (14 to 18 inches) of rootable soil. Monitoring for windthrow damage is necessary. However, the risk of windthrow can be reduced if trees are harvested before they reach a height where they might be more susceptible to windthrow or species are planted that remain relatively small (Dobson and Moffat 1995). In addition, planting shorter trees at the perimeter of a grove around taller varieties or adult trees can provide a windbreak by slowing the wind and directing airflow over or around the taller canopy layer. Single-line, hedgerow-like plantings or isolated individuals, especially at the edges of top decks and maintenance roads, leave adult trees vulnerable to strong winds, encouraging windthrow.

How Do I Establish Plants on a Landfill Surface?

While it may be difficult to establish native plants in almost all areas in the U.S., site-specific considerations will increase the chances of success. A proper site-specific planting plan is necessary in the revegetation of a landfill or waste containment area. It is most cost efficient to combine the application of the nursery crop and the native seed planting. In addition, the success of the native seeding is much higher and the reseeding potential of the nursery crop lower. Once the site is stable, appropriate species can be introduced by hand. Planting clusters of habitat can promote seed dispersal, such as by birds and insects, and they will assist in introducing local native species. In general, options exist for restoring a site, including:

- **Planned planting of all plant types, such as grasses, shrubs, and trees, at the very outset of restoration**. This approach may require the most advanced planning but should provide the greatest element of control in the design and outcome of the overall plant community. The final plant community would be established and maturing early in the revegetation and post-closure maintenance program. Some invasive volunteerism by outside plants could occur if the operator does not exercise aggressive control efforts.

- **Providing the proper environment and soil conditions to encourage plant growth volunteering by local native plants.** This approach provides the lowest element of control on the types of plants that may be introduced to the site because it depends on the unpredictable phenomenon of natural plant establishment and succession. Some sort of initial soil stabilization by planting with a rapid-growing annual and perennial grass or ground cover will still be required to prevent erosion of the landfill surface. The plant succession process occurs as the selected area matures. Pioneer plants (typically low-growing or prostrate weeds and grasses with deep taproots, most adapted to the harsh conditions of bare, usually poor-quality soils) establish first in the ruderal environment and begin the process of soil nutrient construction and softening. Taller grasses then gain a foothold and establish themselves. In time, legumes, herbaceous perennials, and woody perennials begin the larger plant occupation as soil quality and nutrient content continues to improve. Eventually, shrubs and the larger trees assume the mature level on the location.

- **Combining planned planting with volunteering by adjacent native species to create the final vegetation cover.** This approach has a high potential for erosion and the cost of controlling invasive species is also high. Invasive species typically thrive in early successional habitat and once established will be difficult and expensive to combat. Efforts may still be required to control undesired invasive species. An effective and cost-efficient method to revegetation in the woodland and shrubland habitat includes planting islands of habitat to attract wildlife, such as birds, that can disperse seeds to expand the habitat.

What Maintenance and Repair Should be Expected?

Planting on landfill surfaces will require some maintenance, but the use of native plants should create a self-sustaining habitat that minimizes the requirements. The following maintenance and repair should be expected to support revegetation of the landfill surface:

The following Web site provides information on management of invasive species:
http://www.invasivespeciesinfo.gov/council/actiond.shtml

The following Web site describes many monitoring and management techniques:
http://www.ciwmb.ca.gov/LEACentral/Closure/Revegetate/Part6.htm

The following Web site provides additional information on performance criteria:
http://www.ser.org/content/ecological_restoration_primer.asp#8

- **Monitoring and Management of Habitat at Initial Planting**. When plants are first established on the site, monitoring and management could consist primarily of re-seeding and irrigating, if necessary, to ensure the health of the plants and control of invasive species. A program may be needed to safeguard against disease, insect pests, drought, windthrow, and wildlife damage. Various control methods can be used to control invasive species on landfill surfaces, including hand pulling, prescribed burning, or use of herbicides; the most appropriate method depends on the final use of the site. This type of program may be required only during the first 5 years, may diminish over time, and will cease as the plants mature. In addition, guidelines on mowing may need to be developed and followed, particularly as forbs and young trees will be effectively removed if they are inadvertently mowed.

- **Maintaining Site Access**. Maintaining access to the site and other components of the remedy is necessary and includes pruning or removing plants that could interfere with access roads and trails that lead to vents and other features of the landfill surface. Signage may be used to designate newly planted areas and to restrict mowing.

- **Long-Term Monitoring and Management of Habitat**. Mechanical methods such as prescribed burning, light disking, mowing, grazing, chemical application, or a combination of methods may be required during the first five years to maintain early successional habitat. Once native plants are established, the habitat will require minimal maintenance. Periodic removal of plant affected by windthrow, disease, drought, and frost also may be required. After plant roots are established, the frequency of maintenance can be reduced, and natural processes will take over. Highly invasive species may continue to pose a problem after five years and should be periodically monitored. In addition, data on the quantity and composition of leachate generated within a landfill can be an indicator of the integrity of the cover system. While leachate generation should be minimal with a properly designed cover, leachate control should be considered during the design phase and monitored as necessary.

What are the Important Things to be Aware of?

- The grass is **not** always greener - especially during the first couple of years. For the first couple of years, native, warm-weather bunch grasses spend their energy growing roots and establishing themselves below ground.

Site-Specific Examples/Case Studies

Bower's Landfill, Ohio:
http://www.epa.gov/superfund/programs/recycle/success/casestud/bowercsi.htm

Walsh Landfill, Pennsylvania
http://www.epa.gov/reg3hwmd/super/sites/PAD980829527/index.htm

Woodlawn County Landfill, Maryland
http://www.epa.gov/reg3hwmd/npl/MDD980504344.htm

Therefore, it may initially appear as if the seeding wasn't successful - as only a little plant material will be visible above ground. But most of the growth is occurring below the surface. A trained restoration ecologist familiar with native plants can tell you if the planting was successful and will become more manifest with time. Technical performance measures used for turf grasses (for example, 50 percent growth within a measurement hoop) are not appropriate. Unfortunately, sometimes a planting will fail and will need to be repeated.

- To maximize success - or minimize failure - note that **native plant seeds may be difficult to sow.** They require specialized equipment, such as drill seeders, available from groups familiar with native plant restoration (such as the Fish and Wildlife Service; state agencies; Park Service; local native plant societies; and native plants restoration ecologists). The keys are timing (the time of year, which varies by species and geographic location) and maintaining soil contact (use of a drill seeder is essential in this regard). Do not expect to be able to measure significant success in the first growing season.

- If the soil used as a borrow source for the cover originally supported vegetation, it can be expected to do so after being moved to the site. If the borrow source supported weeds, weed seed will be present on the cover system and weed growth will likely require control methods.

- Native plant materials - either seed or growing stock - are best obtained with as much **lead time** as possible. Do not wait till the last minute to try to purchase the plant materials. This long lead time is dictated by both the limited availability of the plant material from reliable sources and the need to plant at the most opportune time. The U.S. Department of Agriculture (USDA)/NRCS maintains Plant Material Centers that can augment commercial nurseries, but these centers need advanced notice. Many native plants suppliers can provide healthy material at a reasonable cost if awarded a contract in advance for a specified delivery time. The more time they have, the better, especially for harvesting local genotypes for planting in nearby restoration projects. The seed must be collected and then grown for planting, which is time intensive. In addition, you should assume you will have to save 10 percent of your budget to reseed or replant.

- Do not forget to post **DO NOT MOW** signs after the planting. Some sites have ongoing contracts with landscaping firms - some with other agencies. Many a first flush of growth was killed or severely damaged by well-intended maintenance workers. This caution also applies to spraying herbicides.

- Managing wildlife is often overlooked and can be a problem. The biggest culprits are deer. They can overbrowse a newly planted site and leave it vulnerable to invasive non-native species. In addition, small mammals can debark trees causing significant damage or killing the trees. Wildlife control is difficult, however. Options include repellents such as putrefied egg solids and home-made soap. Providing alternative food sources can work, although they should not be located near the new growth. Other options can include constructing physical barriers (such as tall fencing, cages, or nets), providing access to hunters, and planting at a higher density to compensate for expected loss. The over planting approach applies to seeding rates as well as stocking rates for plants. Options should be explored with the local community to ensure that they are acceptable.

Additional Information Resources

References used to prepare this fact sheet include the following:

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Flower, F.B. et al. 1981. "Landfill Gas, What It Does to Trees and How It's Injurious Effects May Be Prevented." *Journal of Agriculture.* Volume 7. Pages 43 through 52.

Handel, S.N. et al. 1994. "Biodiversity Resources for Restoration Ecology." *Restoration Ecology.* Volume 2, Number 4. Pages 230 through 241.

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Watson, D. and Valerie Hack. 2000. *Wildlife Management and Habitat Creation on Landfill Sites - A Manual of Best Practice. Ecoscope Applied Ecologists.* UK.

Waugh, W.J. 1994. "Paleoclimatic Data Application: Long-Term Performance of Uranium Mill Tailings Repositories." *Workshop Proceedings: Climate Change in the Four Corners and Adjacent Regions.* Grand Junction, CO. September 12-14.

Wong, M.H. and A.D. Bradshaw. 2002. *The Restoration and Management of Derelict Land - Modern Approaches.* World Scientific Publishing Co. NJ.

Web sites to obtain additional information include the following:

U.S. Environmental Protection Agency Land Revitalization Offices and Programs
http://www.epa.gov/swerrims/landrevitalization/index.htm

U.S. Environmental Protection Agency Green Landscaping
http://www.epa.gov/greenacres

U.S. Department of Agriculture Beltsville Agricultural Research Center (BARC)
http://www.barc.usda.gov

U.S. Department of Agriculture - PLANTS Database
http://plants.usda.gov/index.html

U.S. Department of Agriculture, Natural Resource Conservation Service
http://soils.usda.gov/survey/printed_surveys/

Center for Plant Conservation
http://www.centerforplantconservation.org

Plant Conservation Alliance (PCA)
http://www.nps.gov/plants

Society for Ecological Restoration International
http://www.ser.org

State of California Guide to Revegetation and Environmental Restoration on Closed Landfills
http://www.ciwmb.ca.gov/LEACentral/Closure/Revegetate/

Wild Ones: Native Plants, Natural Landscapes
http://www.for-wild.org

Wildlife Habitat Council
http://www.wildlifehc.org/

Internet Seminars on Ecological Restoration
http://www.clu-in.org/studio/seminar.cfm

Interstate Technology and Regulatory Council (ITRC): Ecological Enhancements.
http://www.itrcweb.org/gd_EE.asp

Other Guidance, Policies, and Executive Orders

EPA Municipal Solid Waste Landfill Regulations
http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/msw_regs.htm

EO 13148 Greening the Government through Leadership in Environmental Management
http://www.epa.gov/greenacres/EO13148.pdf

EO13112 Invasive Species
http://www.invasivespeciesinfo.gov/laws/execorder.shtml

Title 40 Code of Federal Regulations Parts 60, 62, 258, and 445
http://www.epa.gov/docs/epacfr40/chapt-I.info/

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PLANTING NATIVE VEGETATION ON LANDFILL CAPS AND FORMERLY CONTAMINATED WASTE SITES IN THE MID ATLANTIC

INTRODUCTION

In the past, most landfill caps and remediated waste sites have been vegetated with a monoculture of cool season non-native turf grasses (e.g., Tall Fescue or Kentucky 31). These non-native species may provide quick cover that can stabilize soils, but they require regular mowing and periodic fertilizing to maintain plant vigor. These species are also invasive and can out-compete native plant species. These non-native species generally provide little food or cover for birds or other wildlife. The use of these species essentially wastes land that could be productive for wildlife. This is especially critical when numerous studies document the loss of native species critical to our nation's biodiversity and the health of our native ecosystems.

ALTERNATIVES

There are alternative strategies that produce vegetative cover that can stabilize the soil and provide erosion control, sequester more carbon, provide habitat for a wide range of birds and other wildlife, and have lower maintenance costs than what is currently used.

Native vegetation provides extremely valuable habitat for all varieties of wildlife, from pollinating insects to birds and mammals. Native warm season grasses used to create meadows, for example, provide extremely valuable habitat for ground-nesting birds and many mammals. Native vegetation which is naturally adapted to site-specific conditions makes for long lasting, stress tolerant, low maintenance plants. When compared with a mowed lawn, a native planting with a plant layer from one to four feet tall is actually less attractive to woodchucks and other animals whose burrows may negatively impact the performance of a cap. Once the planting is established, the burrows of these animals are typically limited to the perimeter of the cap.

Alternatives to monoculture turf grass "habitats" may include grasslands, mixed meadows, scrub/shrub habitats, and woodlands. While the selection of alternatives depends on site conditions and the desired future use of the site, appropriate selection will result in lower costs and the provision of more ecosystem services.

No opportunity to create or replace habitat should be considered too small or too isolated. Even areas of less than an acre dotting the landscape provide habitat islands for highly mobile species such as butterflies, birds, and bats, as well as their food sources.

Grasslands and Meadows

A diverse grassland community provides habitat for several species of grassland birds with declining populations. Breeding bird surveys note continuing declines in populations of many grassland birds (e.g., field sparrows, grasshopper sparrows, and Henslow's sparrow). Planting a seed mix with a both native warm and cool season grasses can provide necessary habitat and achieve all of the objectives that have already been described. Cool season grasses grow and flower in the early and cooler part of the summer. Warm season grasses grow in the later and warmer part of the summer. Warm season grasses are better adapted to poor soils and drier conditions, making them well suited for landfill and other caps systems, as well as most formerly contaminated waste sites. The bunch-type habit of these grasses provides space for the inclusion of native forbs, wildflowers, and legumes to further improve habitat quality.

The root biomass of native warm season grasses far exceeds that of the introduced cool season grasses. This characteristic provides increased organic matter critical to soil fertility and carbon sequestration. According to an Ohio State University Fact Sheet, "Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately reemitted. This transfer or "sequestering" of carbon helps off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality... Soil carbon sequestration can be accomplished by management systems that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure, and enhance soil fauna activity."

While grassland and meadow communities do require some mowing/haying to prevent woody species invasion (if desired) and to maintain plant vigor, these grasses can often be managed on a three year mowing rotation. Conversely, species typically planted (e.g., Kentucky 31 fescue) require mowing and fertilization at least twice a year. In many cases in the Mid Atlantic, former waste sites may be mowed as often every three to four weeks during the growing season, depending on weather conditions. Thus the long-term mowing costs of these non-native species, as proposed for many cap systems, may be well over ten times the cost of mowing a native warm season grass community. Using 2013 estimates, it can cost well over $50/acre to mow a Resource Conservation and Recovery Act (RCRA) cap. Using Kentucky 31 as a cap seed mixture on a 30 acre landfill and mowing monthly from May through September for six years costs $45,000. However, managing the same site planted in native grasses for six years costs $3,000. A significant savings can be realized when considering the lifetime maintenance of a landfill cover system. Several states are migrating to the use of native grasses. For example, the state of Delaware Department of Transportation (DOT) is using native species to reduce road side mowing costs.

Establishing a native grass / meadow community does take more effort, planning, and care initially. Seeding must be done at appropriate times, and sometimes requires specialized equipment. It also takes two years to fully establish the warm season grass plants. But the long-term maintenance costs will pay off, and the difference in habitat value for wildlife species and other ecological services is substantial.

<u>Site Preparation</u>

Final cover material should be tested for routine agronomic parameters to ensure it provides a suitable growing matrix. Native grasses are very adaptable, but grow particularly well on moderately well drained soils or better. Soil pH should be adjusted to achieve a pH of 5.5 or higher. Bring fertility up to medium levels for phosphorus and potassium, but **do not** apply nitrogen at or before planting time. Nitrogen will only stimulate weed competition. As soil used for final cover on waste sites is often imported from other areas, it may contain levels of contaminants that are harmful to ecological receptors or be devoid of organic carbon and a natural microbial community. Project managers should consult with the BTAG to determine if soil amendments are necessary to reduce contaminant bioavailability, increase organic matter, or modify the seed mixture.

Seed Mix

The following seed mix is an example of what can be used for restoration. These species are available from commercial vendors, but orders should allow sufficient time for delivery. The seed mix and seeding rates can and should be adjusted to site specific and seasonal conditions; however these species are adapted to a wide variety of site conditions. At former waste sites where low levels of contaminants remain in the soil, species must be selected based on their tolerance of the chemical contamination in the soils.

All seeding rates are per acre of pure live seed (PLS). The PLS should be specified when ordering.

Native Grassland Species	Pounds/acre PLS
Big Bluestem (*Andropogon gerardi*)	4
Little Bluestem (*Schizachyrium scoparium*)	6
Switchgrass (*Panicum virgatum*)	2
Indiangrass (*Sorghastrum nutans*)	6
Canada Wild Rye (*Elymus canadensis*)	10
Partridge Pea *(Chamaecrista fasciculata)*	2

Cover Crop Options	Pounds/acre
Annual Ryegrass (*Lolium multiflorum*)	25
Oats (*Avena sativa*) – February through August	25
Winter Rye (*Secale cereale*) – August through January	25

The heavier seeding with the cover crop provides immediate erosion control, as it will sprout and easily become established. In the spring the cover crop and the Canadian wild rye will also act as a nursery crop to protect the smaller seedlings of the other species until they can become established. Alternatively, oat (spring through summer planting) or winter rye (fall through winter planting) seeds should be added to the mix at 25 pounds per acre. Planting of a legume species (partridge pea) will improve soil conditioning and habitat quality. When the nurse crop dies after one year, the other warm season grass species should be fairly well established, and will provide the longer term erosion control needed on landfill caps or other cap systems. Wildflowers can also be planted with the mix to provide nectar source for birds, butterflies and other insects. The following wildflower species are widely distributed and adapted to similar conditions and should be added where additional plant diversity, wildlife value, and color is desired. All of the species listed are tall enough that they will be able to compete with native grasses for sunlight.

Wildflower Species	Pounds/acre
Black-eyed Susan (*Rudbeckia hirta*)	½
Lanceleaf Coreopsis (*Coreopsis lanceolata*)	½
Common Milkweed (*Asclepias syriaca*)	½
Wild Bergamot (*Monarda fistulosa*)	½
Ox Eye Sunflower (*Heliopsis helianthoides*)	¾

There are several commercial suppliers of native seed mixes suitable for use in Region 3. These suppliers offer mixes blended for specific habitats and wildlife management needs.

Application of Seed

Spring seeding must take place by the typical regional date of last frost (for example, May 15 in southeastern Pennsylvania). Fall seeding must be delayed until soil temperatures are below 55 degrees and the seeding rate must be increased by at least 25% to account for seed loss due to herbivory and mortality. At these fall temperatures some cool season grasses will sprout immediately, however, the warm season grasses will not sprout until the next spring. The nurse crop of oat or winter rye will germinate and provide the necessary cover and erosion control. Planting, regardless of the season, should not be done during periods of severe drought, high winds, excessive moisture, frozen grounds, or other conditions that preclude satisfactory results.

Seeds of native grasses and wildflowers typically require shallow planting for good germination. Shallow planting of the seed mix can be achieved by two approaches: 1) using a grass seed drill (e.g. Tyedrill or Brillion drill seeder), set at ¼ inch depth or 2) broadcasting the seed and then spraying a ¼ to ½ inch layer of moist compost on top.

If the soil is known or suspected to contain large numbers of weeds seeds or roots, then the weeds should be allowed to sprout and be treated with herbicide prior to seeding with a native seed mix.

If steep slopes are seeded, a biodegradable erosion control blanket (e.g., jute) should be staked over the seeded area to reduce soil and seed erosion.

Monitoring and Maintenance of Grasslands / Meadows

Monitoring the seed germination and controlling weeds in the first growing season is critical to success of the grass/forb planting (Ernst 2010). Monitoring must begin once soil temperatures reach 60 degrees. Grasses, forbs, and weed seedlings must be identified.

During the first full growing season the cool season grasses (e.g., Canada Wild Rye) will be the first plants to sprout. The warm season grasses (e.g., Bluestems, Switchgrass, and Indiangrass) take longer to sprout, and will primarily establish roots during this season.

Throughout the first growing season, mowing should be used to reduce the competition from weeds and prevent weeds from dropping seeds. Seeded areas must be mowed including any strips of grass between trees and shrubs. Each time the weeds reach 18 inches tall or form flowers, the area will be mowed to 7 inches high using a sickle bar or brush hog (Ernst 2010). A lawn mower is not acceptable for this task unless the blade can be set above 7 inches. Mowing will generally be required two, perhaps three times, depending on rainfall, to reduce annual weed invasion and enable light to reach some of the small warm season grass seedlings. Mowing should be timed to prevent seed production by annual weeds (Ernst 2010).

Monitoring will resume in the early spring of the second growing season. Grass areas should be mowed in early spring with the blade height at 4 inches above the ground to avoid damaging the crowns of the plants. In late spring, the grasses, forbs, and weeds will be identified. The area will be mowed again only if weeds are growing to 18 inches or blooming. Mow no lower than 8 inches, as mowing lower will significantly damage the crown of these grasses, cause mortality, or open site for invasion by less desirable species.

During the third and subsequent growing seasons, mow one-third of the site once a year in early spring (before April 1), and rotate so that each area of the site is mowed approximately once every three years. Alternatively, half the site can be mowed each year. These cycles may be adjusted to meet local concerns or needs, but mowing should occur no more frequently than once per year, and ideally rotating portions of the site will not be mowed annually. After mowing, the area should by "hayed" (i.e., collect debris) because the warm season grasses are very dense and mowed debris will kill new growth trying to germinate. As an alternative to haying, mow the site in a weave pattern, followed by a second pass perpendicular to the first to ensure adequate mulching of the cut vegetation. Mowing should not be done during the nesting season (April 15 through July 30) to preclude killing ground-nesting birds and their eggs/young. Mow no lower than 8 inches, as mowing lower will significantly damage the crown of these grasses, cause mortality, or open site for invasion by less desirable species. As an alternative to mowing, prescribed fires may be used to manage grassland and meadows. Prescribed fires replicate the natural processes of these fire-dependent communities and return nutrients back to the soil. Prescribed fires should also be performed prior to nesting by birds (before April 1) and must be performed by trained professionals.

It is important to note that warm season grass species take several years to become established and substantial top growth may not occur until the third year. As long as weed species are mowed as specified to provide sunlight to the small seedlings, these grass species are relatively easy to establish.

Additional Monitoring and Maintenance Concerns

During the establishment period, the site should be managed for the control and elimination of non-native invasive plant species (e.g., fescue, Johnson grass, Japanese honeysuckle, Chinese lespedeza) from within and from the perimeter of the planting. Techniques employed for control of undesirable plant species can consist of physical removal and the spot or wick application of herbicides. Control of these invasive species should only be necessary during the establishment period.

During the establishment period, the site should be monitored for any significant erosion. Areas exhibiting erosion should be restored to pre-disturbance conditions as soon as possible and stabilized with standard erosion controls methodologies including, but not limited to: biodegradable matting, seeding with a native seed mix that includes a cover crop, and depending on severity of erosion, silt fencing, or staked hay bales to reduce soil runoff. Jute matting is preferred as it is 100% biodegradable and is less harmful to wildlife.

Performance Standards

A metric that can be used to monitor the success of a warm season grass planting is the number of healthy seedlings of the target species. In late summer of the seeding year, the minimum acceptable standard is an average of at least 2-4 vigorous seedlings per square foot. By mid summer of the second year, an average of 2 vigorous seedlings per square foot should be present. Utilizing these metrics in the first two years, suitable total areal target coverage should be achievable by mid summer of the fourth year. At this point the vegetative cover at two feet above the ground should be 85%. Monitoring and maintenance of the grasses and forbs may be discontinued when the seeded plants provide 80 % soil cover and weeds occur at less than 10%.

Scrub/Shrub and Woodland Habitats

Trees and shrubs can be planted after seeding of grasses and forbs has been completed. Deciduous trees and shrubs may be planted from mid October through mid May (mid April in Virginia) whenever soil conditions permit. Most conifers should only be planted in the spring. If seeding has been done in the late spring or later, then planting of woody plants must be delayed until fall. Bareroot plants can be installed with a tree planter or by hand, whereas potted plants must be planted by hand. Trees and shrubs are generally planted in staggered rows with row and plant spacing determined by the species being planted. Generally species are randomly mixed within each row. Tree and shrub selections must be made according to habitat desired and site specific conditions, including, as necessary, their tolerance of the chemical contamination in the soils. Project managers should consult with the BTAG to determine the appropriate species for the conditions and objectives at each site.

Monitoring and Maintenance Requirements and Performance Standards

Monitoring of the woody plants must be performed annually in spring and fall. Evidence that each species of trees/shrub is growing is provided by monitoring 10% of the plants (e.g., height, spread). Each plant will be examined for evidence of browse or insect damage, bark stripping, or disease. If damage is present on greater than 40% of the plants, a control program should be implemented (e.g., routine spraying, installing tubes). Dead or moribund trees and shrubs will be replaced in October. Herbaceous vegetation should be mowed between the rows of trees and shrubs annually until the plants get tall enough to compete. Monitoring and replacement of woody plants must be conducted to achieve 80% tree survival and 80% shrub survival of at least half the species planted.

ROOTS

The greatest hesitancy surrounding the use of any vegetation other than turf grasses for site restoration is associated with the misunderstanding of root systems of the alternative species. Excavation of plants and examination of root structures indicates that most roots:

- are within the top 18" of soil;
- follow water, won't go through impervious material in search of water;
- follow the path of least resistance; even grow horizontally over an impervious layer;
- take advantage of cracks in clay caps that are most likely attributable to desiccation'
- will "drain" any water that flows into the voids in the cap

(Robinson and Handel 1995, Handel et al. 1997, Mooney et al. 2007),

REGION 3 EXAMPLES

Delaware

- Tybouts Corner, Wilmington
- Wildcat Landfill, Dover

Maryland

- NAS Patuxent River, MD (Site 11 Former and Current Sanitary Landfills, Sites 1 Fishing Point LF and Site 12, Landfill Behind the Rifle Range)
- Southern Maryland Wood Treating, Hollywood
- Woodlawn County Landfill (LF), Cecil County, Woodlawn

Pennsylvania

- Berks County Landfill, Sinking Springs
- BoRit Asbestos, Ambler
- Butz Landfill, Monroe County Township
- Craig Farm Drum Dump, Armstrong County
- Dorney Road Landfill, Mertztown
- Eastern Diversified Metals, Schuylkill County Rush Township
- Hamburg Lead Site, Hamburg
- Industrial Lane Landfill, Northhampton County
- Metal Bank, Philadelphia
- MW Manufacturing, Valley Township, Montour County
- Navy Ship Parts Control Center, Mechanicsburg
- Revere Chemical Co., Nockamixon Township
- W.R.G. 4 Vermiculite Site, Ellwood City

Virginia

- Avtex Fibers, Warren County, Front Royal
- Norfolk Naval Shipyard, Portsmouth
- USN St. Juliens Cr. Annex, Chesapeake

West Virginia

- West Virginia Ordnance, Pt. Pleasant

REFERENCES AND RESOURCES

Andreas, L., et al. 2005. Physical Properties of Steel Slag to be Reused in a Landfill Cover. Proceedings Sardinia 2005, Tenth International Waste Management and Landfill Symposium. https://www.ltu.se/polopoly_fs/1.39418!physical_prop_steel_slags_landfill_cover.pdf

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ATTACHMENT B

EROSION CONTROL

United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-002 September 1999

EPA

Storm Water Technology Fact Sheet
Turf Reinforcement Mats

DESCRIPTION

This fact sheet describes the use of turf reinforcement mats (TRMs). TRMs combine vegetative growth and synthetic materials to form a high-strength mat that helps to prevent soil erosion in drainage areas and on steep slopes. TRMs are classified as a "soft engineering practice," in contrast to concrete and riprap, which they may replace in certain erosion control situations.

High-volume and high-velocity storm water runoff can erode soil within open channels, drainage ditches, and swales, and on steep exposed slopes, increasing the transport of sediments into receiving waters. Water quality impacts of increased sediment load include the conveyance of nutrient and pesticide pollutants, disruption of fish spawning, and impairment of aquatic habitat.

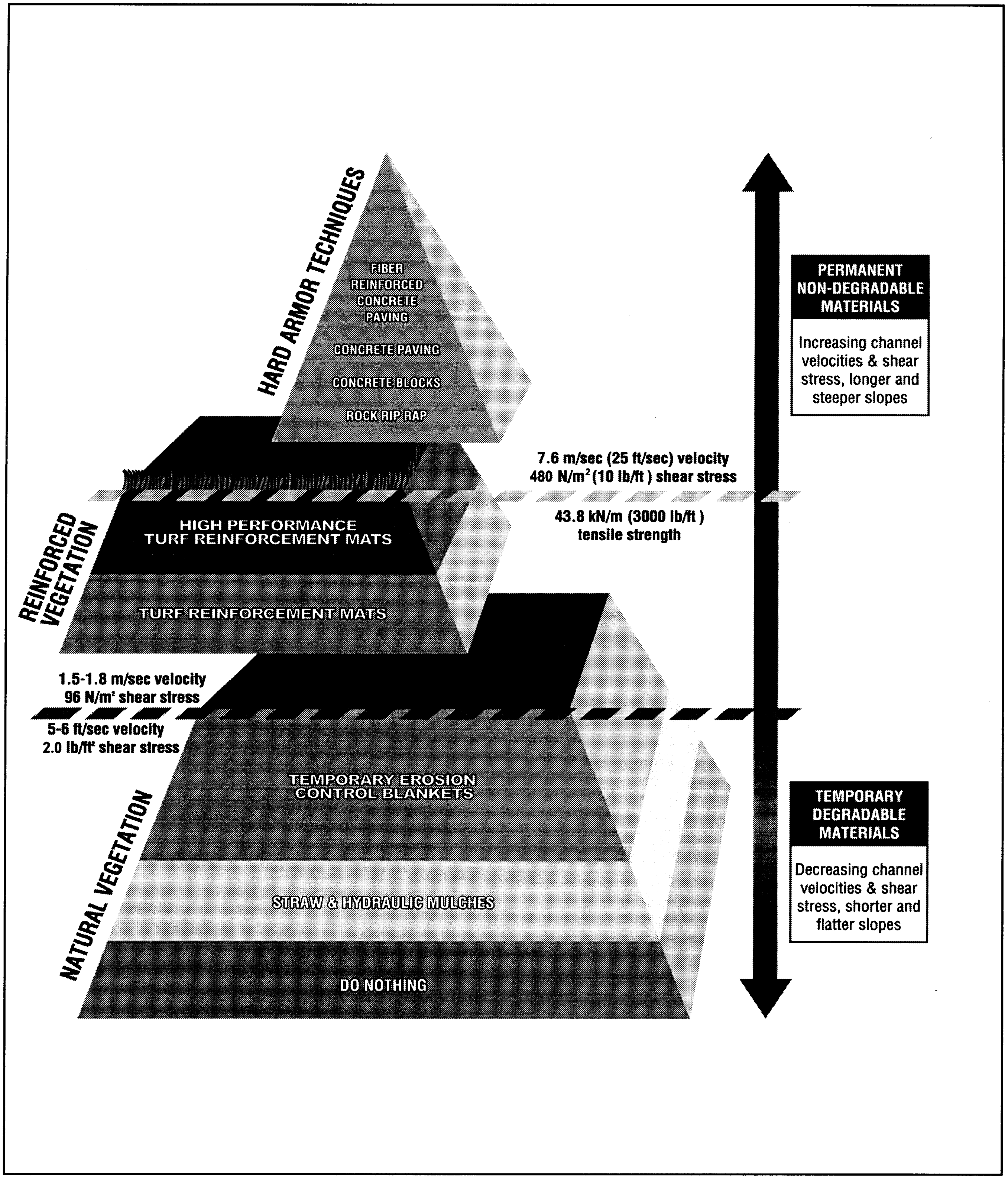
Traditionally, hard-armor erosion control techniques such as concrete blocks, rock riprap, and reinforced paving systems have been employed to prevent soil erosion in these highly erosive areas. Although these permanent measures can withstand great hydraulic forces, they are costly, and they do not provide the pollutant removal capabilities of vegetative systems.

TRMs enhance the natural ability of vegetation to permanently protect soil from erosion. TRMs are composed of interwoven layers of non-degradable geosynthetic materials such as polypropylene, nylon and polyvinyl chloride (PVC) netting, stitched together to form a three-dimensional matrix. They are thick and porous enough to allow for soil filling and retention. In addition to providing scour protection, the mesh netting of TRMs is designed to enhance vegetative root and stem development. By protecting the soil from scouring forces and enhancing vegetative growth, TRMs can raise the threshold of natural vegetation to withstand higher hydraulic forces on stabilization slopes, streambanks, and channels. In addition to reducing flow velocities, the use of natural vegetation provides particulate contaminant removal through sedimentation and soil infiltration, and improves the aesthetics of a site.

TRMs offer high shear strength, resistance to ultraviolet (UV) degradation, and inertness to chemicals found in soils. Figure 1 illustrates the applicability of TRMs within the spectrum of available erosion control techniques. Temporary erosion control blankets and mats, also shown in Figure 1, eventually leave vegetation unprotected and unreinforced, and should only be used to establish vegetation under mild hydraulic situations.

TRMs, unlike temporary erosion control products, are designed to stay in place permanently to protect seeds and soils and to improve germination. TRMs can incorporate natural fiber materials to assist in establishing vegetation. However, the permanent reinforcement structure of TRMs is composed of entirely non-degradable synthetic materials. The structure of a typical TRM is illustrated in Figure 2. A variety of ground-anchoring devices can be used to secure TRMs, including: u-shaped wire staples, metal pins, and wood or plastic stakes. Appropriate ground anchoring devices are chosen based on site-specific soil and slope conditions.

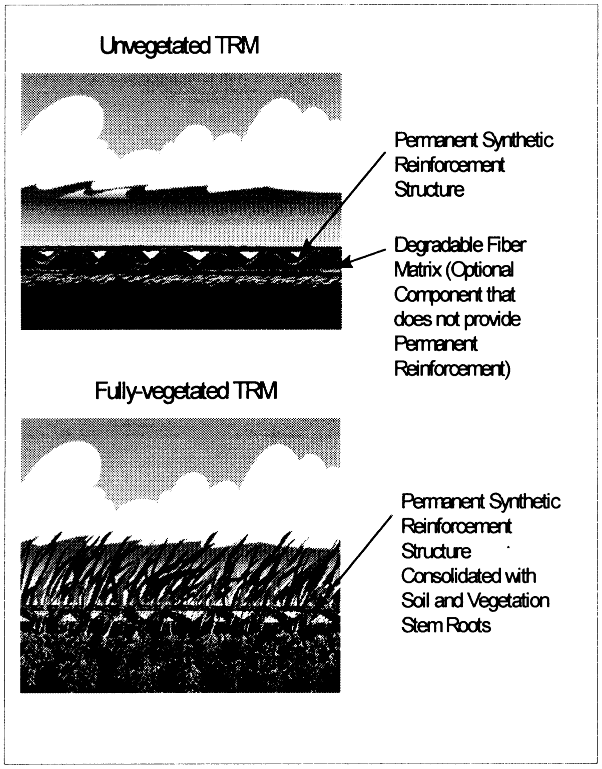
Vegetative seed selection is based on the geographic region of the project and site specific concerns. Sources of information on seed selection



Source: Synthetic Industries, 1998.

FIGURE 1 EROSION CONTROL TECHNIQUES

include: the U.S. Natural Resource Conservation Service (NRCS); various university extension services;and state transportation departments. The installation area may be seeded before or after the TRM is installed, depending on the matting construction and manufacturer's recommendations.



Source: Modified from North American Green, Inc., 1998.

FIGURE 2 THE STRUCTURE OF A TYPICAL TURF REINFORCEMENT MAT

APPLICABILITY

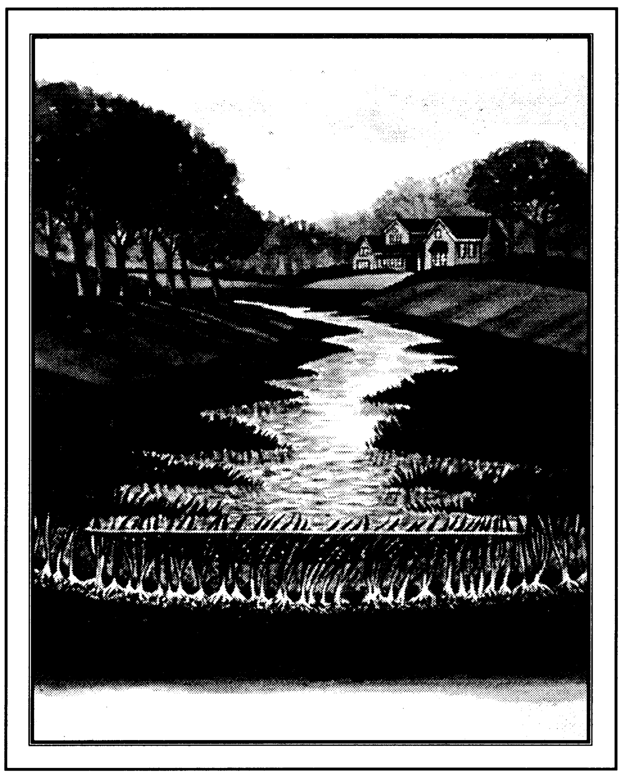
Turf reinforcement technology may be used in conjunction with temporary sediment and erosion control measures to re-establish and protect vegetation at construction sites. Sediment and erosion control measures, which are typical components of storm water pollution prevention plans, are designed to mitigate construction impacts on receiving waters. Commonly applied sediment and erosion control measures include photodegradable and biodegradable natural fiber blankets and hydraulic mulches. The use of TRMs allows vegetative cover to be extended to areas where site conditions would otherwise limit it. This helps to establish and maintain a continuous vegetative cover throughout the applied area. TRMs can be applied to most sites or structures where permanent erosion control is required. This technology has been effectively used in both urban and rural areas and in a variety of climatic conditions. Although most effective when used in fully vegetated areas, TRMs have been used to prevent erosion even in arid, semi-arid, and high-altitude regions with limited vegetative growth. In these areas, vegetation establishment is slow or difficult, and the TRM matrix is typically filled with native soils for protection (with the mat acting to prevent erosion permanently).

Under most climatic or environmental conditions, reinforced vegetation can protect:

- Surface water conveyance systems (see channel lining, Figure 3).
- Surficial erosion of slopes.
- Pipe inlets and outlets.
- Shorelines and banks.

ADVANTAGES AND DISADVANTAGES

TRMs are being used to control erosion and stabilize soil to control runoff from land-disturbing activities with steep slopes, and to prevent scouring in storm water detention ponds, water storage ponds, small open channels, drainage ditches, and runoff conveyance systems within parking lot



Source: Synthetic Industries, 1998.

FIGURE 3 TRMs AS PROTECTIVE CHANNEL LININGS

medians, and along streambanks and shorelines.

In addition to their use for new construction projects, TRMs have been used to retrofit existing hard armor systems. For example, in 1994, the City of Chattanooga, Tennessee, began a program to improve water quality by protecting aquatic habitat and reducing sediment transport to receiving water bodies. The City chose to retrofit existing concrete-lined storm water channels into vegetative swales. Depending on the hydraulic conditions of the application, the City chose to use both biodegradable rolled erosion control products and turf reinforcement mats. The City has retrofitted over 32 kilometers (20 miles) of storm water conveyance systems using this technique.

In addition to improving water quality, TRMs can provide aesthetic enhancement, especially in areas lacking vegetative growth. In the city of Louisville, Kentucky, TRMs are being used to stabilize soil for vegetation in Waterfront Park, an abandoned industrial area being converted into a recreational area (North American Green, 1998). In Waterfront Park, which is being developed on a hilly site adjacent to the Ohio River, TRMs not only control erosion, but they also make it possible for vegetative growth in the park setting

TRMs will perform well only within their specified design limitations. Some hydraulic and environmental conditions dictate that hard armor techniques are the most appropriate solution. In general, TRMs should not be used:

- To prevent deep-seated slope failure due to causes other than surficial erosion.
- When anticipated hydraulic conditions are beyond the limits of TRMs and natural vegetation.
- Directly beneath drop outlets to dissipate impact force (although they may be used beyond the impact zone).
- Where wave height may exceed 30 centimeters (1 foot) (although they may be used to protect areas up-slope of the wave impact zone).

To perform properly, the TRM must be installed properly and remain in proper contact with the ground. Critical points in conveyance system applications where mats can lose support include points of overlap between mats, projected water surface boundaries, and channel bottoms. The Erosion Control Technology Council (ECTC) publishes installation guidelines for both permanent and temporary rolled-erosion control products (Lutyens 1997).

DESIGN CRITERIA

Many state and local erosion and sediment control manuals, which assist developers in complying with state and local National Pollutant Discharge Elimination System (NPDES) programs, specify guidelines for TRM use and applicability. Additional design procedures for TRM use have been developed by the U.S. Federal Highway Administration (Chen and Cotton, 1988) and the American Association of State Highway and Transportation Officials (AASHTO, 1992). Most state transportation departments have a list of approved products meeting their minimum performance standards. These standards are typically based on physical properties of the product, such as mass per unit area, thickness, resiliency, porosity, and stiffness.

PERFORMANCE

TRMs provide water quality benefits by allowing the growth of vegetation in areas where impervious conveyance systems would otherwise be used. In general, the performance of TRMs is closely tied to the vegetative establishment and growth. In a laboratory study, Clary, et al. (1996) found that the presence of herbaceous vegetation enhanced sediment deposition and the channel restoration process in small-stream systems. Through experiments in a simulated small stream channel, Thornton, et al. (1997) found that the ability of vegetation to entrap and retain sediment increases with blade length and cross-sectional area of the vegetation, with retention rates ranging from 30 to 70 percent. The performance of vegetation in removing sediment and other pollutants depends on site-specific hydrologic conditions as well as the underlying soil types, the type of vegetation, the height and density of growth, and proper selection and installation of the TRM.

The performance of the TRM-lined conveyance system depends on the duration of the runoff event to which it is subjected. For short-term events, TRMs are typically effective at flow velocities of up to 50 meters per second (15 feet per second) and shear stresses of up to 380 Newtons per square meter (8 pounds per square foot) (Cabalka and Trotti, 1996). However, specific high-performance TRMs may be effective under more severe hydraulic conditions.

TRMs provide long-term water quality benefits by allowing the growth of vegetation in areas where impervious conveyance systems would otherwise be used. While they may reduce flow velocities, hard armor techniques do not remove pollutants as does natural vegetation. TRMs can be used in conjunction with temporary sediment and erosion control measures to assist communities in complying with state and local NPDES requirements. Additionally, TRMs provide a cooler substrate than traditional hard armor techniques, reducing water temperature increases that could otherwise impact aquatic life. Further, the vegetation itself provides wildlife and aquatic life habitat. The water quality benefits of TRMs depend on site conditions and the type and density of vegetation.

COSTS

In general, the installed cost of TRMs ranges from $6 to $18 per square meter ($5 to $15 per square yard). Factors influencing the cost of TRMs include:

- The type of TRM material required.
- Site conditions, such as the underlying soils, the steepness of the slope, and other grading requirements.
- Installation-specific factors such as local construction costs.

In most cases, TRMs cost considerably less than concrete and riprap solutions. For example, a project in Aspen, Colorado, used over 19,000 square meters (23,000 square yards) of TRMs to line channels for a horse ranch development project (Theisen, 1996). The TRMs were installed at a cost of $9.90 per square meter ($8.25 per square yard) (in 1996 dollars). This was substantially less than the $24 per square meter ($20 per square yard) estimate for the rock riprap alternative.

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ADDITIONAL INFORMATION

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Evansville, IN 47711

Synthetic Industries, Inc.
Deron Austin
4019 Industry Drive
Chattanooga, TN 37416

Washington State Department of Transportation
Dave Rodin, Landscape Architect Office
P.O. Box 1709
Vancouver, WA 98668

For more information contact:

Municipal Technology Branch
U.S. EPA
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401 M St., S.W.

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AUGUST 1999 VOL 3, NO. 8

Soil Stabilization using Erosion Control Blankets

Erosion Control Blankets can be effective in minimizing the erosive effect of rainfall when used to cover bare or newly planted soil. Their use stabilizes the soil to protect new plantings and reduces the potential for introducing sediment into storm water run-off, a win-win situation! Erosion Control Blankets can be specified by designers for protection of newly graded slopes, open areas, or drainage swales to allow germination of seed mixes and plantings. Contractors may also choose to use Erosion Control Blankets for temporary erosion control on highly erodible areas.

Several types of erosion control blankets are in the process of being installed on a slope to evaluate their effectiveness.

What are Erosion Control Blankets?

Erosion Control Blankets are biodegradable materials that can be used to protect disturbed slope and channel areas from wind and water erosion. The blanket materials are natural materials such as straw, wood excelsior, coconut, or are geotextile synthetic woven materials such as polypropylene.

Tell Me More

Erosion Control Blankets are effective for soil stabilization on steep to moderate slopes, new landscaped areas, and drainage swales and ditches that are to be planted or seeded. Additional desirable attributes include:

- They increase water infiltration into the soil.
- When used with a seed mix, they protect the mix from being eroded during heavy rainfall or wind.
- They increase the retention of soil moisture to promote seed germination.
- Most importantly, they reduce soil erosion.

Consult with the **District Landscape Architect** for guidance in the proposed use of specific Erosion Control Blanket products. There are many types of products available for erosion control. Product selection is based on many factors, such as:

- Duration required (short or long term temporary usage).
- Effectiveness compared to other soil stabilizers.
- Relative cost of purchase, installation and maintenance.
- Visual impact to the public.
- Environmental acceptability. Synthetics may biodegrade more slowly than natural materials.
- *Any changes to specified products should be approved by the* ***District Landscape Architect.***

Getting the Most from Erosion Control Blankets

Erosion Control Blankets provide excellent short and long term temporary erosion control - *when properly installed and maintained*. Proper soil surface preparation is critical to the effectiveness of the installation:

- All rocks, clods, debris, and vegetation should be removed to ensure full contact between the blanket and the soil surface.
- Check the special provisions or follow the manufacturer's recommendations for seed application requirements when used with blanket installation.
- The blanket should be anchored to the soil using metal wire staples as specified in the special provisions or recommended by the manufacturer.
- The staples should be driven through the blanket and into the soil, flush with the soil surface.
- Erosion Control Blankets should not be used where final vegetation will be mowed, because material and staples may be caught in the mowers.
- If the area identified for Erosion Control Blankets installation is unusually steep or rocky, consult with the **District Landscape Architect** for guidance.

Inspections and Maintenance

As with any storm water Best Management Practice (BMP), the result depends on the product selected, the installation quality, and the commitment to maintenance. The inspection and maintenance of Erosion Control Blankets should be conducted as follows:

- Inspect the site during installation.
- Inspect the installation before, during and after significant rain events.
- Repair or replace all damaged materials.
- Recompact all soil washout areas.

STORM WATER HOME

Engineering With Nature

Alternative Techniques to Riprap Bank Stabilization

FEMA

Engineering With Nature

Alternative Techniques to Riprap Bank Stabilization

Contents

Introduction

We have always endeavored to harness and manipulate our environment. Efforts to shape or restrict nature often involve mechanically or artificially forcing our surroundings to bend to our will. Sadly, many of these activities have serious effects. Clear cutting forests, pollution, endangering entire species or simply driving them to extinction are just some of the major impacts. As we grow and develop technologically and as a society, we often overlook just what we are doing to the land around us, frequently until it is too late.

Over the past century, the Pacific Northwest has seen a significant amount of development in the areas of agriculture, housing, urbanization and population. The 12 counties spanning the area of Puget Sound in Washington State alone have seen growth in numbers of up to 4 million people since the 1950s. This continuing expansion has put increased pressure on the multitude of rivers, streams and other bodies of water that festoon the region, and growing presence is having a marked impact on those waters.

The more development this area undergoes, the more we are forced to restrict and inhibit the environment, in particular the varying and numerous waterways that surround us. While land erosion, stream migration and even flooding are natural processes, they can cause havoc when occurring near human populations. This has led to the creation of a number of measures to control or eliminate such hazards. Unfortunately, while many of these techniques solve the immediate problem, they are not always the safest or most environmentally conscious choice for the long-term.

Riprap, or hard armoring, is the traditional response to controlling and minimizing erosion along shorelines or riverbanks. As demonstrated by past multiple disasters in Washington State, the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) has provided funding assistance for the repair to these riprap facilities.*[1] The very nature of having to repair these facilities counters the popular engineering belief that riprap is the best solution for mitigating stream bank erosion.

[1]* Funding is contingent upon eligibility criteria established under the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended

Riprap

Put simply, riprap is the layering of rocks (angular rocks generally being preferred,) along a threatened area to counteract the constant wearing away of land brought about by repetitive hydrologic activity. Whenever waves or moving waters meet unprotected soil, there will always be erosion. Covering exposed soil with rock helps protect it from being washed away, securing an embankment against further erosion.

Problems arise because the effects of riprap do not stop at the point of installation. When positioned along a section of riverbank, for example, riprap has a number of negative impacts on the surrounding environment. Riprap tends to increase the speed of water flow along an armored reach, as the water has no points of friction to come up against and nothing to slow it down. This additional strength of flow presents issues further downstream from a riprap protected bank, as water is deflected off the riprap and directed at other points of riverbank. The increased strength and speed of the water only increases erosion suffered at these new locations, the typical result of which is the necessity of installing additional armoring, which merely moves the problem further down the stream.

Riprap impedes the natural functions of a riverbank or shoreline, as it interrupts the establishment of the riparian zone, or the point of interface between land and flowing water. A properly functioning riparian zone is important for a number of reasons; it can reduce stream energy and minimize erosion; filter pollutants from surface runoff via biofiltration; trap and hold sediments and woody debris, which assists in replenishing soils and actually rebuilding banks and shorelines; and it provides habitat diversity and an important source of aquatic nutrients. Not to mention, a naturally functioning riparian zone simply looks better.

Another aspect of riprap is its considerable effect on wildlife, specifically fish that live in and utilize streams and rivers where eroding banks have undergone armoring. While erosion can cause potential problems for fish, especially in high-silt locations, the installation of riprap leads to other, more significant, issues. When riprap is the primary or only form of riverbank stabilization measure, the end result is typically a uniform, smooth channel, with no complexity. This means that there are no areas of vegetation either in or overhanging the water, leaving fish at risk from predation. In addition, a lack of riverbank diversity denies fish a place to seek refuge during periods of high-water, which often results in their being washed out of a fast moving system during flooding.

Riprap causes other, albeit less significant, problems as well. In areas of low vegetation, when exposed to direct sunlight, the rocks that comprise riprap can reflect light into the water, which increases water temperatures to an unhealthy degree for fish. Riprap also tends to suffer from structural integrity issues during and after high-water events. Losing rocks to high water or fast flows, a riprap structure will soon begin to fail in its purpose. Once the soil that the riprap is designed to protect is exposed, the damage continues as before its installation. This possibility requires constant monitoring and maintenance, which ultimately becomes expensive and problematic.

Alternative Techniques

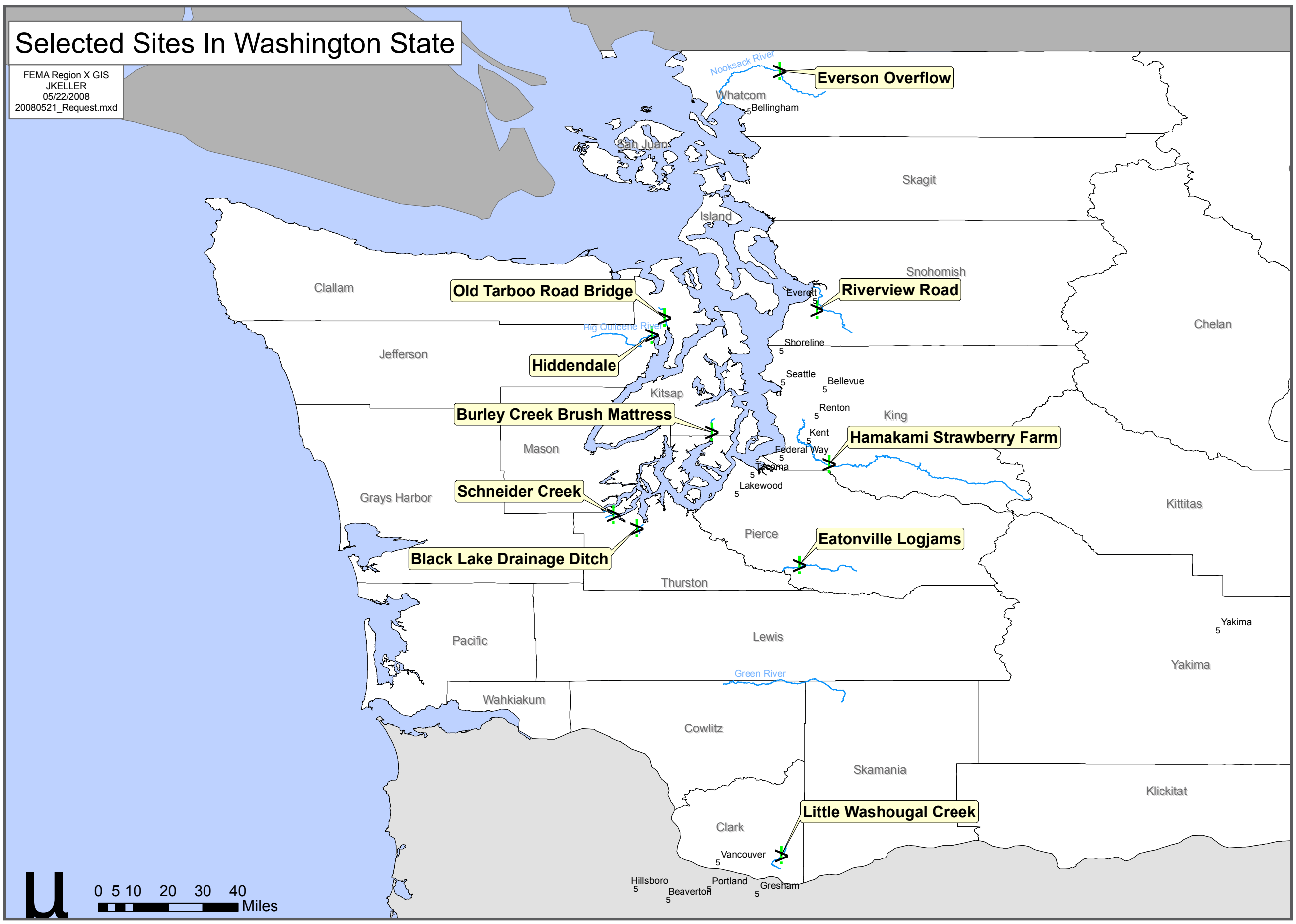
The old saying goes “the more things change, the more they stay the same.” This adage, in many ways, can be applied to the discussion of riverbank stabilization. As technologies and techniques have advanced in finding ways to secure our land from the constant ravages of erosion, we begin to see that perhaps modernizing these efforts might not be the only way to approach these issues.

Nature has always been capable of taking care of itself. Long before we began manipulating our environment, nature has run its own course. Is it possible, then, that we can look to nature for examples to follow in making life near eroding or flood-prone waterways less risky while leaving as minimal a footprint as possible? Proponents of environmentally conscious and responsible construction believe so.

As the realities and consequences of riprap and hard armoring riverbanks and shorelines have come to light, there are those who have begun to work towards changing the traditional approaches to erosion and flood control. New and old engineering techniques are being introduced regularly that incorporate natural functionality with modern technology and design. Bio-engineering, hydro-seeding, controlled planting and the construction of engineered logjams are just some of the many efforts being taken to demonstrate the successful options that exist in the pursuit of land preservation and increased safety.

Purpose

Standard engineering calls for hard armoring an eroding bank. Lately, the tide has turned on the accepted practice of hard armoring due to public conscience of the eroding environment we live in. The 10 stories in this booklet represent a handful of successful alternatives to riverbank stabilization that have been taken throughout Western Washington. While this collection is in no way complete, it offers a comprehensive look at some of the varied techniques that are available for consideration. These best practices illustrate the fact that we can manipulate streams and rivers without completely overriding nature's design, that indeed, it is possible to work hand in hand with nature to make living by the water not only viable, but much safer and secure in the long run.



Hamakami Strawberry Farm:
Adding Roughness to River Keeps Farm Running Smoothly

In 1994, King County built a bioengineered bank stabilization project on the Middle Green River at the site of John Hamakami's Strawberry Farm. The site was designed at a time when the Washington State Department of Fish and Wildlife, the Muckleshoot tribal fisheries groups, and King County ecologists were realizing that the continued placement and replacement of riprap was harming fish and their habitat. Hamakami Strawberry Farm became a demonstration site for the positive effects of using natural elements, particularly wood and vegetation, as opposed to hard armoring in a high energy river environment.

"We started looking at how river hydraulics were interacting with wood," said Andy Levesque, a King County senior engineer, who works in the River and Floodplain Management Unit. "We wanted to see how wood could be used constructively without destabilizing banks, while actually helping to direct the river flow to make the banks more stable if possible. The actual design and construction work was overseen by Jeanne Stypula, one of our engineers, working with a consulting biologist, Alan Johnson."

"We wanted to see how wood could be used constructively without destabilizing banks." - Andy Levesque

Numerous logs are placed along the toe of the riverbank.

In 1990, the Middle Green River created a whole new quarter mile meander bend in just over one day. In the process, the river demolished 150 feet of rock lined levee, a dozen maple trees and a couple acres of the Hamakami Strawberry farm. Historically on the Green River, rock riprap was used to prevent embankment scour. On such an alluvial floodplain as the Hamakami property, with an abundance of silt and sand, however, slumping is the primary cause of bank failure. Fine grained materials do not provide bank resistance, so in a high energy event, like the one that occurred at the Hamakami site in 1990, the Green River was able to move laterally at a very rapid pace.

During flooding additional woody debris is recruited by the original logs.

Recruited vegetation lends cohesion to the riverbanks.

The 1990 flood event left a steep 10 to 15-foot high raw embankment along the Hamakami Strawberry Farm. As a result, over the following years, the farm lost a significant amount of land to the river meander that was moving rapidly through the property. In fact, strawberries from the farm were literally falling into the river channel.

In 1994, King County stabilized 500 feet of the rapidly eroding riverbank using bioengineering measures. Over 60 logs were placed along the river's toe and secured to the bank with coir fabric, soil wraps and vegetation. The logs were placed in groups of three every 20-25 feet and buried into the embankment. As a demonstration project, the idea was to show that installing natural elements added roughness to the channel, which increased flow resistance and slowed the river down.

"We used wood and vegetation to slow the river processes down," said Levesque. "When the wood that showed up in the next flood landed, it started forming a jam. The jam evolved and recruited sediment, and the sediment recruited vegetation. That slowed the water down enough to deposit the gravels upstream, which caused the river to cut multiple channels across the bar that it had previously built. Now we've got 100-fold the habitat edge, variety, complexity, structure, interaction, and process that we did right after the flood event. We counted fish at the site, before our installation, and there were four of them. Now there are five different species at ten different times of year."

The Hamakami site exemplifies that if a bank stabilization design can jump-start channel processes, ecological rehabilitation will occur. The logs placed by the county now have wood, debris, sediment, and vegetation surrounding them. As a result of the project, several side channels have been created which distribute the system's energy, allowing sediments to disperse and vegetation to thrive. In total, the site's ecological productivity is greatly improved.

"This type of technique is what I would advocate even in a high energy environment," said Levesque. "It can be done with wood. It can be done with vegetation. There are some precautions that have to be taken depending on the landscape. If the river meander has basically cut itself to the edge of where it's going to go, just respect that meander belt and add some structure back into it. Get things jump-started. You get your process back. You get things reshaped and you get environmental benefits."

"Now we've got 100-fold the habitat edge, variety, complexity, structure, interaction, and process that we did right after the flood event." - Andy Levesque

Riverview Road:
Several Steps to Safety in Snohomish County

Riverview Road in Snohomish County, Washington runs beside a section of the Snohomish River. The road was built by landowners in the late 1800s and then expanded and improved in the early 1900s. It primarily serves the local farming communities as both a thoroughfare and as the base of a flood control levee system. At the time of its construction, these levees were created with drag lines which pulled soil from the river bottom and deposited it on the top of the riverbank. The material was then flattened for use. The pulled river soil is described as alluvial sediment and is composed of fine grained, porous material.

Problems arise when such material is subject to inundation. Over the years, as the County developed, modern surfacing was laid over the old roadway originally built from the river alluvium. During periods of high water resulting from floods on the Snohomish River, the road embankment becomes saturated. When the water recedes, the material tends to compact, and the saturated soils begin to slide down towards the river. This process often compromises the stability of the riverbank, undermining the integrity of the road itself.

"This is happening at a number of places where there are levees on the lower Snohomish River," said Jeffrey Jones, an Engineering Geologist for Snohomish County's Public Works Department. "Every time the water comes up and goes back down, we find new problem sites."

The Riverview Road area of the Snohomish River is a migration corridor for Chinook salmon and Bull trout, both listed under the Endangered Species Act (ESA). The increase of sedimentation from the collapsing embankment into the river was regarded as potentially harmful to fish, as sedimentation can negatively impact oxygen levels, suffocate salmon eggs and decrease visibility for feeding. Because riprap reduces cover, increases temperature and eliminates access to spawning areas, it can have a negative impact on habitat. Based on these potential effects the team sought out other alternatives.

Jones, working with Dave Lucas, a River Engineer for the Snohomish County Surface Water Management Department, designed a system of embankment stabilization. This environmentally-friendly design incorporated wood and vegetative plantings. The design was successful because it kept the road from collapsing and avoided placing major amounts of rock into the river.

Since the embankment along Riverview Road is so steep, typical stabilization techniques were impractical. Jones and his team of Snohomish County Road Maintenance workers built a structural earth wall (SEW) composed of a number of soil wraps placed in a step-like fashion starting from the waterline and climbing to the top of the embankment. Each step is created by laying down a 13-foot wide roll of polypropylene or polyethylene geo-grid fabric. The grids are

The offsetting of the soil wraps comprising the structural earth wall (SEW) give it its step-like appearance. The logs anchored to the toe of the embankment protect the structure from fast flowing woody debris and provide habitat for migrating fish during high water.

Dave Lucas and Jeff Jones standing atop their structural earth wall on Riverview Road.

The willow cuttings planted throughout the embankment lend root cohesion and stability to the structural earth wall.

weighted down by layers of compacted gravel-borrow taken from a local quarry. The geo-grid is folded over, and another layer of gravel is used to weigh it down further. As each wrap is completed, the following one is offset by at least one foot, creating the step-like appearance. The outer face of the wall is covered with a layer of heavy coir fabric, and topsoil which is then hydro-seeded. This allows the geo-grid to lock in place and secure the embankment without threat of degradation from exposure to ultraviolet light. Finally, the entire embankment is planted with live willow cuttings which ultimately take root. As the trees grow, their root structures add to the stability of the embankment.

According to Lucas, Snohomish County utilizes a native plant program to assist in habitat restoration projects such as the Riverview Road effort. Not only are they able to determine which plants and trees are appropriate for a particular location, they also incorporate a holding facility that grows the plants to be used. With advance notice of upcoming projects, the holding facility personnel can have the plants ready and perform the recommended planting.

"In the toe of the embankment we anchored a continuous row of logs," said Jones. "They're about 20 or 30 feet long, with the root wads still attached. We use "Manta Ray" type anchors, vertical anchors and horizontal anchors to hold them in place."

The Snohomish River at this location is tidally influenced, which means the logs are not in the water at all times. During high tide the logs provide necessary shelter for migrating fish. They also act as a shield, preventing larger woody debris from puncturing the base of the soil wraps during periods of high water or flooding. Over time, additional woody debris is recruited by the logs and absorbed into the shoreline, further enhancing the establishment of habitat.

The first stage of the Riverview Road stabilization project was completed over four years ago, just down the road from the most recent construction. At this point in its progression, the first area has assumed a completely natural appearance. The planted vegetation has grown and continues to develop a functioning root system that further strengthens the embankment. The logs on the waterline have recruited additional woody debris, incorporating them into the habitat, and the surface of the project is overgrown by the hydro-seeded grass and planted vegetation. The geo-grids holding the embankment in place are now completely invisible.

When speaking about the success of the project, Lucas was confident in its long-term value.

"Overall, this type of design will require less ongoing maintenance than riprap," said Lucas. "It secures the riverbank against erosion, and it helps to meet our commitment towards maintaining salmon habitat, a stated goal of Snohomish County. When we can add those elements together and stabilize a County road in a habitat friendly manner, I think the project speaks for itself."

Eventually the coir fabric and the structural earth wall itself will be completely overgrown with hydro-seeded grass and other vegetation.

The completed project, a short distance down the road, is now fully vegetated and looks entirely natural.

Eatonville Logjams:
Engineered Logjams Protect Banks on Mashel River

Four of the engineered logjams designed by Herrera Environmental Consultants on the Mashel River outside of Eatonville, WA.

On the Mashel River, just outside of the town of Eatonville, Washington, Smallwood Park contains a pond utilized by the town's residents for their annual fishing derby. Every few years the Mashel River is subject to flooding and the park, along with the pond, becomes inundated with floodwaters. The river embankment by this pond has begun to erode, and with each new flood event, the park, and the County road nearby, are potentially threatened with damage.

Following a major flood in 1996, the Army Corps of Engineers funded the installation of a riprap structure on the threatened riverbank. That area of the river happened to be a straight channel providing no complexity to slow the river's flow, or for fish habitat. As is often the case with riprap, the speed of the river in that reach accelerated, and increased the threat of erosion on banks further downstream. In addition, the riprap itself ultimately began to fail, with the rocks that comprised the bank protection falling into the river.

To address the problem, a private company, Herrera Environmental Consultants was contracted to install several engineered logjams along a number of reaches in the river along the Smallwood Park bank. The intent was for the logjams to slow down water flow, while providing long-missing habitat for fish that utilized the Mashel for spawning and migration.

"One of the main limiting factors of that area of the river was that it had been very simplified by prior human activity," said Jose Carrasquero, a Fisheries Biologist and Project Manager for Herrera. "Logging and removal of wood had negative effects on the riparian areas, and left no complexity to the stream. There were very few pools for juvenile salmon to utilize for rearing, or off-channel habitat for much-needed protection during high flows. Spawning habitat for returning adult salmon was also lacking. The area had also been cut off from its floodplain, and therefore, it conveyed water during high flows very fast, which was effectively flushing the fish out of the system."

Another important consideration was that the riprap installed by the Corps was having an impact on the levee on the opposite bank of the river where erosion had also started to occur. Behind the levee was another pond that sat beside an old mill site. There was concern that the water from this other pond was contaminated by pollutants left over from the mill, and that, if the bank collapsed and the levee was breached during a flood, those pollutants would be released into the water.

Funding for the installation of the logjams was provided by the Salmon Recovery Funding Board (SRFB), which gives money to a number of different organizations throughout Washington State for the restoration of salmon fish habitat. The South Puget Sound Salmon Enhancement Group, one of the groups that received money from the SRFB, then contracted with Herrera to have the logjams installed in 2005.

The initial funding provided by the Salmon Enhancement Group allowed for the removal of the riprap along that section of the river and the construction of 11 logjams. The logjams were modeled in detail at the Herrera offices, and then meticulously constructed on site.

"We needed to figure out what we could do to help fix the riverbank and change the flow characteristics of the river without accelerating flow through the reach," said Ian Mostrenko, a Civil and Environmental Engineer for Herrera. "We looked at potential hydraulic effects, calculated potential scouring, and determined how big the structures needed to be to accomplish our goal. Typically, natural logjams are stabilized by very large pieces of wood. We couldn't get natural 36-inch diameter, 120-foot long logs to the site, so we had to simulate that stability in other ways. In this case, we used a combination of vertical log pile structures and gravity structures. We put in vertical log piles for lateral stability, and then we built what are called gravity structures, which hold the structures in place through their height and weight."

The logs comprising the base of the logjam structures are driven deep into the riverbank, some as much as 15-30 feet in depth. A criss-crossed pattern of logs forms the core, which is likened to that of an elevator shaft. The logs interlock in place underground, lending the entire structure strength. The outer face of the jams extend into the river approximately 10-15 feet, creating the roughness elements necessary to not only slow the river flow down, but preserve the river banks from erosion, and form the pools that establish vital fish habitat.

While vegetation was not included in the original budget for the logjam construction, the Salmon Enhancement Group chose to address that issue on its own. In collaboration with the town of Eatonville, as well as the Nisqually Indian Tribe (who are involved with the project as stakeholders and eager participants,) they utilized volunteers and initiated a vegetation planting program on the logjam sites.

"We propose planting as an important component to the process," said Carrasquero. "You want that root cohesion to be a structural element of the logjam as well as the river banks. It's not ornamental. It will also provide habitat. From the restoration perspective, and the structural perspective, we see that as a critical element of the stability of the structures."

During the November 2006 flood (which was listed as a 25-year event) the sites suffered no damage, and no logjams were lost to high water. Additionally, the jams performed their intended function of providing protection, and no evidence of erosion was reported on either bank of the river.

"We needed to figure out what we could do to help fix the riverbank and change the flow characteristics of the river without accelerating flow through the reach." - Ian Mostrenko

The complexity added by the logjams is important for slowing down water flow on the river.

The pools established behind each jam provide much needed habitat and refuge for migrating fish.

The installation of the original 11 logjams, which covered three reaches of the river, totaled approximately $400,000. The logjams have proven so successful that the Salmon Enhancement Group contracted with Herrera for the construction of two additional jams, bringing the number of Herrera-designed structures on the Mashel to 13.

In the year since the logjams have been in place, a three-fold increase in salmon numbers has been observed. The South Puget Sound Salmon Enhancement Group has performed snorkeling surveys to monitor fish utilization of the river. Data from these tests demonstrates that there is considerably less usage by fish in riprapped sections of the river, compared to banks that have been treated with wood.

"Obviously, development is going to continue," said Carrasquero, "but it can be done in a way that's restorative of habitat functions so that it can be sustainable. I think this type of technique is demonstrative of that. In a situation where you have constraints; infrastructure to be protected, a major transportation thoroughfare to consider, a recreational area that has to be maintained, you have to come up with concepts that will meet all those expectations. I think, so far, that riprap has demonstrated that it can't do all that. We live in a time in society where people have really started to care more about the environment. Right now, our water is one of our most important resources, and we need to protect it. I think this type of natural approach is more protective of that important resource."

Herrera Environmental Consultant employees Leonard Ballek, Jose Carrasquero, Ian Mostrenko and Chris Brummer stand firmly behind (and on) their design.

Burley Creek Brush Mattress:
Natural Armor Protects Bank in Mason County

In October of 2006, a property owner along Burley Creek contacted the Kitsap County Conservation District for assistance. The landowner was dealing with a stream that was eroding his backyard. When the embankment adjacent to his shed began to fail, the landowner sought outside help.

Upon evaluation of the site, Rich Geiger, District Engineer for Mason Conservation District, identified the site's significant problem areas. Although Burley Creek is a small system, its alluvial soils easily erode, making it a significant cause for concern.

"There were two issues," said Geiger. "First was the severity of the bend. Second was the ease at which these soils were being eroded. They had no internal strength."

Because coho salmon utilize this section of Burley Creek for spawning, choosing an embankment stabilization method was a complex matter. In addition, the site required immediate management. However, the embankment failure occurred in the Fall, which is spawning season for coho salmon. At that time of year, it is almost impossible to install stabilization measures without negatively affecting fish habitat.

Geiger's solution was to design a brush mattress along 77 feet of the creek. The mattress was built by tying 6-foot long Douglas fir and Grand fir tree tops to 4-foot long, 2-inch by 2-inch cedar stakes, driven in a 1-foot by 2-foot pattern into the stream bank. The tree tops are placed with the butt upstream, with each piece tied to at least three separate stakes, and shingled so the upstream tree overlaps two-thirds

Rich Geiger standing by the brush mattress as it develops.

of the downstream tree. After placement, additional living tree stakes are driven through the brush mattress to promote root growth for soil retention. In this case, a natural fiber geotextile was placed against the bare soils, and the stakes were driven through the fabric for additional soil retention. As the structure is composed entirely of natural materials, it is much more expedient to pass through the permitting process than a hard-armoring embankment stabilization project.

"It was during a period when the Fish and Wildlife Department would normally not allow you to do any kind of work in this stream," said Geiger. "However, these types of structures can be installed with just about zero sedimentation. This qualified us for the streamlined Hydraulic Project Approval, which takes a much shorter time to permit, and eliminates the

The eroding property prior to the start of the project.

Construction of the brush mattress underway.

requirement to get local permits. Since the structure is 100-percent wood, the Corp of Engineers does not consider it fill and therefore they don't require a permit. If we had used more traditional techniques, we would have had to wait for permitting."

Geiger explained that the brush mattress technique can be adapted to the specific water velocities at alternate sites.

"You can vary the strength of this based on the length and diameter of the stakes and the tensile strength of the rope used to tie down the trees," said Geiger. "You then determine how much shear stress this installation will be able to resist based on those parameters."

"This is a very easy armor to install, and in short order you can have an area protected." -Rich Geiger

Four months after it was installed, the brush mattress structure at Burley Creek withstood the February 2007 100-year-flood, suffering minimal damage in the event.

In sensitive ecosystems, when emergency management is needed for stream bank erosion control, brush mattresses can inhibit erosion without threatening habitat and requiring costly mitigation measures at a later time. Installing the brush mattress does not significantly disturb fish spawning habitat and once installed, the structure provides complex habitat for fish and other aquatic species.

Cedar stakes driven into the creek bank provide additional soil retention.

The added vegetation to the creek provides habitat and cover for fish.

"The reason that we are allowed to do this work is that Washington State Fish and Wildlife considers it an enhancement to the stream," said Geiger. "It simulates a heavily vegetated stream bank. Fish just love it. We've actually seen fish using it as we are installing it. They get right in there and use it for cover and so forth. It was pretty surprising."

The average longevity for brush mattresses is yet to be determined. Even though the Kitsap County Conservation District originally installed these structures as a temporary measure, many of the original structures installed over four years ago are still functioning today. The key to the brush mattress' long term success is to plant through the stakes with vegetation.

Characteristic of bioengineering techniques that work with nature, the brush mattress will completely biodegrade and integrate into its surroundings. The planted vegetation strengthens the bank's soils after the mattress decomposes and provides the root system and brush necessary for future stabilization. Root mass, soil strengthening properties, hydraulic drag, and compatibility with the natural environment are all characteristics to consider when choosing vegetation to incorporate into a brush mattress installation.

"If you need to do something right away and you don't want to be facing a heavy mitigation requirement after the project is installed, then this is a good technique," said Geiger. "This is a very easy armor to install, and in short order you can have an area protected."

Everson Overflow:
Keeping Floodwaters in Check on the Nooksack River

One of the scour holes being stabilized by the Overflow project. Woody debris has begun to collect and will be incorporated into the riverbank.

The Everson Overflow, located outside the town of Everson in Whatcom County, Washington, has wide-reaching affects during high water events. The overflow is a high ground divide situated between the Nooksack River Basin and the Fraser River Basin. During significant flood events at this site, water tends to overtop the right bank of the Nooksack River and spill into the Everson Overflow. It can then surge into the Johnson Creek floodplain, flowing north, and ultimately reaching the Fraser River Basin in British Columbia, Canada. In the aftermath of one such occurrence in 1990, the Trans-Canada highway was closed for several days and millions of dollars of damage occurred. To address this trans-boundary flooding issue, an international taskforce assembled consisting of a number of agencies and technical experts from both Canada and the U.S.

Recently, several flood events occurred in Whatcom County that necessitated emergency management measures along the Everson Overflow. To forestall another disaster, the County, from 2003 to 2006, implemented four temporary rock riprap projects stabilizing two large scour holes within the project reach. In 2006, the County was permitted to construct a permanent bank stabilization design. In accordance with the Lower Nooksack River Flood Hazard Management Plan, which recommends protocols for flood management problems pertinent to the Everson Overflow, the County's objective was to sustain the Nooksack River's current bank elevations along the Everson Overflow.

"Our management approach now is to maintain the existing geometry," said James Lee an engineer with Whatcom County's Public Works Department. "We do not want to increase or decrease water flow over the bank, we just want to make the banks as stable as possible. By lowering or raising this bank elevation you alter how much flow leaves the Nooksack River Basin and heads north, ultimately reaching the Fraser River Basin in British Columbia during a significant flood event. By maintaining the existing bank elevations we are not changing this dynamic, known as the Everson Overflow."

Whatcom County's engineers designed a bank stabilization project with the intent of halting the chronic failure occurring along 1400 feet of the lower main stem Nooksack's right bank. The project was initially funded through the Whatcom Flood Control Zone District and the local Sumas-Nooksack-Everson River Subzone. Additional grant funding was later made available through the Federal Emergency Management Agency's (FEMA) public assistance program.

The project involved a combination of hard and soft armoring measures focused on halting further erosion of the scour holes, securing the embankment's toe, and stabilizing the slope. Providing for fish habitat was integral to both the design and the permitting process.

"The lower main stem Nooksack is an important river for a number of species," said Lee. "It is a migratory reach for Chinook and coho salmon, as well as steelhead trout. Bull trout, which are listed under the

The timber piling structures capture woody debris, which provides roughness to the river, and ultimately establishes additional habitat.

Endangered Species Act (ESA), can also be using it anytime of year in their different life stages, and it is used by Pink salmon in odd number years."

The county placed timber piling structures in the outside edge of the pools created by the two main scour holes. The decision to keep the two large scour holes along the embankment's edge is a primary benefit for fish. The scallop-shaped holes interrupt the linearity of the bank, creating irregularities perfect for fish habitat.

"The fisheries biologists don't want to see a straight smooth bank," said Lee. "Those irregularities are areas of slack-water back currents where the fish can go to get out of the main current."

The piling structures further enhance the habitat complexity which shelters the fish and stabilizes the river channel during large flows. In addition, the pilings recruit debris flowing through the channel during high water events.

"In terms of the bank stabilization project, the timber pilings are a stand-alone component," said Lee. "This means that if some of the timber piling structures are damaged, the integrity of the entire bank stabilization design is not compromised. At the same time, there are bank stability benefits provided by these structures. They provide an incredible amount of roughness along the portions of the riverbank where they are located. This slows the water along the bank behind them, promoting deposition and the establishment of vegetation, which helps to further stabilize these areas."

Along the linear portions of the embankment, the county laid large limestone rock up to the ordinary high water mark. Seventy-five pieces of large woody debris were then placed along the project length with their root wads facing outward toward the flow. The debris provides asymmetry to the otherwise straight-edged sections of the channel, and the root wads create scour that diverts energy away from the toe, thus decreasing the likelihood that the rock toe will fail.

The County reconstructed the slope of the upper bank with coir fabric, soil lifts, and live willow cuttings.

"The fisheries biologists don't want to see a straight smooth bank. Those irregularities are areas of slack water back currents where the fish can go to get out of the main current." - James Lee

"Using three-quarter-inch plywood that was eight feet long and 12 inches high, we built forms to aid in the construction of over a couple miles of soil lifts," said Lee. "Basically, we laid down the coir fabric, planted the willow cuttings, and placed the dirt. The wooden form provided something for the dirt to push up against as you ran over it with the walk-behind compactor. Otherwise, if you just simply had coir fabric holding back the soil when you put the compactor on it, the fabric would bulge out and likely rupture. The forms allowed us to build the soil lifts in a uniform manner. As the crews got proficient, we started to make excellent production numbers per day. It really worked well."

Because the coir fabric eventually decays, the live stakes are the source of long-term stability for the slope. For the Everson Overflow project, the Whatcom County Public Works Department planted 10,000 thriving willow cuttings. In addition, a twenty-foot wide buffer was designated along the top length of the project. The buffer is planted with a mix of native tree species such as cedar, fir and alder, providing a great improvement to this section of the bank which had previously been overgrown with an invasive, non-native blackberry species.

"Engineers would be well-served to come out and look at some of these projects," said Lee. "I've stood out here at flood flows and seen the ferocity of the flows and the amount of water and the debris that comes down the system. When the water recedes and you see that the project has held up well, it is solid evidence that these techniques can work if designed and built properly. People need to keep their minds open. It does what we need from the flood hazard perspective, but it also goes further to benefit the salmon recovery effort."

Coir fabric covers the upper bank.

Hiddendale:
Combining Wood and Rock to Protect Property

In Quilcene, Washington, the small community of Hiddendale sits beside the Big Quilcene River. Development of Hiddendale began in the 1960s, and to protect the houses under construction, the developer built a dike several hundred yards long using material from the river. Immediately, problems began when flooding occurred because the material used to create the dike was not strong enough to form an effective barrier against rising water. Within a short time, the dike had begun to erode.

In 1996, engineers from Agua Tierra Environmental Engineering were looking for an area to conduct a riparian demonstration project utilizing bio-engineering. The community of Hiddendale was chosen, as the dike had reached a critical point of potential failure. Portions of it had actually disappeared due to chronic erosion from periodic high water on the Big Quilcene, and several homes were threatened.

"The first step was to pull the dike back about 40 feet and make a little more room for the river to occupy," said Al Latham, District Manager for the Jefferson County Conservation District. "They then installed three rock groins into the river along a 200- foot section of the Hiddendale riverbank, the outer edges of which were approximately at the edge of the prior levee's location. Then the entire area was heavily planted with willows and other vegetation."

Downed trees claimed by the Forest Service provide the skeleton for the rock groin structure.

The rock groins were carefully designed with several considerations in mind. Calculations were taken into account for such factors as the river's width, water flow during average and flood stages, as well as impact of the structures to the overall area.

The first step in installing the groins involved temporarily blocking the river from entering the construction site. Since the project was undertaken while the river was at a seasonally reduced level, only a small area had to be coffered off with sandbags. Once the construction site was secured, three trenches extending 25 feet back into the bank were dug, and tapered down into the river channel. Multi-sized rocks similar to that used in riprap design were then carefully layered into the trenches.

Planted willows, dogwoods, conifers and other trees will create a mat of roots to help stabilize the riverbank.

Al Latham stands on top of one the groins extended into the river.

The National Forest Service donated almost forty 25 to 30-foot long logs, several with root wads still attached, which the Forest Service retrieved from areas of blow-down during previous storms. The logs were laid within the trenches, several logs to a trench, with the root wads sticking out into the river. To lock the structures in place, the logs were integrated with the rocks. Additional rocks were then piled on top of the logs, giving the structures strength and stability.

Hundreds of branch cuttings from several different species of local trees were laid within the trenches before they were filled in with the final layer of rocks, and then topped with soil. The intertwining of the various root systems provided by the cuttings as they grow plays an integral part in the success of the project.

"We planted a lot of willow in there," said Latham. "Along with red ochre dogwood, alder, some conifers, as well as Douglas firs and cedars. By the time the logs decay, which is a long way off, there will be such a mat of roots from the vegetation that it's going to make the banks really stable."

By the time the logs decay, which is a long way off, there will be such a mat of roots from the vegetation that it's going to make the banks really stable."
- Al Latham

The Big Quilcene River serves as migration reach and spawning ground for several species of fish, including coho, Chinook and King salmon, as well as steelhead and cutthroat trout. Prior to the setback of the dike and the introduction of the rock groins to the river, the channel was essentially a straight passage with a minimal amount of woody debris, offering limited habitat diversity for migrating fish. With the rock groins installed, root wads extended into the river and the vegetation established throughout the area, the habitat provided for the fish is far more extensive than ever before.

The Hiddendale bank stabilization project was funded through a $50,000 grant from Washington State's Flood Control Assistance Account Program, which provides money for a number of different flood control activities throughout the state. Additional assistance was made available by the Department of Natural Resource's Jobs for the Environment program, which provides funding to hire displaced logging professionals to perform restoration activities.

Since the introduction of the rock groins to the Hiddendale area 13 years ago, the Big Quilcene River has been subjected to several high water flood events. According to Latham, the groins have withstood the floods, sustaining no damage and no significant impact to their stability. They have also provided invaluable protection for migrating fish and, best of all, the properties once threatened by the river have remained completely safe.

"The typical approach before we did this would have been to line the banks with riprap, using the same size material we used in the groins," said Latham. "The thing is, when you go that way, currents accelerate along riprap, and you're just sending the problem downstream. You don't get any improved habitat or channel diversity. It's just a rock wall. With these three small groins, it didn't establish a big footprint, but it's really kept the thalweg, or the main part of the river, well out beyond the bank, preventing any further erosion. It also created all this habitat in between each groin. Now the bank has been stabilized as well or better than riprap ever could do it."

In the background stands one of the Hiddendale properties protected by the project.

Old Tarboo Road Bridge:
New Bridge Design Eliminates Flooding

Old Tarboo Road in Jefferson County, Washington crosses Tarboo Creek, which is a small, steady stream running from its spring-fed headwaters in the hills east of the Olympic Mountains down to Tarboo Bay. The stream is used for migration and spawning by coho and fall chum salmon, as well as steelhead, sea run and resident cutthroat trout. Juvenile summer chum salmon and Chinook salmon rear in the estuary of Tarboo-Dabob Bay about two miles downstream. Three of these species; steelhead trout, summer chum and Chinook salmon are listed as threatened under the Endangered Species Act (ESA).

The county road was originally built in the 1890s, and numerous forms of crossings have been utilized over the years, including wooden bridges and various forms of culverts. In the 1970s, a six-foot wide, 40-foot long culvert was installed under the road. During especially high water events, such as the flood of 1996, water would back up and overtop the creek banks and cover the road. Directly downstream of the culvert, the creek flowed into a straight ditch approximately eight-feet deep with steep banks. Over the years, this led to problems of bank erosion and flooding as well as impeding travel of some of the weaker species of fish that could not traverse the culvert.

"There was riprap on either end of the culvert, as well as some downstream where the channel had eroded the banks," said Peter Bahls, an aquatic ecologist, fish biologist and Director of the Northwest Watershed Institute. "When a large amount of water goes through a culvert, it acts as a fire hose, and it can cause a lot of impacts further downstream as well."

In 2004 the Northwest Watershed Institute, in partnership with Jefferson County, pulled the culvert from under the road and built a bridge over Old Tarboo Creek. Removing the culvert opened up passage for the creek, significantly reducing the threat of ongoing erosion while also reestablishing a migration route for fish that had been cut-off from traditional spawning waters for over 20 years. An added benefit of the project was the reconnection of the creek to the local floodplain.

During construction of the bridge, the designers took the opportunity to lower the gradient of the creek, reducing it to less than one-half a percent under the bridge for a length of approximately 100 feet. This had the effect of slowing water flow throughout the reach, further reducing erosion and making it easier for migrating fish to traverse.

"When a large amount of water goes through a culvert, it acts as a fire hose, and it can cause a lot of impacts further downstream as well." -Peter Bahls

Wood positioned downstream of the bridge slows water flow and provides habitat for fish and other wildlife.

Coir matting and planted vegetation stabilize the creek banks under the bridge.

The bridge was installed with the use of concrete pilings driven approximately 20 feet into the ground, removing the threat of instability due to possible undercutting. Though the channel width was only 13 feet at its maximum, they designed the bridge to span over 40 feet in length.

The extra wide design of the bridge ensures adequate room for water flow during flood conditions.

"The main mistake in bridge construction, and the reason you often have problems with bridges and flooding is because the span is not long enough," said Bahls. "They don't leave enough room for flood and scour flow. We made sure our bridge was long enough to handle the flow spreading out under the bridge, without causing scour along the banks."

Bahls also stated that, as a rough rule of thumb, the width of the floodplain under the bridge (including the stream channel,) should be at least twice the bankfull channel width of the stream from bank to bank. At the Old Tarboo Bridge, the bankfull channel is approximately 12 feet wide and the total floodplain width was designed to be approximately 20 feet. With the addition of sloping banks up to the bridge this required a 40-foot long bridge.

A floodplain bench was built under the bridge on each side of the creek and extending 30 feet up and downstream, starting with large, rounded river rock laid in a single row along each stream bank. Soil was then infilled behind the rock for the floodplain bench. The rock was laid atop a layer of heavy coir fabric which was then pulled over the rock, wrapping around it and securing it to the bank. The coir creates a layer of strengthening material to hold the bank together and prevent further erosion.

"The rock is holding down the coir, and providing stabilization from below," said Bahls. "And now you can't even see the rock because the floodplain is actually acting the way it's supposed to, and has started to accumulate sediment."

Another portion of the bank stabilization and habitat complexity involved the addition of wood in the creek immediately past the bridge, as well as further downstream. The wood establishes important habitat for fish traversing the stream, and causes flow to slow down considerably during periods of high water, further adding to the protection against erosion.

"All the wood is put in naturally, with natural log placements," said Bahls. "Along with specifically placing it, we bury the wood from one-half to two-thirds of its length into the banks. A lot of the wood that is seen in this area is actually buried way back into the earth. We use different sizes, different types of wood and different positioning to secure the logs."

Planting of native vegetation also comprises an important part of the bank stabilization, as active and healthy root systems lend strength to the creek banks.

"We're starting to get some alder and willow growth in the riparian area," said Bahls. "This will get more shaded as the trees grow in, and we're hoping that they'll take over and shade out some of the non-native, invasive species of vegetation that often move into any new restoration site."

Interestingly, the land around Old Tarboo Road had been purchased for conservation use by famed ecologist Aldo Leopold's granddaughter, Susan, and her husband, Scott Freeman. According to Bahls, the Freemans worked with Jefferson County vigorously to reestablish the area ecologically.

Many of the logs are actually buried in the banks.

"They've been great, active participants in the restoration," said Bahls. "They do a lot of the planting and cutting back of invasive plants, and they've worked with us the entire time of the project."

The entire area is now covered by a conservation easement held by the Jefferson Land Trust, which protects the land from any form of development or use other than as an ecological preserve.

In addition to funding from Jefferson County and the Northwest Watershed Institute, money for the project was also provided by the National Fish & Wildlife Foundation, the National Oceanic and Atmospheric Administration (NOAA) and the Community-based Restoration Program. The cost of the installation of the bridge totaled approximately $150,000, while the downstream re-meander came to an additional $100,000, bringing the total cost of the Old Tarboo Road Bridge and stream restoration project to $250,000.

When speaking about the advantages of utilizing more naturalistic techniques than riprap and hard armoring, Bahls was definitive in his preference.

"It can be done," he said. "If you design the bridge right, holistically in context of the stream reach, get the gradient of the stream correct, and make the bridge span long enough, you don't need to worry about slapping a bunch of riprap on. In fact, riprap is counter-productive because not only does it not protect the banks over a long period, but it will ultimately fall into the creek and cause problems behind it. The riprap also constricts your channel, so you end up with less floodway under the bridge for the water to flow through. If you can take pressure off your banks by leaving more floodway and reducing the gradient under the bridge a little, adding wood downstream and stabilizing the banks with planting, that's better for your stream in the long run. We've had some major floods here in the past three years, and because of this design, we've had no bank erosion near the bridge, and the flood flows have stayed safely under the bridge instead of flowing over the road."

The entire area is protected as an ecological preserve.

Peter Bahls, director of the Northwest Watershed Institute.

Black Lake Drainage Ditch:
Live Crib Wall Increases Options for City of Olympia

In 2004, Craig Tosomeen, an engineer with the City of Olympia, faced the challenge of stabilizing eroding stream embankments on Percival Creek at the Black Lake Drainage Ditch on RW Johnson Drive. The culvert running under the road was rated as the number one fish barrier in Thurston County. A four-foot drop in stream grade prevented Endangered Species Act (ESA) listed fish, such as Chinook and coho salmon, as well as other protected species like cutthroat trout, from migrating through the ditch. The decision was made to replace the original culvert with a bottomless arch culvert similar to a bridge. Tosomeen was tasked with designing a fish-friendly plan for controlling erosion on the vertical earthen bank. both up and downstream of the removed culvert.

Craig Tosomeen beside the Black Lake Drainage Ditch.

Black Lake Drainage Ditch is a human-made channel characterized by steep embankments and high stream velocities. Because of this, the option of setting the bank back to lower the slope gradient was not available. To meet the recommended 2:1 to 3:1 ratio for bank setback, the 20-foot vertical embankment on RW Johnson Drive would have to be moved back 40 to 60 feet. Not only would this action have caused difficult "right of way" issues, but it would have also required the removal of a large stand of Douglas fir trees.

"There was no point making the culvert for fish passage if that habitat doesn't remain," Tosomeen commented.

Preserving the riparian shading provided by the Douglas firs benefited fish habitat, and was key to facilitating fish passage.

Tosomeen considered several techniques to halt embankment erosion, including sheet pile weirs, a concrete wall, and a live crib wall. Experience, however, had taught Tosomeen that streams can erode concrete structures.

"I've seen a lot of concrete-lined ditch failures," said Tosomeen. "Once the water starts to get underneath the structure, concrete has nothing it can do but break and become a further obstruction, diverting more water into where it shouldn't be going."

Unlike the other options considered, live crib walls meet Washington State Department of Fish and Wildlife's fish habitat criteria. They also provide structural support to sheer embankments, and with maturation they ecologically integrate into their surroundings. Live crib walls are constructed with interlocking, untreated logs and live stems. The logs are anchored into the slope, forming the wall, and vegetation is initially used to tie the logs together.

Long-term stability to the slope is further developed with the vegetation's root growth. With time, the logs naturally degrade and the vegetation becomes the structure itself.

Dogwood and willows were the primary types of vegetation used in the wall design. Willows are hardy and thrive well in harsh, wet environments. Traditional live crib walls are built as gravity mass walls, but because of the embankment's 20-foot height, Tosomeen designed this structure as a retaining wall. Steel anchors bolt the log wall into the vertical embankment and provide security to the wall until the vegetation is established. In addition, the most critical point at the bottom of the live crib wall is secured with a solid riprap toe. To remedy the stream's four-foot drop in grade log weirs were placed in 6-inch increments over the project length.

Overexposure to sunlight can inhibit the establishment of a live crib wall. The vegetation needs plenty of shading to thrive. To ensure that the crib wall does not dry out, it is also important to choose appropriate backfill.

"If you pick too granular of a soil, the wall dries out and the stakes die," said Tosomeen. "Sun exposure is critical. You might have to consider watering if you have a lot of sun exposure and/or you use very granular backfill. One section of our wall got a lot of

"Once the water starts to get underneath the structure, concrete has nothing it can do but break and become a further obstruction, diverting more water into where it shouldn't be going."
-Craig Tosomeen

The restructured channel is now far easier for fish to traverse during migration.

The crib wall will overgrow with vegetation, which will ultimately become the structure itself when the logs finally decay.

sun exposure. It took a lot longer to establish than the section that was shaded by the big trees and not facing direct sunlight. That section had perfect establishment straight away."

The success of the project has been far-reaching. The live crib wall has stabilized the sheer embankments both up and downstream of the removed culvert. Over a mile of previously blocked fish passage leading into Black Lake, (the largest lake in the Olympia area,) is now accessible to fish. In addition, the site and adjacent walking trails have become a community gathering place. The City of Olympia has taken advantage of this educational environment and incorporated other ecologically friendly structures. Porous concrete, which allows rain water to absorb directly into the earth and improves water quality of streams by reducing storm water runoff, has been used to create bicycle lanes and sidewalks in the grounds surrounding the site.

Structural revetments require periodic inspections to ensure that they are working. A live crib wall engineered with nature becomes part of the natural processes and does not demand the same amount of maintenance. For erosion to destroy a live crib wall, water must undermine the entire structure. As the live crib wall develops, it becomes a natural part of the riparian corridor.

"The ability for nature to heal itself, to take up the long term maintenance for us is huge," said Tosomeen. "You know if the design isn't perfect, nature will tell you. It is very unforgiving, so to be able to make up for that with a structure that can be forgiving and can accommodate and grow and adapt to the changing environmental conditions is really the only way to go."

Little Washougal Creek:
Woody Debris Catcher Prevents Erosion and Protects Bridge

The Lower Columbia Fish Enhancement Group (LCFEG) is a nonprofit organization that receives funding for stream restoration projects from the Washington State Recreation and Conservation Office Salmon Recovery Board. The LCFEG works closely with local communities on habitat restoration within Lower Columbia's watersheds. When a local landowner on the Little Washougal Creek in Clark County sought counsel from the LCFEG about a land erosion problem, a collaborative opportunity arose.

In October 2003, the Little Washougal began encroaching upon a bridge that provided access to six properties. Erosion along the approach to the bridge endangered residents' access to their homes. Riprap, which was placed upstream of the bridge in the aftermath of a large flood event in 1996, accelerated the erosion threatening the bridge. To amend the problem, the LCFEG designed and installed a woody debris catcher. The bank stabilization structure successfully diverted the Little Washougal Creek away from the bridge, preventing further embankment erosion along the bridge's approach and mitigating future damage to the bridge.

The success of a woody debris catcher largely depends on how it is anchored and how the surrounding embankment is vegetated. At this particular site, the work crew laced, and then bolted, a large number of logs together. At points where two logs crossed, steel bolts were drilled into the wood, and the upper layers of logs were then bolted to a log frame which was buried in the ground.

Debris catchers are a practical choice in hydraulic systems that carry a large abundance of wood.

"A rock-based design is inappropriate for river systems in Western Washington that transport large amounts of woody debris," said Tony Meyer, Executive Director for the LCFEG. "Often, as debris comes downstream it will hit the stacked rocks, knocking them off, and destroying the shape of the vane."

Re-vegetation is the key to the longevity of any woody debris project aimed at bank stabilization. Ultimately, as the wood decays, the vegetative root system replaces its function by providing cohesion to the stream bank. To ensure the success of the vegetation stage of their projects, the LCFEG follows the protocols of Jeff Whittler, an Environmental Services Manager with Clark County Public Utilities District.

The porous design of the debris catcher allows fish to swim through the structure unimpeded.

Steel bolts lock the log frames together providing stability and strength to the structure.

"Whittler's goal is to close the canopy within three years," Meyer commented. "To close the canopy you have to have your spacing very close together, but once the sunlight is taken out from the ground, nothing else can grow. The key is to go in there, maximize the native species, and wipe out the nonnative species. Give those native species time to get up and close the canopy."

In addition to providing bank stability, the woody debris catcher impedes erosion by slowing down the creek-water's velocity. This is accomplished by reconnecting the watercourse to its adjacent flood plain. During the first major flood event, as a result of the debris catcher's installation, the river was redirected onto the opposite side of a gravel point bar, giving the Little Washougal access to side channels that had previously dried up.

"Because the structure is porous, water is able to flow underneath it, maximizing the ability for fish and aquatic organisms to live inside the structure itself and be secure from predation." - Tony Meyer

Essentially, this watercourse shift reduced the power of the stream by taking it out of a confined environment and allowing it to spread out among many smaller courses.

"As soon as the river exceeds that bankfull height and spreads out into the flood plain, the excess water has no velocity, so it doesn't harm anything," said Meyer. "When the river moved onto the other side of the gravel bar, it increased the interval in which it will go out into the flood plain and take the energy out of the system."

Creating access for the Little Washougal to disperse into side channels has demonstrated the benefits of the bioengineered debris catcher to landowners. The river is no longer threatening the bridge and the access to the landowner's property is protected. During periods of high water, the river flows into side channels and the concentrated destructive energy of the system is dissipated. This increase in off-channel area has created fish-rearing habitat. The nutrients deposited during high flows have stimulated the growth of plants and aquatic organisms.

The woody debris catcher also enhances fish habitat by providing shelter. As the debris catcher recruits wood from mature trees, complex habitat for fish and other aquatic organisms develops. In fact, the catcher provides ecological benefits that exceed State permitting requirements. The significance of this is that the Little Washougal provides spawning habitat for winter steelhead trout, coho and Chinook salmon, which are all listed under the Endangered Species Act (ESA).

"A woody debris catcher is a very porous structure," explained Meyer. "When the current runs into the structure, its debris load gets trapped. Because the structure is porous, water is able to flow underneath it, maximizing the ability for fish and aquatic organisms to live inside the structure itself and be secure from predation."

In November 2006, the biggest flood in the area's recent history hit the Little Washougal and the site was subjected to severe high water conditions. Throughout the event, the woody debris catcher remained stable, and no damage was experienced at the site. The watercourse continued to flow on the opposite side of the gravel point bar away from the approach to the bridge. As a result, residents were able to easily cross the bridge and access their homes.

Tony Meyer, executive director for the Lower Columbia Fish Enhancement Group.

Schneider Creek:
Adding Wood to Water Wins Over Rock

Wood added to the banks of Schneider Creek slows water flow and improves habitat diversity.

On Schneider Creek in Thurston County, Washington, landowner Sonny Bridges' property has been threatened with increasing erosion. Since buying the property several years ago, Mr. Bridges watched his land steadily erode at a rate of approximately 5 feet per year. In total, an estimated 2000-square feet of the Bridges' property has been lost along the banks of the creek.

Growing concerned with the constant loss of his property, Mr. Bridges contacted the South Puget Sound Salmon Enhancement Group for assistance. Schneider Creek serves as a migratory channel for at least five species of fish, including chum, Chinook and coho salmon, as well as steelhead and cutthroat trout, which made the problem and its solution very pertinent to the Salmon Enhancement Group.

"This is a very significant salmon spawning stream," said Mike Kuttel Jr., a Habitat Specialist for the Thurston Conservation District. "It flows into Totten Inlet, near the mouth of Kennedy Creek, which is one of the biggest chum salmon spawning streams in the area. Also, both the Chinook salmon and steelhead trout are listed under the Endangered Species Act (ESA), making their protection critical."

The Salmon Enhancement Group partnered with the Thurston Conservation District to initiate a project to halt the erosion of the Bridges' property, while creating habitat for migrating fish. Mr. Bridges did not want this to be done through the use of hard armoring, and requested that the project remain as true to natural processes as possible.

Anchor Environmental, LLC was the company contracted by the Salmon Enhancement Group to design the project. Pat Powers, the engineer for Anchor, implemented two of the recommended techniques from Washington State's Integrated Streambank Protection

Mike Kuttel surveys the successfully completed project on the Bridges' property.

Guidelines to stabilize the Bridges' creek bank. The project was approached almost as a case study, with both techniques being examined for their feasibility.

On the upper portion of the creek, they installed several engineered woody debris logjams. Anchored to the creek bank, the jams are extended into the water, creating roughness elements which reduce Schneider Creek's flow speeds along this reach. The reduced water flow eases the pressure on impacted banks, significantly cutting down on erosion and protecting the Bridges' property.

"They use a vertical log that's sharpened like a pencil," said Kuttel. "They load the logs up and jackstraw them together. Then they take the sharpened log and drive it down into the bank through the middle of the other logs, pinning them all in place. Then they further secure the entire structure with rebar. It all worked very well."

In addition to preserving the bank integrity throughout the impacted area, the logjams also provide habitat for migrating fish. The introduction of the wood into the creek creates many areas for the fish to hide in and rest, as well as giving them protection from fast-moving floodwaters.

The second portion of the project involved the introduction of rock cobbling to the lower portion of the creek on the Bridges' property, which was intended to reduce the velocity of the water, while covering the

The entire bank is covered with willow cuttings for root strength.

The logjams are extended into the water providing needed roughness.

unprotected sediment that had been exposed by the constant erosion. Unfortunately, during the flooding of November 2006, the cobble was blown out by high, fast water, which continued the threat of further erosion.

To address the problem, instead of replacing the destroyed cobble with additional rock, it was decided to add several new logjams to the creek. In subsequent flood events, (specifically the high water of December 2007,) the logjams were completely successful and held the banks in place, while protecting migrating fish by slowing down the water flow throughout the stream.

"It's ultimately better that they switched to using all wood for this project," said Kuttel. "The logjams stabilize the toe of the bank and improve the in-stream habitat. There used to be just a vertical bank with no shade and no place for the fish to hide. Historically, armoring eroding banks with riprap (angular basalt rock) was the method-of-choice to stop bank erosion. Unfortunately, the rock gathers heat, reflecting it out into the water, which is really bad for the fish. Not to mention, there's no habitat diversity when you do it that way. The logjams used on this project provide habitat diversity and give fish many places to hide."

In addition to the introduction of logjams to Schneider Creek, the project design also called for a widespread series of plantings. Willow cuttings positioned throughout the bank area are taking root, and once grown to significant size, the root structures will lend the bank further strength and stability. The intent is to recreate a riparian zone along the bank, which has virtually ceased to exist due to the constant erosion.

Though it takes years for the plantings to grow, the designers prefer to use smaller willow cuttings, approximately 24-inches in height, to start. Once the willow tree roots have taken hold and begun to reinforce the strength of the bank, they will go back to the site to perform additional rooted plantings with conifer trees and other larger species to further the strengthening process.

"I know that some people like to go in right away and use the really big ball and burlap plants," said Kuttel. "The problem is they're so expensive in terms of transportation and equipment to get them in the ground. A lot of the time they can die because of the transplant shock. You can plant a lot of small trees and keep them in good shape for the same cost of one big tree. It may take longer for the small trees to grow and do what you need them to, but if that one big, expensive tree dies, you're basically out of all that money."

The Schneider Creek bank stabilization was funded by a grant of $20,000 provided by the National Fish & Wildlife Foundation. The wood for the logjams was provided by the contractor who performed the installations at no additional cost, and from donations by the Washington Department of Transportation, which considerably reduced the total cost of the project.

"The whole site is a lot more ecologically functional for fish and wildlife habitat now, not to mention the banks being protected" said Kuttel. "When you use plant materials, it actually slows the water down. When you armor a bank, it is protected from erosion, but the energy is often redirected to the opposite bank downstream, causing damage to someone else's property. Then the next landowner has to do it, and then the next, just to protect their property. When you use something like willow cuttings, the water just lays them down and the energy is dissipated instead of tearing the banks all apart."

The logs in the jams are secured to each other with rebar.

"When you armor a bank, it is protected from erosion, but often times the energy is redirected to the opposite bank downstream, causing damage to someone else's property." - Mike Kuttel Jr.

Conclusion

As the stories in this booklet illustrate, there are numerous options when it comes to the complex issues of riverbank stabilization. These examples merely scratch the surface, highlighting only some of the basic alternative measures successfully used. As technology advances, and our knowledge of the effects we have on our environment increases, it is inevitable that even more of these techniques will be discovered and improved upon and that the traditional approach of riprap or hard armoring a bank will no longer be the norm.

We tend to leave a large footprint in our interactions with our environment. As we manipulate and attempt to control the water we so love and depend upon, we need to look at the long-term effects we have on our immediate surroundings. Finding methods of restricting riverbank erosion while allowing natural processes to function normally is just one important step in achieving equilibrium with our environment and investing smartly for our future.

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ATTACHMENT C

SLOPE STABILIZATION

Advances in Geosynthetics Materials and Applications for Soil Reinforcement and Environmental Protection Works

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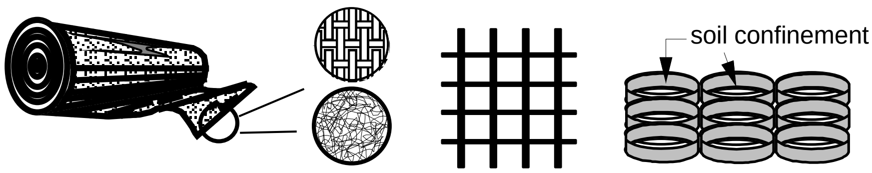
ABSTRACT

Geosynthetics have become well established construction materials for geotechnical and environmental applications in most parts of the world. Because they constitute manufactured materials, new products and applications are developed on a routine basis to provide solutions to routine and critical problems alike. Results from recent research and from monitoring of instrumented structures throughout the years have led to new design methods for different applications of geosynthetics. Because of the significant breath of geosynthetic applications, this paper focuses on recent advances on geosynthetics products, applications and design methodologies for reinforced soil and environmental protection works.

INTRODUCTION

Geosynthetics have been increasingly used in geotechnical and environmental engineering for the last 4 decades. Over the years, these products have helped designers and contractors to solve several types of engineering problems where the use of conventional construction materials would be restricted or considerably more expensive. There is a significant number of geosynthetic types and geosynthetic applications in geotechnical and environmental engineering. Due to space limitations, this paper will examine the advances on the use of these materials in reinforcement and in environmental protection.

Common types of geosynthetics used for soil reinforcement include geotextiles (particularly woven geotextiles), geogrids and geocells. Geotextiles (Figure 1a, Bathurst 2007) are continuous sheets of woven, nonwoven, knitted or stitch-bonded fibers or yarns. The sheets are flexible and permeable and generally have the appearance of a fabric. Geogrids have a uniformly distributed array of apertures between their longitudinal and transverse elements. These apertures allow direct contact between soil particles on either side of the sheet. Geocells are relatively thick, three-dimensional networks constructed from strips of polymeric sheet. The strips are joined together to form interconnected cells that are infilled with soil and sometimes concrete. In some cases 0.5 m to 1 m wide strips of polyolefin geogrids have been linked together with vertical polymeric rods used to form deep geocell layers called geomattresses.



(a) Geotextiles (b) Geogrids (c) Geocells

Figure 1: Geosynthetics commonly used for soil reinforcement (Bathurst 2007)

A wide variety of geosynthetics products can be used in environmental protection projects, including geomembranes, geosynthetic clay liners (GCL), geonets, geocomposites and geopipes. Geomembranes are continuous flexible sheets manufactured from one or more synthetic materials. They are relatively impermeable and are used as liners for fluid or gas containment and as vapour barriers. Geosynthetic clay liners (GCLs) are geocomposites that are prefabricated with a bentonite clay layer typically incorporated between a top and bottom geotextile layer or bonded to a geomembrane or single layer of geotextile. When hydrated they are effective as a barrier for liquid or gas and are commonly used in landfill liner applications often in conjunction with a geomembrane. Geonets are open grid-like materials formed by two sets of coarse, parallel, extruded polymeric strands intersecting at a constant acute angle. The network forms a sheet with in-plane porosity that is used to carry relatively large fluid or gas flows. Geocomposites are geosynthetics made from a combination of two or more geosynthetic types. Examples include: geotextile-geonet; geotextile-geogrid; geonet-geomembrane; or a geosynthetic clay liner (GCL). Geopipes are perforated or solid-wall polymeric pipes used for drainage of liquids or gas (including leachate or gas collection in landfill applications). In some cases, the perforated pipe is wrapped with a geotextile filter. Figure 2 presents schematically these products.

Because geosynthetics are manufactured materials, technological developments of the polymer and engineering plastics industries have been continuously incorporated in geosynthetics products, enhancing relevant engineering properties of these materials. Research results have also lead to the development of new and more powerful design and construction methods using geosynthetics. The combination of improved materials and design methods has made possible engineers to face challenges and to build structures under conditions that would be unthinkable in the past. This paper describes recent advances on geosynthetics and on the applications of these materials in soil reinforcement and in environmental protection projects.

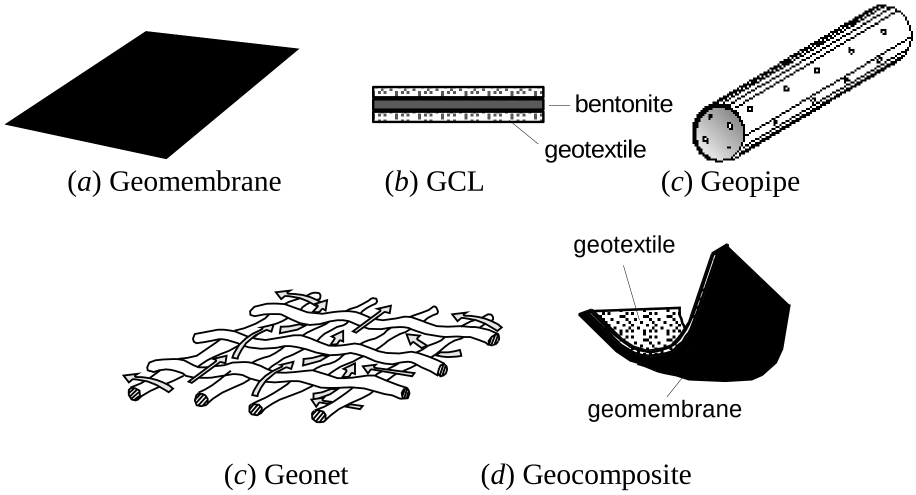


Figure 2: Schematic view of some typical geosynthetics used in environmental protection works (Bathurst 2007).

DEVELOPMENTS IN GEOSYNTHETICS MATERIALS TYPES AND APPLICATIONS

The axiom that there is nothing new under the sun regarding geosynthetics is simultaneously true and totally false. The truth is that the geotechnical problems that engineers use geosynthetics to solve are timeless: erosion, slope failure, poor bearing capacity etc. The products used to solve these problems could also be described as timeless as they derive from textile manufacturing techniques that date into antiquity. The falseness of this premise is revealed by the incremental advancements in the creation of geosynthetic solutions in the form of both product and geotechnical design. But what are the areas of incremental improvement in soil reinforcement and environmental applications? As the following capsules illustrate there is no end in sight for innovative application of geosynthetics.

For example, there are many developments in mechanically stabilized earth (MSE) walls and slopes and in basal stabilization. The MSE concept is essentially a uniaxial force problem and is served by the insertion of tensile members whose principal strength is uniaxial and that property is oriented to the expected forces of failure in the design. In 1993 a textile geogrid was employed using an ultra high strength polymer (the aramid known as Kevlar) to construct a road over karst terrain, as schematically shown in Figure 3. In 2001 a 15 meter wide sinkhole opened under the road which remained intact for more than one hour against a specification time of 15 minutes. Another textile geogrid application technology advance is the development of construction techniques that permit bridge abutments to be constructed where the sill beam rests directly on the GRS (geosynthetic reinforced soil) block while the GRS does not require a stiffening facing (Alexiew 2008). Textile geogrid reinforcement techniques are combined with other geosynthetic systems to build steep slopes on columns and piles, over geosynthetic encased stone columns and in piled embankments (Brokemper et al. 2006). Textile geogrid constructions mitigate landslides and debris flow and withstand storm surge exposure in a working platform. Yet another polymer, PVA, works in textile grid applications to withstand high alkali environments and especially the combination of lime and cement stabilizers and PVA grids in cohesive soils where there appears to be a synergistic effect resulting in higher strength and higher resistance to pullout failure (Aydogamus et al. 2006).

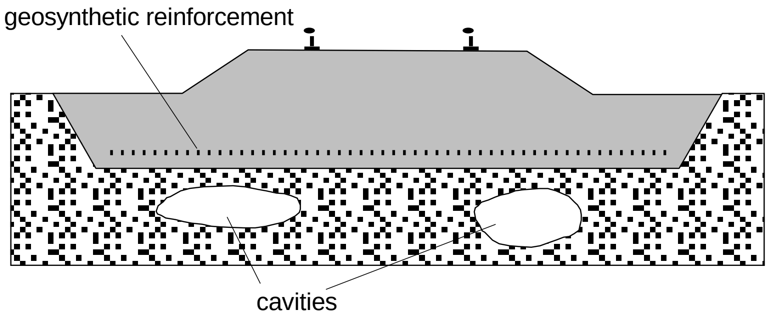


Figure 3: Reinforced embankment on unstable foundation soil.

Rigid grids have also experienced innovation with the development of new punching patterns that yield triangular shaped apertures after the stretching process. The new shape has several benefits in the product profile, rib thickness and in plane stiffness and this three dimensional structure is expected to offer improvement in confinement which will yield improved rut resistance and better load distribution (Tensar International 2008).

Soil reinforcement has seen the entry of a third type of geogrid, welded strapping (also described as strips or bars), which is rigid in structure. Produced in both polyester and polypropylene, the welded strapping grid is used in both uniaxial and biaxial applications. Properties of interest are strong junctions, excellent creep characteristics in the polyester form, and high chemical resistance. In the biaxial form two bars are employed in the cross machine direction giving a three dimensional structure to aid in confinement applications (Elias 2000).

Geogrids have been employed to resist or remediate reflective cracking in asphalt for many years (Fig. 4, Palmeira 2007). Nonetheless, innovation is present here in the continuing study and analysis of performance of these products. One claim is that bitumen coatings provide a superior bond to other polymers, enhancing grid performance in preventing crack propagation.

A three dimensional structure is a key to effective erosion control, what else is vegetation but a three dimensional structure that alters water flow characteristics? Efforts to impart three dimensional characteristics to erosion control products have been an important focus among manufacturers and one approach is embodied in the type of 3-D products developed by using combinations of yarns which have different shrinkage profiles. Products woven from these materials in two planes assume a three dimensional shape after exposure to heat in which some yarns contract in a controlled manner resulting in a three dimensional sheet (Propex 2007).

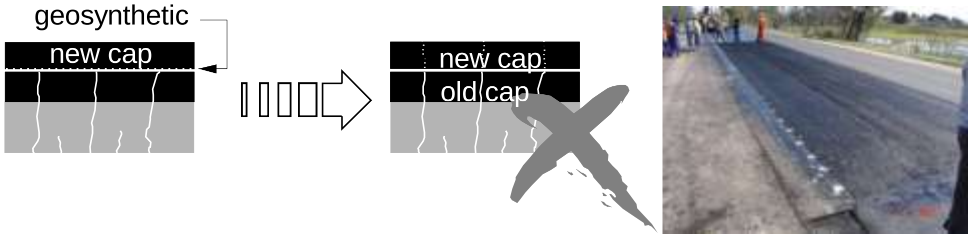


Figure 4: Geogrids to avoid reflective cracking in pavements (Palmeira 2007).

The three dimensional theme is carried forward in confinement applications by the development of three dimensional surfaces on geomembranes. Sliding failures, usually identified to occur at the interface between geomembrane and geotextile or geomembrane and soil, have been alleviated by the development of textured and embossed surfaces on geomembranes. Three dimensioned geomembranes, embossed surfaces for example, have consistent thickness, consistent asperity height and consistent properties and are easy to install and, most important, result in improved performance (better adhesion, better resistance to sliding) (Frobel 1996).

Electrokinetics and electroosmosis are techniques employed in manipulating pore pressure and plasticity indices of soils. Formerly hampered by difficulty in establishing suitable electrodes in soil structures, electrokinetics and eleectroosmosis are becoming viable technologies for soil reinforcement and environmental rehabilitation and geosynthetics are one of the means of introducing anodes and cathodes into a soil structure (Fig. 5), soil nailing is another. The concept of electrokinetics is the use of current to induce water flow. The technique can be used in environmental remediation wherein contaminants are recovered or removed from soil by causing groundwater to flow to a collection point. Anodes and cathodes are created from geosynthetics by using conductive materials such as carbon fiber, or by interlacing conductors (wire) in the textile. Other geosynthetic applications are mine tailing dewatering and sewage (perhaps contained in geotextile tubes) dewatering. Sports turf is managed by using current to draw off excess water, or by reversing polarity, delivering water to plant roots. The concepts of electrokinetics are applicable to slope stability, mechanically stabilized earth (walls), drainage and can result in cementation wherein ions precipitated from solution cement clays and the result is stiffer clays (Jones 2005).

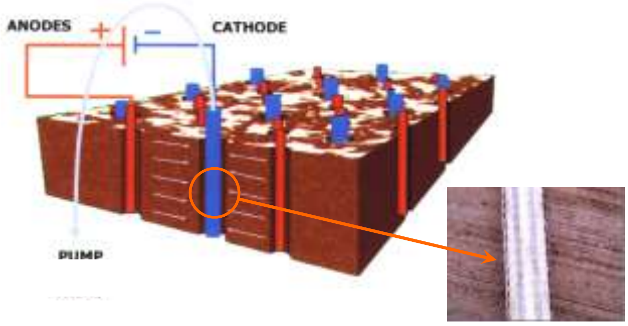


Figure 5: Electrokinetics geosynthetics for soft soil stabilisation (Jones et al. 2005).

Geocells have been used in innovative ways to stabilize aggregate while providing high volume drainage and working platform support. In an airport de-icing compound, the geocell confines the aggregate, improves the load capacity of the aggregate and the subgrade, contains large volumes of fluid in high volume events and drains fluid from the structure in a controlled manner. Another innovative use of geocells is as the facia on avalanche protection earthen mounds in Iceland (Bygness 2007). Five mile long barriers were raised 15 to 20 feet using multi layers of geocells with compacted soil filling as the facia resulting in an aesthetically pleasing alternative to conventional technique of concrete retaining walls.

Originating with applications in the containment industry, geosynthetic clay liners (GCL) continue to evolve in sophistication and improved performance (Fig. 6). In 1987, a patent was filed in Germany concerning a shear resistant mode of manufacture. This system used needled fiber to stabilize and strengthen the products structure. GCL applications continue to expand with applications as seals in substructures of earthen embankments, incorporation in hydraulic structures, and a host of additional applications. There are double layer GCL's which give high assurance of desiccation proof impermeability in landfill caps. Composite structures of GCL's and sand mats are produced for underwater installation. GCL's are employed in waterproofing structures and the sealing of dam faces.

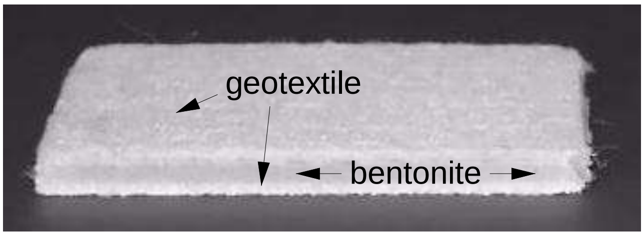


Figure 6: Typical example of a GCL (courtesy of M. Bouazza).

Construction on soft ground using geosynthetics is a well known theme that continues to evolve. As an example, a 16 meter high embankment was constructed over saturated soil in Germany employing a two layer system of 600 kN/m polyester fabric, with the result that a single layer of 1100 kN/m fabric is preferred due to non uniform loading of the two layers (Blume et al. 2006) . The construction scheme employed prefabricated vertical drains to assist in rapid dewatering. A different approach to construction on soft ground was used in Japan where a composite geotextile using a polyester fabric sheet (approximately 70 kN/m) combined with a pattern of woven textile tubes (714 kN/m) forming a lattice was installed and the tube lattice was then filled with pumped mortar (Yoshida et al. 2006). The result was greatly reduced settlements compared to the conventional construction on fabric over soft ground. Prefabricated vertical drains also benefit from innovation with improvement in composition and shape of the core as well as improvement in filter porosity resulting in greatly improved flow rates.

A very important aspect of innovation is the need for testing apparatus and procedures that reflect the product performance in situ and without undue influence. A simple example is the problem of tensile testing. In industry, testing is usually performed on a single unit (carbon fiber) with results extrapolated to a larger construct, perhaps an airframe. The geosynthetics industry has followed a different path in hopes of developing tests and tests methods which reflect properties developed in large areal applications. Tensile testing of geosynthetics has experienced apparatus testing one meter wide specimens, 8 inch samples, single ribs and individual yarns. Gripping devices include clamps, rollers, and devices that sense slippage and apply differential force to compensate. In every case slippage or perhaps more accurately, apparatus failure to avoid influencing results, is the problem causing the single rib method to differ from the wide width method which differs from yarn tests and strip tests. The use of grips which sense slippage in parts of a specimen and compensate, while expensive, are a major step in resolving the problems of apparatus influence on tensile data. Other testing developments include work to improve pull out testing apparatus, monotonic and cyclic loading evaluations, instrumentation studies and work in labs around the world to improve technique and equipment.

SOME ADVANCES IN SOIL REINFORCEMENT USING GEOSYNTHETICS

Advances in Soil Reinforcement in Asia

Construction of geosynthetic-reinforced soil retaining walls (GRS RW’s) and geosynthetic-reinforced steep slopes of embankments has become popular in Asia (e.g., Japan, Korea, China, Taiwan, Vietnam, Thailand, Singapore, Malaysia and India), following pioneering works in Europe and North America. Among the technologies used to construct these numerous geosynthetic-reinforced soil structures in Asia, a couple of unique ones that were developed in this region are reported herein.

GRS RWs Having a Full-Height Rigid Facing

Geosynthetic-reinforced soil retaining wall (GRS RW) having a stage-constructed full-height rigid (FHR) facing is now the standard retaining wall construction technology for railways in Japan (Tatsuoka et al., 1997a, 2007). Figure 7 shows a typical GRS RW having a FHR facing constructed in the center of Tokyo. This new type GRS RW has been constructed in more than 600 sites in Japan, and the total wall length is now more than 100 km as of March 2008. Very importantly, despite that railway engineers are generally very conservative in the structure design in civil engineering practice, the railway engineers in Japan have accepted this new type of retaining wall and this has become the standard retaining wall construction method for railways, including bullet trains.

This new retaining wall system has the following features:

The use of a full-height rigid (FHR) facing that is cast-in-place using staged construction procedures (Fig. 8). The geosynthetic reinforcement layers are firmly connected to the back of the facing. The importance of this connection for the wall stability is illustrated in Figure 9.

The use of a polymer geogrid reinforcement for cohesionless backfill to ensure good interlocking with the backfill, and the use of a composite of non-woven and woven geotextiles for nearly saturated cohesive soils to facilitate both drainage and tensile reinforcement of the backfill, which makes possible the use of low-quality on-site soil as the backfill if necessary.

The use of relatively short reinforcement.

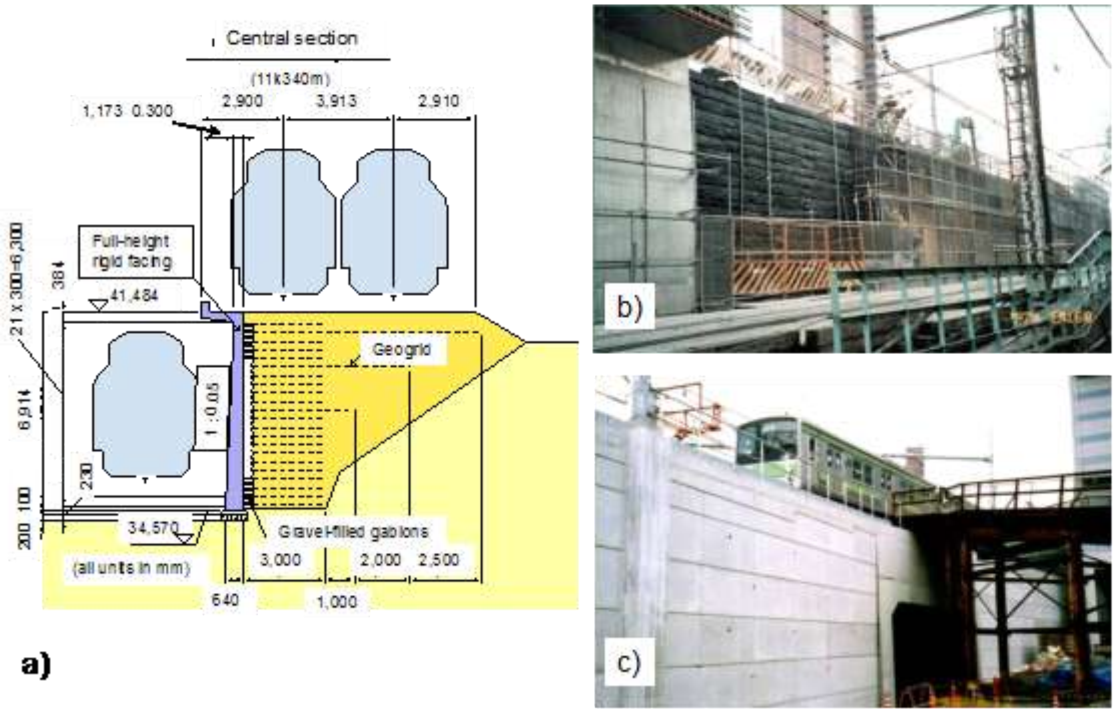


Figure 7: GRS RW having a FHR facing supporting one of the busiest rapid transits in Japan (Yamanote Line), near Shinjuku station, Tokyo (constructed during 1995 – 2000): a) typical cross-section; b) wall under construction; and b) completed wall

The staged construction method (Fig. 8), which is one of the main features of this RW system, consists of the following steps: 1) a small foundation element for the facing is constructed; 2) a full-height GRS wall with wrapped-around wall face is constructed by placing gravel-filled bags at the shoulder of each soil layer; and 3) a thin (i.e., 30 cm or more in the thickness) and lightly steel-reinforced concrete facing (i.e., a FHR facing) is constructed by cast-in-place fresh concrete directly on the wall face after the major part of ultimate deformation of the backfill and the subsoil layer beneath the wall has taken place. A good connection can be made between the RC facing and the main body of the wall by placing fresh concrete directly on the geogrid-covered wall face.

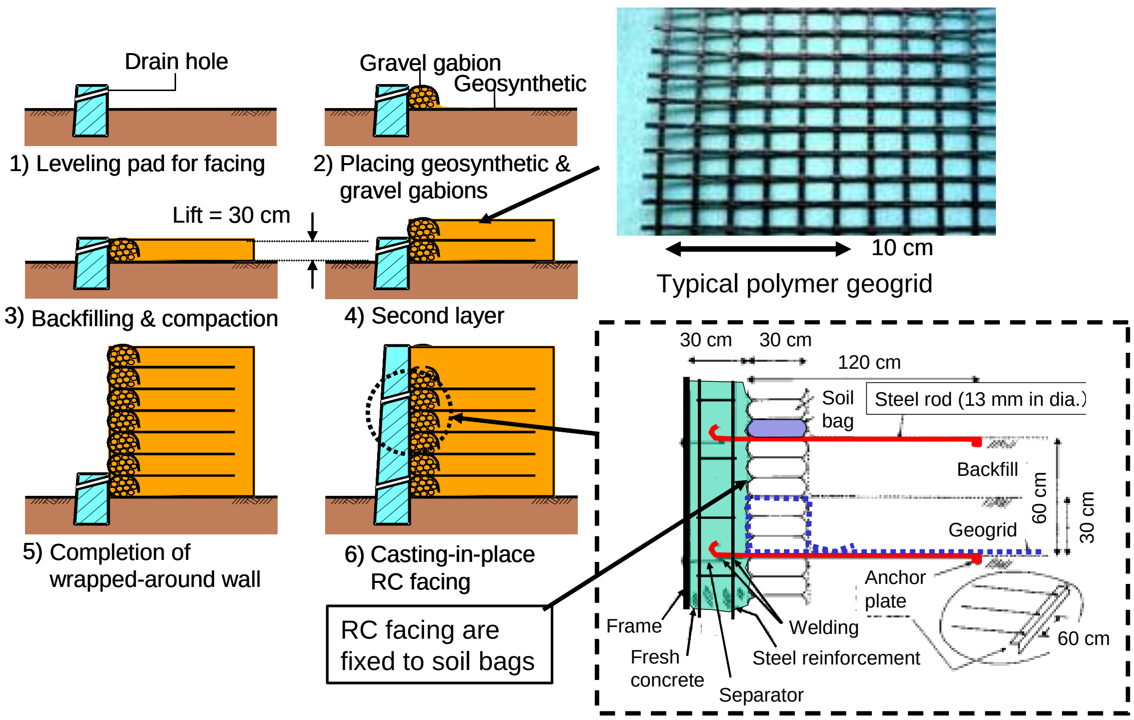


Figure 8: Staged construction of a GRW RW with a FHR facing.

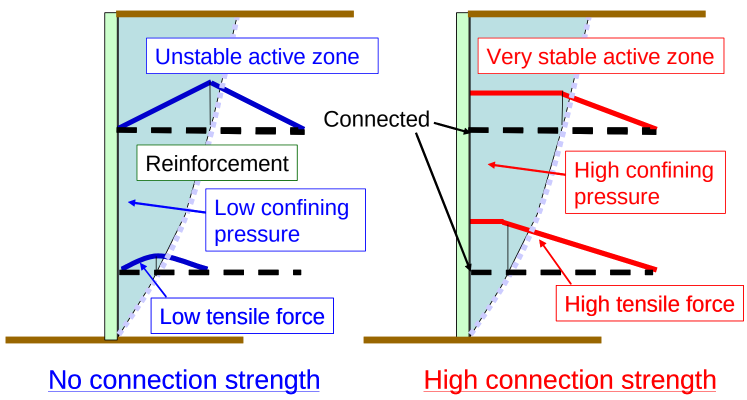


Figure 9: Effects of firm connection between the reinforcement and the facing (Tatsuoka, 1993).

The major structural feature of this new retaining wall is as follows. A conventional retaining wall type is basically a cantilever structure that resists against the active earth pressure from the unreinforced backfill by the moment and lateral thrust force activated at its base. Therefore, large internal moment and shear force are mobilized inside the facing structure while large overturning moment and lateral thrust force develop at the base of the wall structure. A large stress concentration may develop at and immediately behind the toe on the base of the wall structure, which makes necessary the use of a pile foundation in usual cases. Relatively large earth pressure, similar to the active earth pressure activated on the conventional retaining wall, may also be activated on the back of the FHR facing of GRS RW because of high connection strength between the reinforcement and the facing. This high earth pressure results in high confining pressures in the backfill, therefore high stiffness and strength of the backfill, which results in better performance than in the case without a firm connection between the reinforcement and the facing (Fig. 9) . As the FHR facing behaves as a continuous beam supported at a large number of points with a small span, typically 30 cm (Fig. 10), only small forces are activated inside the facing, resulting in a simple facing structure and insignificant overturning moment and lateral thrust forces activated at the bottom of facing, which makes unnecessary the use of a pile foundation in usual cases.

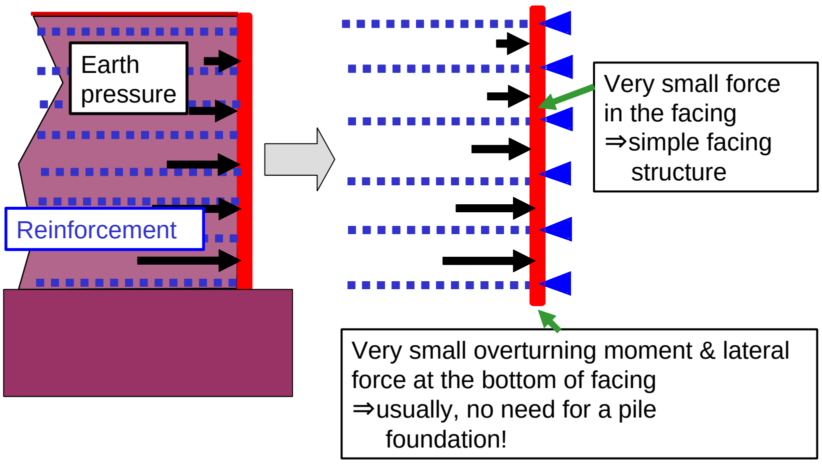


Figure 10: GRS RW with a FHR facing as a continuous beam supported at many points with a small span (Tatsuoka et al., 1997a).

A significant number of case histories until today have shown that the construction of GRS RW having a stage-constructed FHR facing is very cost-effective (i.e., much lower construction cost, a much higher construction speed and the use of much lighter construction machines), therefore a much less total emission of CO_2 than the construction of conventional types of retaining walls. Yet, the performance of the new type of retaining wall can be equivalent to, or even better than, that of conventional type soil retaining walls. The general trend of construction of elevated transportation structures in Japan is a gradual shifting from gentle-sloped embankments towards embankments supported with retaining walls (usually RC cantilever RWs with a pile foundation), or RC framed structures for higher ones, and then towards GRS RWs having a stage-constructed FHR facing (Fig. 11). It is expected that this new retaining wall technology is adopted and becomes popular in not only other countries than Japan in Asia but also many other countries outside Asia.

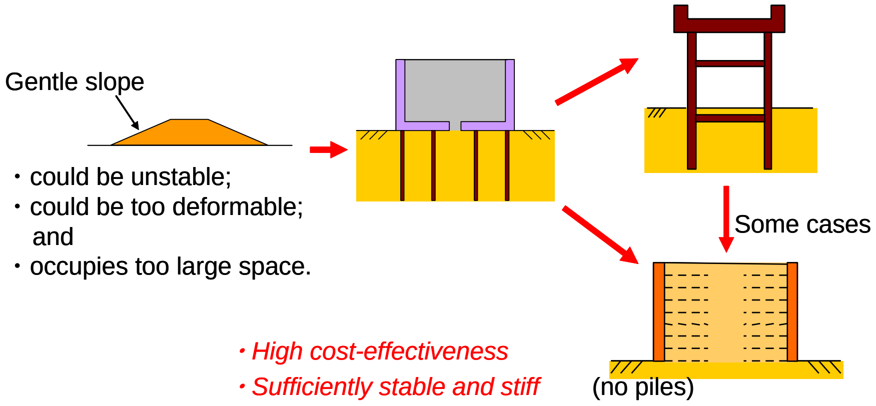


Figure 11: History of elevated railway and highway structures in Japan.

Reconstruction of Failed Embankments and Retaining Walls

Numerous embankments and conventional type retaining walls have collapsed due to flooding and earthquakes in the past in many Asian countries (Fig. 12). Previously, most of the collapsed soil structures were reconstructed to respective original structures despite that these conventional type soil structures have a substantially low cost-effectiveness with very low resistance against flooding and seismic loads. Since early 1990's, reconstruction of railway embankments that collapsed by flooding with embankments having geosynthetic-reinforced steep slopes or GRS RWs, having a stage-constructed FHR facing or their combination, started based on successful experiences of high cost-effectiveness and high performance of GRS RWs having a FHR facing, as described above. Figures 13(a) to (c) show a typical case of the above (Tatsuoka et al., 1997a; 2007). This reconstruction method was employed also in other similar cases after this event of flooding. It was after the 1995 Hyogo-ken-nambu Earthquake (the 1995 Kobe Earthquake) that gentle slopes of embankment and conventional retaining walls that collapsed by earthquakes were reconstructed using geosynthetic-reinforced steep slopes or GRS RWs having a stage-constructed FHR facing or their combination (Tatsuoka et al., 1996, 1977a & b, 1998). In particular, a very high performance of a GRS RW with a stage-constructed FHR facing at Tanata during the 1995 Kobe Earthquake validated a high-seismic stability of this wall type (Figs. 14a and b). Figures 15(a) to 15(c) show the reconstruction of one of the three railway embankments that totally failed during the 2004 Niigata-ken Chuetsu Earthquake using GRS RWs having a FHR facing. In this case, the new type of RW was chosen because of not only much lower construction cost and much higher stability (in particular for soil structures on a steep slope) but also a much shorter construction period and a significant reduction of earthwork when compared to reconstruction to the original embankments. The new type of reinforced wall is also much more cost-effective and needs a much shorter construction period than bridge type structures. During this earthquake, road embankments collapsed at numerous places in mountain areas and many of them were reconstructed using GRS RWs or embankments having geosynthetic-reinforced steep slopes. More recently, the March 25th 2007 Noto-hanto Earthquake caused severe damage to embankments of Noto Toll Road, which was opened in 1978. The north part of this road runs through a mountainous area for a length of 27 km. The damage concentrated into this part, where eleven high embankments filling valleys were extensively collapsed (Koseki et al., 2007). As schematically shown in Figure 16, the collapsed embankments were basically reconstructed using GRS RWs while ensuring the drainage of ground and surface water. The on-site soil that had originally been part of the collapsed embankment was re-used after lime-treatment for the construction of the upper fill.

Figure 12: Gravity type retaining wall without a pile foundation at Ishiyagawa that collapsed during the 1995 Kobe Earthquake (Tatsuoka et al., 1996, 1997b).

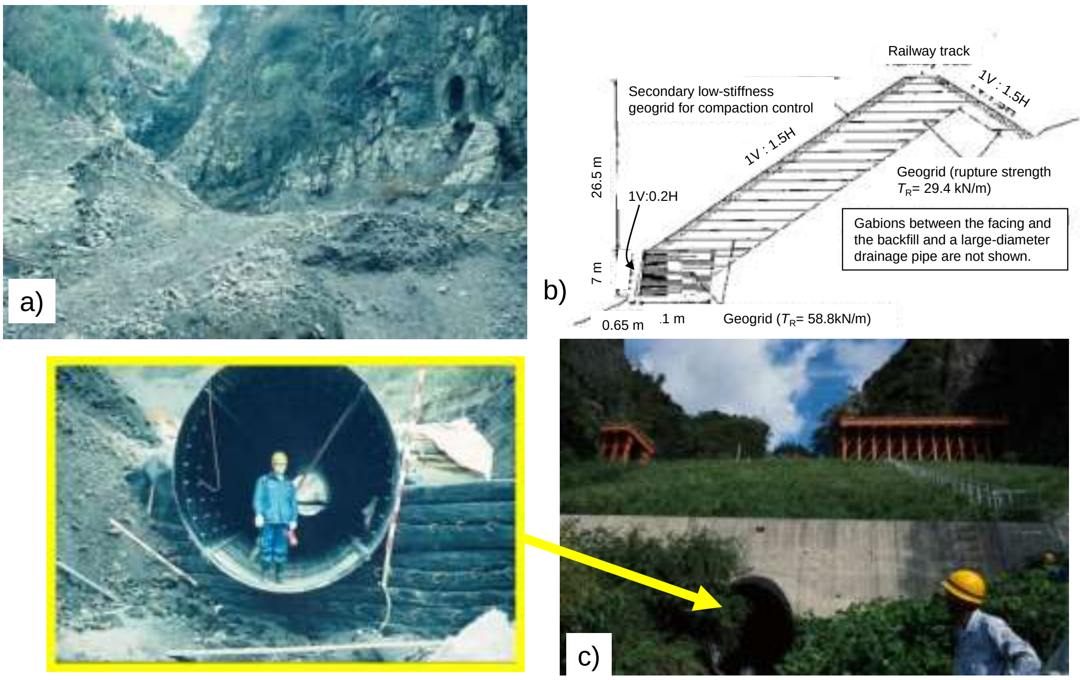


Figure 13: Typical section of a railway embankment damaged by rainfall in 1989 and reconstructed in 1991: a) before reconstruction; b) reconstructed cross-section; and c) after reconstruction (Tatsuoka et al., 1997a; 2007).

Figure 14: GRS RW having a FHR facing at Tanata, Japan; a) immediately wall completion; and b) immediately after the 1995 Kobe Earthquake (Tatsuoka et al., 1996, 1997b).

After a multiple successful case histories of geosynthetic-reinforced soil structures, as described above, when compared to two decades ago, GRS RWs and geosynthetic-reinforced steep slopes are now much more widely accepted as a relevant technology to reconstruct embankments and conventional retaining walls that have collapsed by floodings and earthquakes. This technology was also used to rehabilitate an old earth dam, having a crest length of 587 m and a height of 33.6 m, in the north of Tokyo (Fig. 17). When constructed about 80 years ago, this earth dam was the largest one in Japan.

The reservoir is exclusively for water supply in Tokyo, which will become extremely important in supplying water at the time of disasters, including seismic ones, because of its ability of sending raw water under gravity flow to several water treatment plants downstream. A 17 m-high counter-weight fill having a 1:1 steep slope was constructed on the down-stream slope of the dam aiming at a substantial increase in the seismic stability of the dam removing the possibility of vast disaster to a heavily populated residential area that had been developed in recent years close to the dam. Due to a severe space restriction, the slope of the counter-weight fill was very steep, which was possible by using HDPE geogrids installed over a total area of 28,500 m^2 in the fill.

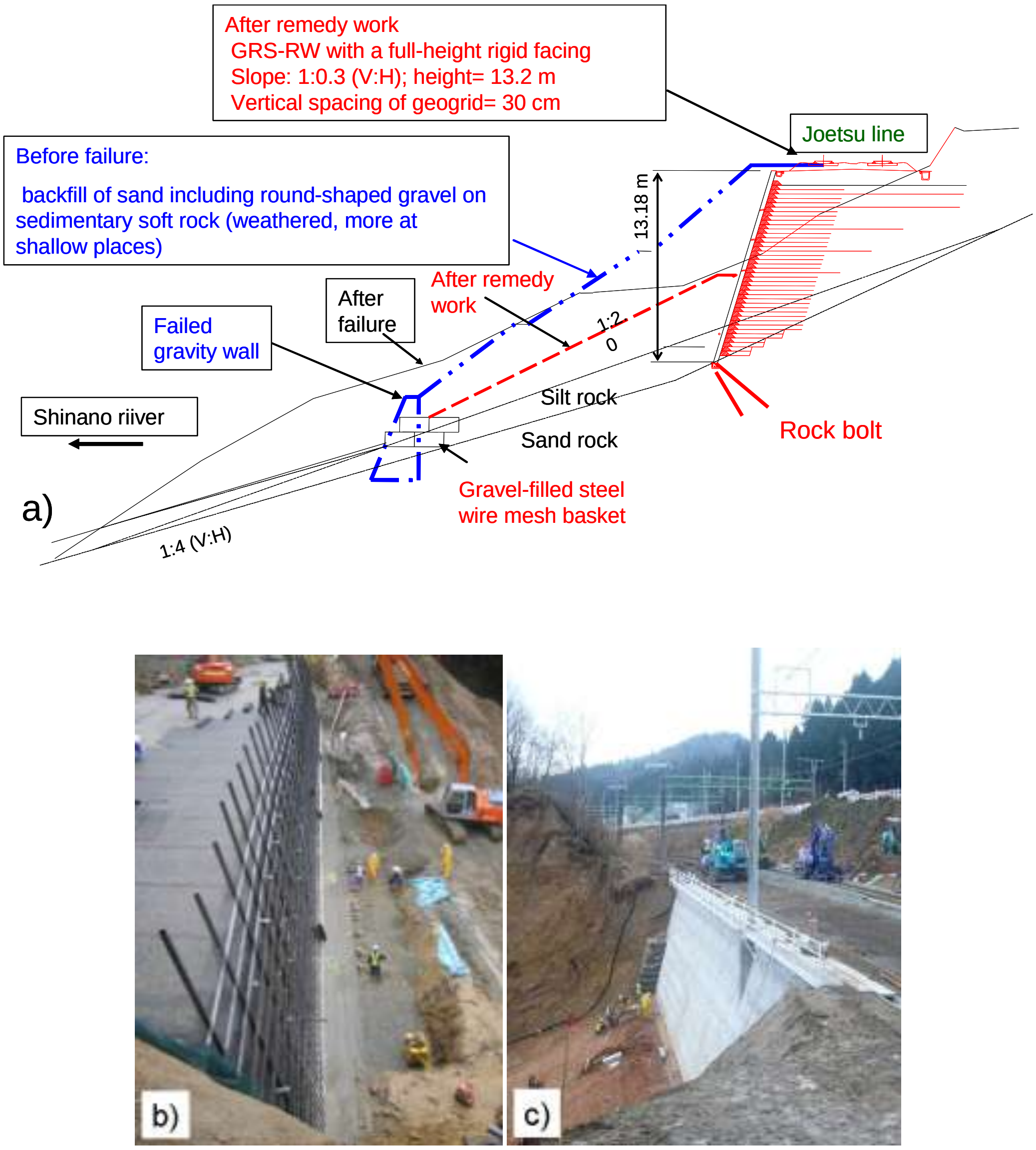


Figure 15: Railway embankment that collapsed during the 2004 Niigata-ken Chuetsu Earthquake and its reconstruction to a GRW RW having a FHR facing; a) cross-sections before and after failure and after reconstruction; b) wall during reconstruction; and c) completed wall (Morishima et al., 2005).

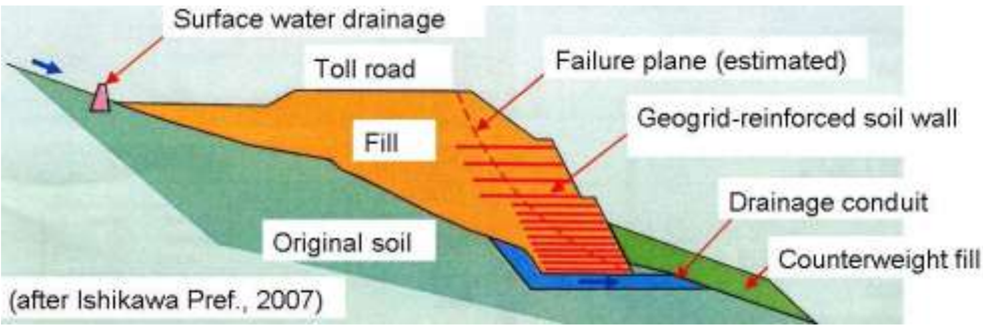


Figure 16: Schematic diagram showing reconstruction to GRS RWs of embankments damaged by the 2007 Noto hanto Earthquake (Koseki et al., 2007)

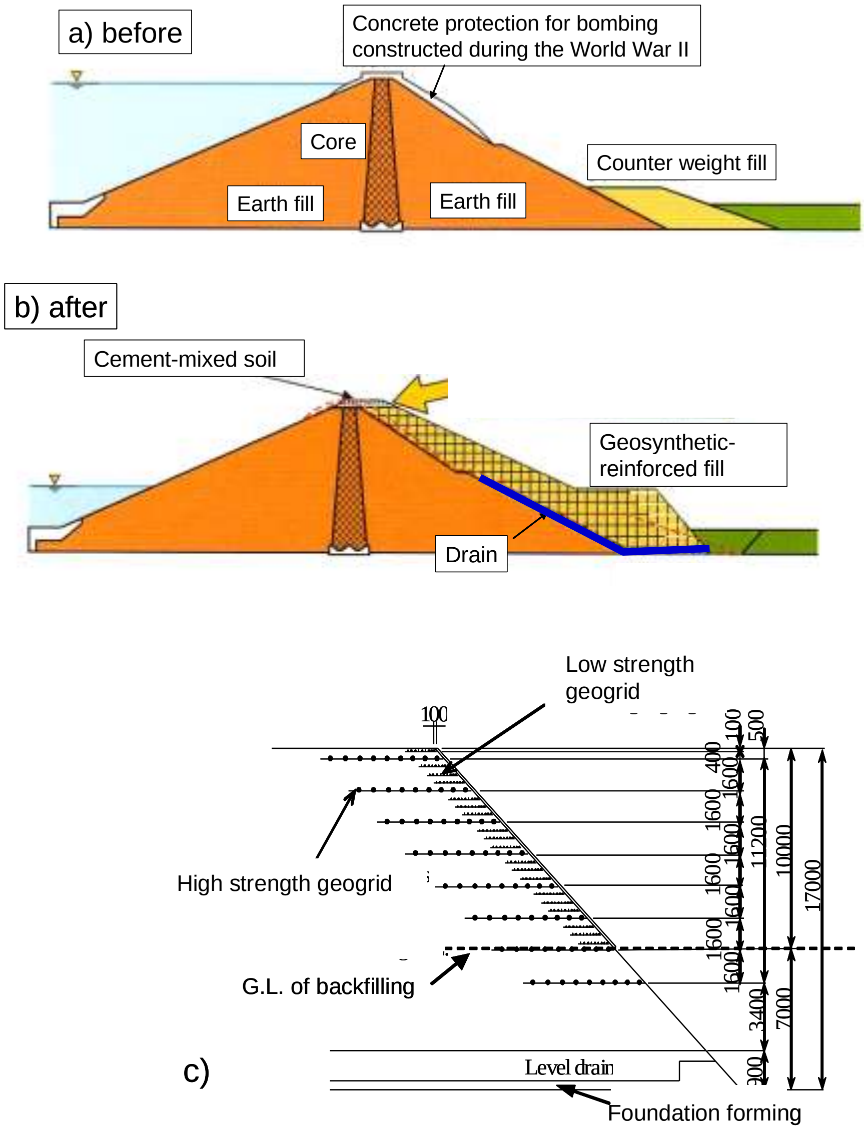


Figure 17: Shimo-Murayama dam in Tokyo: a) & b) dam before and after rehabilitation; and d) geogrid-reinforced counter-weight fill (Maruyama et al., 2006)

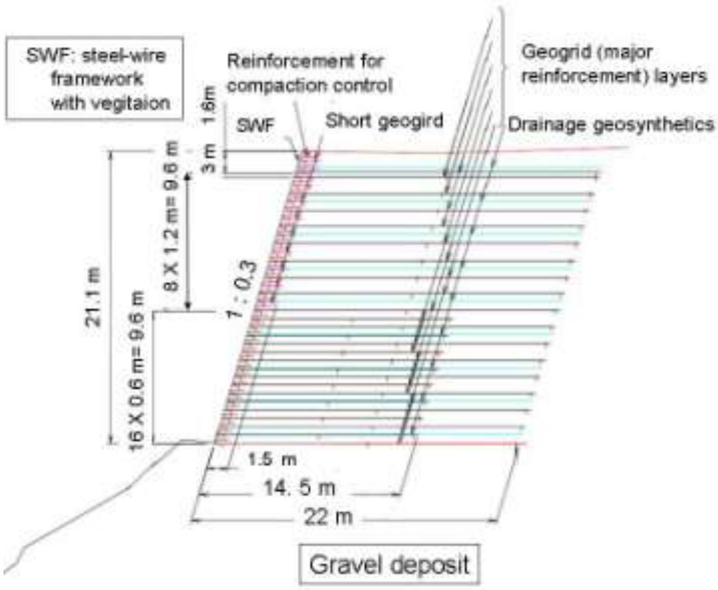
High Geogrid-Reinforced Wall

At the "Fujisan-Shizuoka Airport" in Japan, which is now under construction, two high GRS RWs (21.1 m and 16.7 m high) were constructed to preserve the natural environment, which consists of steep swamp areas, in front of the walls. These areas would be buried if gentle-sloped embankments were to be constructed (Fig. 18a). Figure 18b shows the cross-section of one of the two walls. As the walls support the east side of the airfield runway, minimum residual displacements at their crest are required. A sufficient high seismic stability is another important design issue. Well-graded gravelly soil was selected as the backfill and the backfill was compacted very well to an average degree of compaction higher than 95 % based on the maximum dry density obtained using compaction energy 4.5 times higher than the standard Proctor (Fig. 18c; Tatsuoka et al., 2008). The monitored deformations of the walls (Fig. 18d) showed very small deformations during construction and negligible post-construction deformations after wall completion, indicating high stability conditions. This case history indicates that long-term deformation of geosynthetic-reinforced soil structures can be restrained very effectively by good compaction of good backfill despite that significantly stiff reinforcement members are not used.

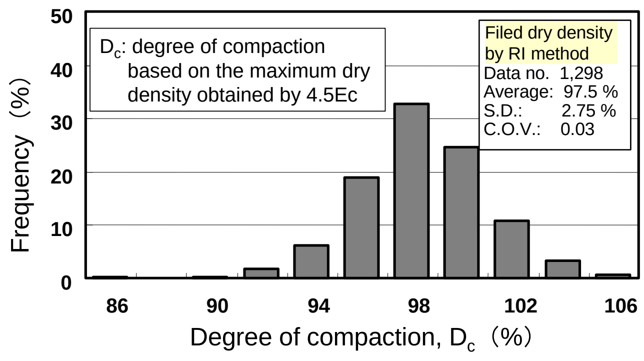
The recorded time histories of the tensile strain in the geogrid also exhibited nearly no increase after wall completion. Kongkitkul et al. (2008) analysed these data based on an elasto-viscoplastic constitutive model of the geogrid developed based on laboratory test results. They showed that the tensile load in the geogrid tends to decrease with time after wall completion, and creep rupture failure of the geogrid by the end of the wall design life is unlikely. The reduction of the tensile strain in the geogrid with time is due to not only the viscous properties of the geogrid but also because of compressive creep strains in the horizontal direction of the backfill caused by the tensile force in the reinforcement. This result indicates that the assumption in current practice that the tensile load mobilised in the geosynthetic reinforcement in the backfill is kept constant over-estimates the possibility of creep rupture failure of geosynthetic reinforcement. In fact, the rupture strength of geosynthetic-reinforcement used in the seismic design of GRS-RWs having a stage-constructed FHR facing is not reduced for creep rupture. Tatsuoka et al. (2006) proposed a new method by which the design rupture strength of the geosynthetic reinforcement to be used in both seismic and static designs of GRS RWs is not reduced for creep rupture.

(Figure 18 (*a*))

(*b*)



(*c*)



(*d*)

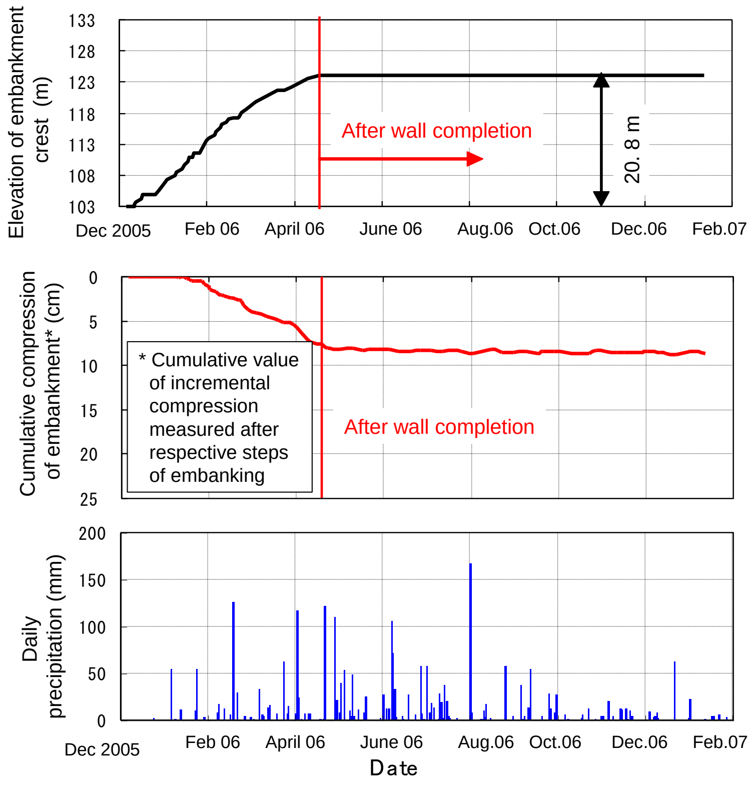


Figure 18: High GRS RW for Fujisan-Shizuoka airport; (*a*) wall in valley 1 (2 Nov. 2007); (*b*) cross-section of wall in valley 2; and; (*c*) measured degree of compaction of the backfill, wall in valley 2; (*d*) deformation of wall in valley 2 (Fujita et al., 2008).

SOME ADVANCES IN SOIL REINFORCEMENT IN NORTH AMERICA

This section is focused on developments in North America related to geosynthetic reinforced soil (GRS) walls. In North America the current common approach for the design and analysis of geosynthetic reinforced soil walls is the AASHTO (2002) Simplified Method. The approach is based on limit-equilibrium of a "tied-back wedge" for internal stability and its origins can be traced back to the early 1970's (Allen and Holtz 1991, Berg et al. 1998). The same allowable stress design (ASD) approach is proposed in the Canadian Foundation Engineering Manual (CFEM 2006) which is an important guidance document for geotechnical engineers in Canada. For segmental retaining walls constructed with discrete dry-stacked module concrete facing units, the most important reference is the guidance document published by the National Concrete Masonry Association (NCMA 1997). This document provides a full treatment for analysis, design and specification of these systems which continue to grow in popularity in North America. Nevertheless, this growth has been largest in the private sector compared to state, province and federal funded-projects. The experience of the writers is that specifications for backfill and modular facing components tend to be stricter for government projects and there continue to be reservations in some jurisdictions regarding durability of dry cast masonry modular facing units in harsh (freeze-thaw) environments.

Many suppliers of segmental retaining walls components (facing units and/or reinforcement materials) have developed computer design aids to facilitate design. However, generic programs are also available. Program SRWall 3.22 is a full implementation of the NCMA manual for static load environments and the seismic supplement (Bathurst 1998) for earthquake design of this class of structure. Program MSWE 3.0 (Leshchinksy 2006) allows the engineer to design complex geometries for geosynthetic reinforced soil walls using AASHTO (2002) for ASD, AASHTO (2007) for LRFD design and the NCMA (1997) (ASD) method.

A brief summary of developments related to geosynthetic reinforced soil wall technology and practice in North America follows below. This review does not claim to be comprehensive but highlights a number of developments that are familiar to the authors.

Cohesive-frictional soil backfills: The use of cohesive-frictional soils as a cheaper alternative to "select" granular fills continues to grow. This is due in part to increasing confidence as more projects are completed using these soils and the recognition that materials with a large fines content can be used as the backfill provided that adequate attention is paid to compaction control during construction and good drainage practice is carried out particularly at the backfill surface. Nevertheless, the use of these materials is largely restricted to private sector projects. A summary of recent experimental walls that have been monitored after being constructed with c-ϕ soils appears in the papers by Miyata and Bathurst (2007) and Bathurst et al. (2008).

Facing units: A very large number of proprietary masonry concrete units are available on the market today. The units vary in size and may be hollow or solid. They have a range of facing appearances and include concrete shear keys, pins or clips for alignment and is some cases for layer shear transfer (e.g. NCMA 1997). However, the use of larger modular block facing units formed from unreinforced wet-cast concrete is growing. The concrete is typically return concrete from wet concrete batch plants. These modular units are often 1 m^3 are larger (Figure 19). Most are solid with concrete shear keys but some systems are hollow to reduce the mass of concrete. The attraction of these systems to designers is that they are very stable and help to ensure a durable facing with good long-term facing alignment. A recent novel development that has appeared in the market place is a product that uses plastic molded shapes to entirely replace the concrete in conventional systems (Figures 20 and 21). The units lock together between courses and the interior components filled with granular soil. A range of different facing appearances are achieved by using different (patterned or textured) thin plastic panels that snap on to the internal molded unit.

Figure 19: Example of large wet-cast concrete modular block.

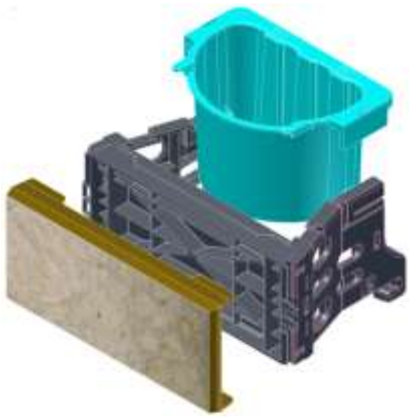


Figure 20: Geosynthetic modular "block" unit components (courtesy Robert Race).

Figure 21: Construction of GRS wall with geosynthetic modular "block" units (courtesy Robert Race).

Bridge abutments: Most GRS reinforced bridge abutments have been constructed with the bridge deck supported by piles taken to a competent foundation layer. Hence, the GRS wall has been required to primarily support only the backfill soil in the approach fill. A more cost effective solution is to have the bridge deck supported by spread footings placed directly on the reinforced soil zone. The first instrumented and monitored wall of this type was the Founders/Meadows structure constructed by the Colorado Department of Transportation in 1999 (Abu-Hejleh et al. 2002) (Figures 22 and 23). An additional advantage of this construction is that the bridge deck and approach fill settle together thus reducing the pavement bump that can occur at the fill-deck joint for conventional structures. A recent variation on this general approach is to place the bridge deck ends directly on the reinforced soil zone leaving a gap between the bottom of the bridge deck and the top of modular block facing. Examples of these structures have been reported by Adams (2008). An additional feature of these walls is the use of closely spaced reinforcement layers to ensure reinforcement capacity redundancy and to create a dense monolithic composite (gravity) mass comprised of the facing, reinforced soil and reinforcement layers.

Figure 22: Founders/Meadows GRS bridge abutment.

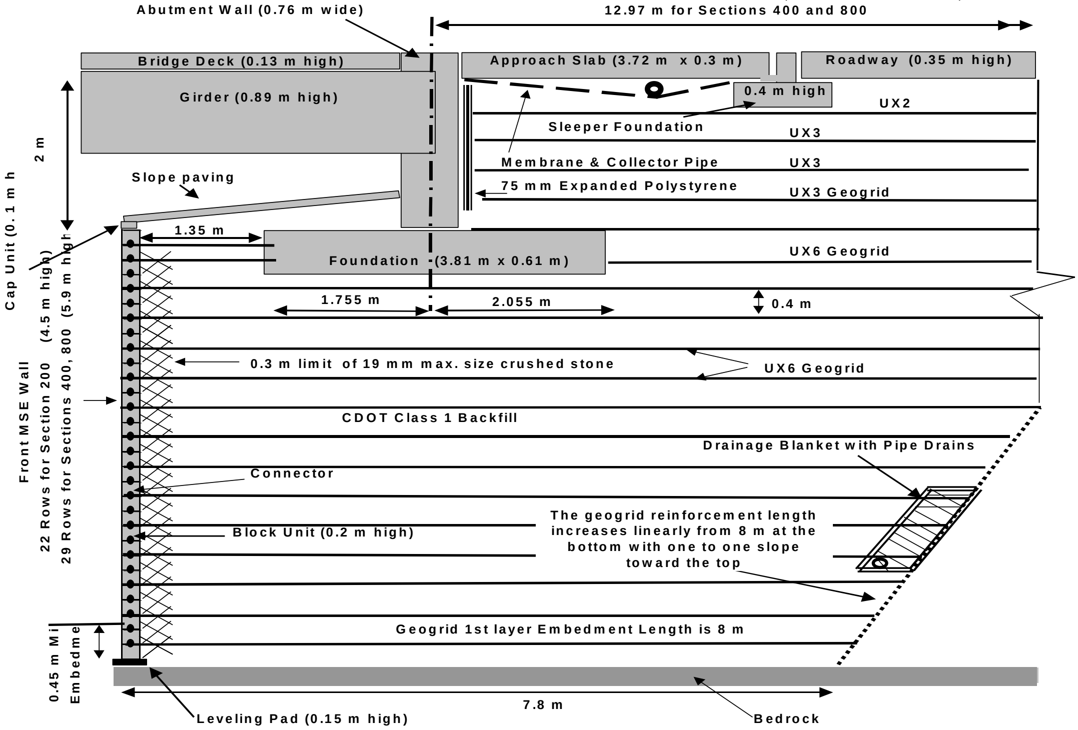


Figure 23: Cross-section view of Founders/Meadows GRS bridge abutment (Abu-Hejleh et al. 2002).

Alternative design methods: The consensus of experienced GRS wall designers is that current ASD-based design methods are conservative with respect to prediction of reinforcement loads under operational conditions. Quantitative evidence in support of this view has been reported by Allen et al. (2002, 2003). They showed that for walls with a hard facing the maximum loads in the reinforcement were (on average) three times higher than predicted values using the conventional AASHTO (2002) Simplified Method and there was no statistically significant relationship between predicted and measured loads. Furthermore, the distribution of maximum reinforcement loads was trapezoidal in shape rather than triangular as is the case for walls with uniformly spaced reinforcement layers supporting dead loads due to soil self-weight and designed using the AASHTO approach. The results of ongoing work have led to a new approach for working stress design for the internal stability design of reinforced soil wall structures called the K-stiffness Method. The origins of the method can be traced back to Allen et al. (2003) and have been implemented in the Geotechnical Design Manual by the Washington State Department of Transportation (WSDOT 2006). The original method was restricted to reinforced soil walls with granular backfill. The method has recently been extended to include c-ϕ soil backfills (Bathurst et al. 2008). The method includes an empirical expression for maximum reinforcement load (T_{max}) in a layer under operational conditions (i.e. a serviceability state characterized by a limit on post-construction wall deformations and a limit on reinforcement strains for the case of granular backfills):

$$T_{max} = \frac{1}{2} K\gamma(H+S)S_v D_{tmax} \phi_g \phi_{local} \phi_{fs} \phi_{fb} \phi_c \tag{1}$$

Here: H = height of the wall; S = equivalent height of uniform surcharge pressure q (i.e., S = q/γ); D_{tmax} = load distribution factor that modifies the reinforcement load based on layer location. The remaining terms, ϕ_g, ϕ_{local}, ϕ_{fs}, ϕ_{fb} and ϕ_c are influence factors that account for the effects of global and local reinforcement stiffness, facing stiffness, face batter, and soil cohesion, respectively. The coefficient of lateral earth pressure is calculated as K = 1 – sinϕ with $\phi = \phi_{ps}$ = secant peak plane strain friction angle of the soil. The cohesion influence factor is of particular importance to walls with backfill soils having a significant and measurable cohesive strength component (c). The cohesion influence factor is calculated according to Miyata and Bathurst (2007) as:

$$\phi_c = 1 - \frac{\lambda c}{\gamma H} \tag{2}$$

Where λ is a fitting coefficient from back-calculated data. The coefficient terms that appear in the above expressions have been back-calculated from a large database of instrumented walls. Quantitative comparison of measured to predicted loads shows that load prediction accuracy is greatly improved over the current AASHTO approach and variants. The first modular block GRS walls to be designed using this method were constructed and instrumented in Washington State. The walls were up to 11 m in height and were constructed with a granular backfill. Verification of the more efficient reinforcement layout and good agreement between measured and predicted reinforcement loads for the highest wall section (11 m) is quantitatively demonstrated by Allen and Bathurst (2006).

Limit states design: A recognized obstacle to even greater use of GRS walls in North America is the lack of an adequate transition to a limit states design (LSD) format (called load and resistance factor design (LRFD) in the United States. This situation is compounded by the observation that the design of retaining walls (at least in government projects) typically involves structural engineers who work in a limit states design environment. An initial step in this direction is the AASHTO (2007) bridge design code which is now fully LRFD. However, the general approach has been to fit limit state equations to ASD equations so that load and resistance factors matching a given reliability index value give the same factor of safety as in conventional practice. This is not an entirely satisfactory approach since it does not guarantee a uniform level of reliability for all possible limit states. Formal procedures to carry out rigorous calibration have only just begun for GRS walls. An example of the general approach described in a way that is familiar to geotechnical engineers can be found in a recent TRR circular (Allen et al. 2005). An advantage of the K-stiffness Method described earlier is that it can be easily recast into a limit states design format (at least for the calculation of internal reinforcement loads) since the underlying deterministic model has been calibrated using a statistical treatment of measured and predicted reinforcement loads. An initial step in this direction can be seen in the WSDOT (2006) design guidance document mentioned earlier.

SOME ADVANCES IN GEOENVIRONMENTAL APPLICATIONS USING GEOSYNTHETICS

Geosynthetics play an important role in environmental applications because of their versatility, cost-effectiveness, ease of installation, and consistency in their mechanical and hydraulic properties. Geosynthetics also can offer a technical advantage in relation to traditional liner systems or other containment systems. The use of geomembranes as the primary water proofing element at the Contrada Sabetta Dam, Italy (Cazzuffi 1987) and to keep an upstream clay seepage control liner from dessicating in the Mission Dam (today Terzaghi Dam), Canada (Terzaghi & Lacroix 1964) in the late 1950's represent applications that have been the precursors of today's usage of geosynthetics in containment systems. Both applications predated the use of conventional geosynthetics by some 20 years. Geosynthetic systems are nowadays an accepted and well-established component of the landfill industry (since at least early 1980's). Containment systems for landfills typically include both geosynthetics and earthen material components, (e.g. compacted clays for liners, granular media for drainage layers, and various soils for protective and vegetative layers).

The state of the art on the use of geosynthetics in waste containment facilities previous to this period has been documented by various important sources, which have set the path for the growth of geosynthetics in this field (e.g. Giroud & Cazzuffi 1989; Koerner 1990; Cancelli & Cazzuffi 1994; Gourc 1994; Rowe et al. 1995; Manassero et al. 1998; Rowe 1998; Bouazza et al. 2002, Junqueira et al. 2006).

This section focuses on some recent advances on the use of geosynthetics in environmental applications, including the design of geosynthetics in liquid collection systems and of reinforced cover systems.

The multiple uses of geosynthetics in the design of modern municipal solid waste landfills is a good illustration of an application in which the different geosynthetics can be and have been used to perform all the functions discussed previously. Virtually all the different types of geosynthetics discussed previously have been used in the design of both base and cover liner systems of landfill facilities. Figure 24 illustrates the extensive multiple uses of geosynthetics in both the cover and the base liner systems of a modern landfill facility (Zornberg & Christopher 2007). The base liner system illustrated in the figure is a double composite liner system. Double composite liner systems are used in some instances for containment of municipal solid waste and are frequently used for landfills designed to contain hazardous waste. The base liner system shown in the figure includes a geomembrane/GCL composite as the primary liner system and a geomembrane/compacted clay liner composite as the secondary system. The leak detection system, located between the primary and secondary liners, is a geotextile/geonet composite. The leachate collection system overlying the primary liner on the bottom of the liner system consists of gravel with a network of perforated pipes. A geotextile protection layer beneath the gravel provides a cushion to protect the primary geomembrane from puncture by stones in the overlying gravel. The leachate collection system overlying the primary liner on the side slopes of the liner system is a geocomposite sheet drain (geotextile/geonet composite) merging into a gravel layer. A geotextile filter covers the entire footprint of the landfill and minimizes clogging of the leachate collection and removal system. The groundwater level may be controlled at the bottom of the landfill by gradient control drains built using geotextile filters. Moreover, the foundation soil below the bottom of the landfill may be stabilized as shown in the figure using randomly distributed fiber reinforcements, while the steep side soil slopes beneath the liner could also be reinforced using geogrids. Different types of geosynthetics (e.g. geogrids, geotextiles, fibers) could have been selected for stabilization of the foundation soils.

The cover system of the landfill illustrated in Figure 24 contains a composite geomembrane/GCL barrier layer. The drainage layer overlying the geomembrane is a geocomposite sheet drain (composite geotextile/geonet). In addition, the soil cover system may include geogrid, geotextile, or geocell reinforcements below the infiltration barrier system. This layer of reinforcements may be used to minimize the strains that could be induced in the barrier layers by differential settlements of the refuse or by a future vertical expansion of the landfill. In addition, the cover system could include geogrid or geotextile reinforcement above the infiltration barrier to provide stability to the vegetative cover soil. Fiber reinforcement may also be used for stabilization of the steep portion of the vegetative cover soil. A geocomposite erosion control system above the vegetative cover soil is indicated in the figure and provides protection against sheet and gully erosion. Fig. 24 also illustrates the use of geosynthetics within the waste mass, which are used to facilitate waste placement during landfilling. Specifically, the figure illustrates the use of geotextiles as daily cover layers and of geocomposites within the waste mass for collection of gas and leachate. Geosynthetics can also be used as part of the groundwater and leachate collection well system. The use of geotextiles as filters in groundwater and leachate extraction wells is illustrated in the figure. Finally, the figure shows the use of an HDPE vertical barrier system and a geocomposite interceptor drain along the perimeter of the facility. Although not all of the components shown in Figure 24 would normally be needed at any one landfill facility, the figure illustrates the many geosynthetic applications that can be considered in landfill design.

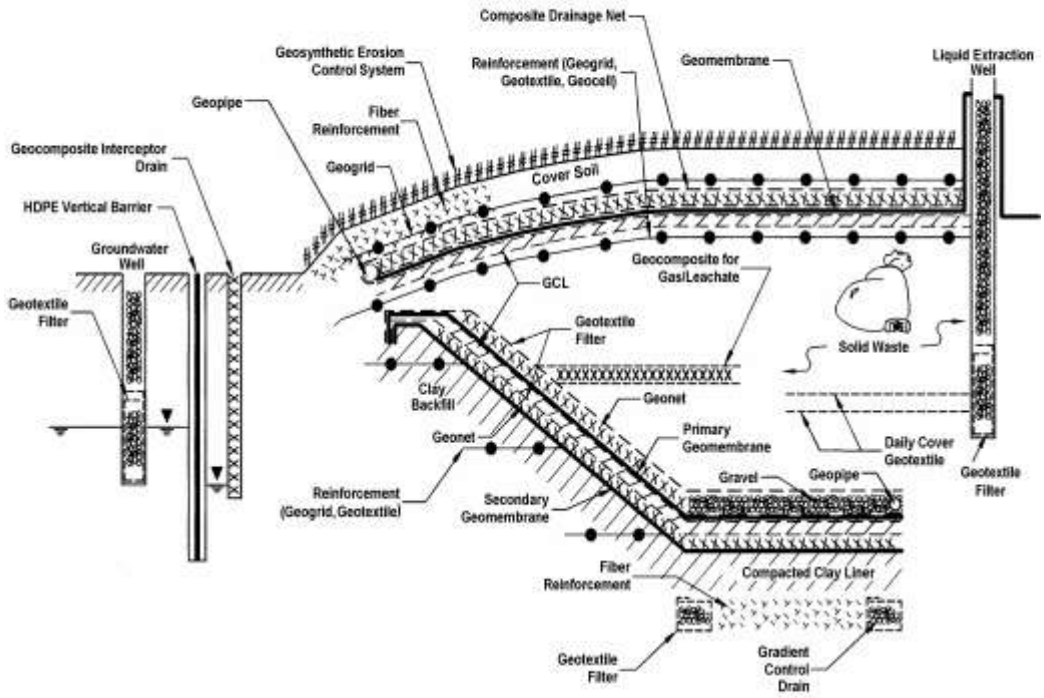


Figure 24: Multiple uses of geosynthetics in landfill design (from Zornberg & Christopher 2007).

Geosynthetics in Liquid Collection Systems

Calculating the thickness of liquid in a liquid collection layer is an important design step because one of the design criteria for a liquid collection layer is that the maximum thickness of the liquid collection layer must be less than an allowable thickness. The term “thickness” is used instead of the more familiar term “depth”, because thickness (measured perpendicular to the liquid collection layer slope), and not depth (measured vertically), is actually used in design.

The thickness of liquid in a liquid collection layer depends on the rate of liquid supply. A typical case of liquid supply is that of liquid impinging onto the liquid collection layer. Two examples of liquid collection layers with such a type of liquid supply can be found in landfills (Fig. 25): (i) the drainage layer of the cover system (Fig. 25a), where the liquid that impinges onto the liquid collection layer is the precipitation water that has percolated through the soil layer overlying the drainage layer; and (ii) the leachate collection layer (Fig. 25b), where the liquid that impinges onto the leachate collection layer is the leachate that has percolated through the waste and through the protective soil layer overlying the leachate collection layer (Giroud et al., 2000a). The terminology “liquid impingement rate” is often used in the case of landfills to designate the rate of liquid supply.

Equations are available (Giroud et al. 2000a) to calculate the maximum thickness of liquid in a liquid collection layer that meets the following conditions:

- the liquid supply rate is uniform (i.e. it is the same over the entire area of the liquid collection layer) and is constant (i.e. it is the same during a period of time that is long enough that steady-state flow conditions can be reached);
- the liquid collection layer is underlain by a geomembrane liner without defects and, therefore, liquid losses are negligible;
- the slope of the liquid collection layer is uniform (a situation referred to herein as “single slope”) ; and
- there is a drain at the toe of the slope that promptly removes the liquid.

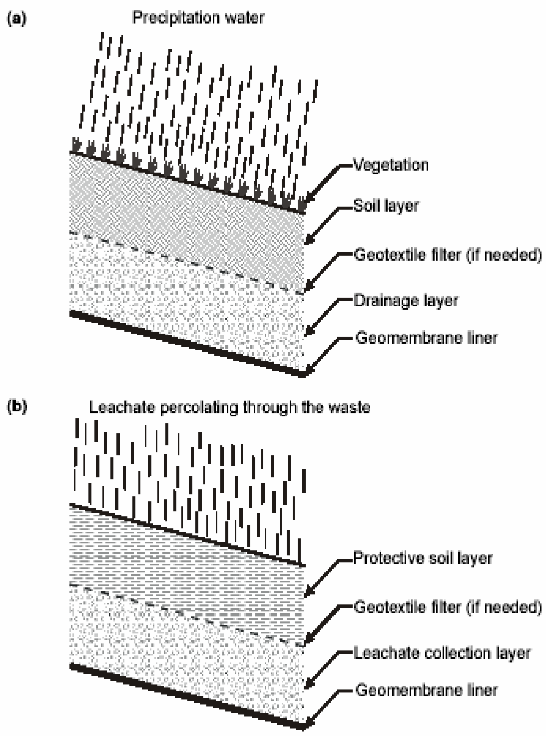


Figure 25: Examples of liquid collection layers subjected to a uniform supply of liquid in a landfill: (a) drainage layer in a cover system; (b) leachate collection layer (Giroud et al. 2000a).

The last two conditions are not met in cases where the liquid collection layer comprises two sections on different slopes, with no drain removing the liquid at the connection between the two sections; in those cases, the only drain is at the toe of the downstream section.

Regulatory equivalency between natural and geocomposite lateral drainage systems is currently based on equivalent transmissivity. However, Giroud et al. (2000c) have demonstrated that this practice is incorrect and non-conservative. An equivalency based solely on transmissivity will lead to selection of a geosynthetic drainage layer that may not provide adequate flow capacity and may result in the development of water pressure.

Equivalency between two lateral drainage systems must take into consideration the service flow gradients and maximum liquid thickness. Giroud et al. (2000c) have shown that, to be equivalent to a natural drainage layer, the minimum transmissivity of the geocomposite must be greater than the tranmissivity of the natural drainage layer. The minimum transmissivity of the geonet is obtained by multiplying the transmissivity of the natural drainage layer by an equivalency factor, *E*. For natural drainage layers having maximum flow depths of 0.30 m, *E* can be approximated as follows:

$$E = \frac{1}{0.88}\left[1 + \frac{t_{prescribed}}{0.88\,L}\,\frac{\cos\beta}{\tan\beta}\right] \tag{3}$$

where $t_{prescribed}$ is the maximum liquid thickness prescribed by regulations. The equivalency defined by Equation 3 is based on equal unconfined flow volumes in natural and geocomposite drainage systems. However, the very low heads associated with unconfined flow in a geocomposite lateral drain will result in a significantly reduced head acting on the underlying liner system, and therefore in a reduced potential leakage.

Reinforced Cover Systems

General considerations

The design of veneer slopes (e.g. steep cover systems for waste containment facilities) poses significant challenges to designers. The use of uniaxial reinforcements placed along the slope (under the veneer and above a typically strong mass of soil or solid waste) and anchored on the top of the slope has been a common design approach (Palmeira and Viana 2003). However, this alternative may not be feasible for steep, long veneer slopes. As the veneer slope rests on top of a comparatively stronger mass solid waste, alternative approaches can be considered. This includes use of uniaxial reinforcements placed horizontally (rather than along the slope) and anchored into the underlying mass. A second alternative includes the use of fiber-reinforced soil. A review of analyses for veneers reinforced using horizontally placed inclusions is presented in this section.

This section presents an analytical framework for quantification of the reinforcement requirements for reinforced veneers where reinforcements are placed horizontally and embedded into a comparatively strong underlying mass. Emphasis in this evaluation is placed on the assessment of an infinite slope configuration. This allows direct comparison of the different reinforcement alternatives.

Design criteria for reinforced soil structure have been the focus of significant debate (Zornberg & Leshchinsky 2001). Although different definitions for the factor of safety have been reported for the design of reinforced soil slopes, the definition used in this study is relative to the shear strength of the soil:

$$FS = \frac{\textit{Available soil shear strength}}{\textit{Soil shear stress required for equilibrium}} \qquad (4)$$

This definition is consistent with conventional limit equilibrium analysis, for which extensive experience has evolved for the analysis of unreinforced slopes. Current design practices for reinforced soil slopes often consider approaches that decouple the soil reinforcement interaction and do not strictly consider the factor of safety defined by Equation 4. Such analyses neglect the influence of reinforcement forces on the soil stresses along the potential failure surface and may result in factors of safety significantly different than those calculated using more rigorous approaches. Considering the normal and shear forces acting in a control volume along the veneer slope (or infinite slope), and assuming a Mohr-Coulomb shear strength envelope, Equation 4 can be expressed as:

$$FS = \frac{c + (N/L)\tan\phi}{S/L} \qquad (5)$$

where N = normal force acting on the control volume; S = shear force acting on the control volume; L = length of the control volume; c = soil cohesion; and ϕ = soil friction angle.

From the analysis of equilibrium conditions, the classic expression for the factor of safety FS_u of an unreinforced veneer can be obtained:

$$FS_u = \frac{c}{\gamma\, T \sin\beta} + \frac{\tan\phi}{\tan\beta} \qquad (6)$$

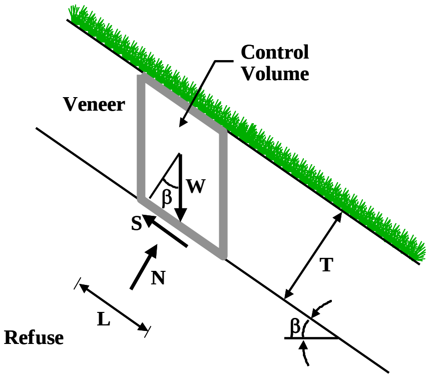


Figure 26: Unreinforced veneer.

Covers Reinforced with Uniaxial Geosynthetics Parallel to the Slope

Figure 27 shows a schematic representation of a cover system reinforced using uniaxial geosynthetics placed parallel to the slope. An infinite slope case is considered. In the case, the shear force needed for equilibrium of the control volume is smaller that the one in the unreinforced case. In this case, the shear force is defined by:

$$S = W \sin\beta - t_p L$$

where t_p = distributed reinforcement tensile stress of the reinforcement parallel to the slope.

When the geosynthetic reinforcements are placed parallel to the slope, the distributed reinforcement tensile stress is a function of the allowable reinforcement tensile strength (T_a) and the total slope length (L_T), as follows:

$$t_p = \frac{T_a}{L_T}$$

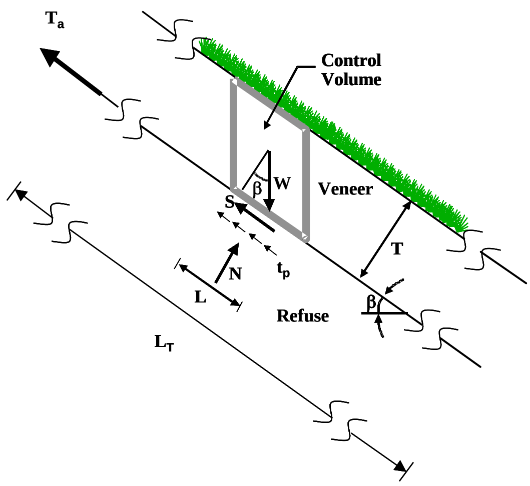


Figure 27: Schematic representation of a cover system reinforced using uniaxial geosynthetics placed parallel to the slope.

From limit equilibrium analysis, the factor of safety for the parallel-reinforcement case, $FS_{r,p}$, can be estimated as:

$$FS_{r,p} = \frac{\dfrac{c}{\gamma\, T\, \sin\beta} + \dfrac{\tan\phi}{\tan\beta}}{1 - \dfrac{t_p}{\gamma\, T\, \sin\beta}} \tag{9}$$

Equation 9 provides a convenient expression for stability evaluation of reinforced veneer slopes. It should be noted that if the distributed reinforcement tensile stress t equals zero (i.e. in the case of unreinforced veneers), Equation 9 leads to $FS_{r,p} = FS_u$.

Covers Reinforced with Horizontal Uniaxial Geosynthetics

Figure 28 illustrates a cover (veneer) reinforced using horizontal uniaxial geosynthetics. Also in this case, the shear and normal forces acting on the control volume are defined not only as a function of the weight of the control volume, but also as a function of the tensile forces that develop within the reinforcements. For the purpose of the analyses presented herein, the reinforcement tensile forces are represented by a distributed reinforcement tensile stress t_h, which corresponds to a uniformly distributed tensile force per unit height. For a given slope with layers of reinforcement t_h can be expressed by:

$$t_h = \frac{T_a}{s}$$

where T_a = allowable reinforcement tensile strength and s = vertical spacing.

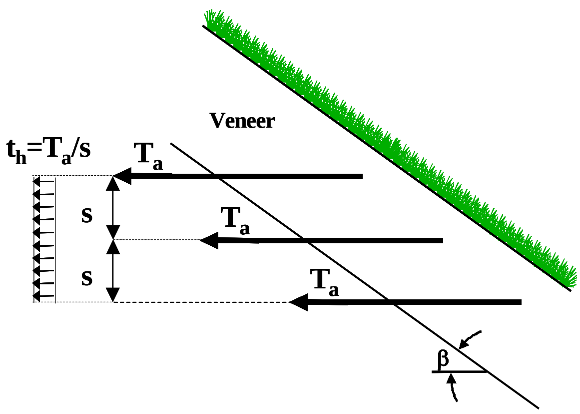


Figure 28: Veneer reinforced with horizontal uniaxial geosynthetics

From limit equilibrium analysis, the following expression can be obtained for the factor of safety $FS_{r,h}$ of a veneer reinforced with horizontal uniaxial geosynthetics:

$$FS_{r,h} = \frac{\dfrac{c}{\gamma\, T\, \sin\beta} + \dfrac{\tan\phi}{\tan\beta} + \dfrac{t_h}{\gamma\, T}\sin\beta\, \tan\phi}{1 - \dfrac{t_h}{\gamma\, T}\cos\beta} \tag{11}$$

Equation 11 provides an expression for stability evaluation of reinforced veneer slopes. It should be noted that if the distributed reinforcement tensile stress t_h equals zero (i.e. in the case of unreinforced veneers), Equation 11 leads to $FS_r = FS_u$

Additional aspects that should be accounted for in the design of reinforced veneer slopes include the evaluation of the pullout resistance (i.e. embedment length into the underlying mass), assessment of the factor of safety for surfaces that get partially into the underlying mass, evaluation of reinforcement vertical spacing, and analysis of seismic stability of the reinforced veneer.

Covers Reinforced with Randomly Distributed Fibers

A promising potential alternative for stabilization of steep landfill covers involves the use of fiber-reinforcement. Advantages of fiber-reinforcement over planar reinforcement in the stabilization of landfill covers are:

- Fiber-reinforcement is particularly suitable for stabilization of veneer slopes, as it provides additional shear strength under low confining pressures. A small increase of shear strength under low confinement has a significant impact on the stability of shallow slopes.

- Randomly distributed fibers helps maintaining strength isotropy and do not induce potential planes of weakness that can develop when using planar reinforcement elements.

- No anchorage is needed into solid waste as in the case of reinforcement with horizontal geosynthetics or at the crest of the slope as in the case of reinforcement parallel to the landfill slope.

- In addition to stabilizing the cover slopes, fiber reinforcement has the potential of mitigating the potential for crack development, providing erosion control, and facilitating the establishment of vegetation.

Relevant contributions have been made towards the understanding of the behavior of fibers. A soil mass reinforced with discrete, randomly distributed fibers is similar to a traditional reinforced soil system in its engineering properties but mimics admixture stabilization in the method of its preparation (Gray & Al-Refeai 1986; Bouazza & Amokrane 1995). Potential advantages of fiber-reinforced solutions over the use of other slope stabilization technologies have been identified, for example, for slope repairs in transportation infrastructure projects (Gregory & Chill 1998) and for the use of recycled and waste products such as shredded tires in soil reinforcement (Foose et al. 1996). Several composite models have been proposed in the literature to explain the behavior of randomly distributed fibers within a soil mass. The proposed models have been based on mechanistic approaches (Maher & Gray 1990), on energy dissipation approaches (Michalowski & Zhao 1996), and on statistics-based approaches (Ranjar et al. 1996).

Fiber-reinforced soil has often been characterized as a single homogenized material, which has required laboratory characterization of composite fiber-reinforced soil specimen. The need for laboratory characterization has been a major drawback in the implementation of fiber-reinforcement in soil stabilization projects. To overcome this difficulty, a discrete approach that characterizes the fiber-reinforced soil as a two-component (fibers and soil) material was recently developed (Zornberg 2002). The main features of this approach are:

- The reinforced mass is characterized by the mechanical properties of individual fibers and of the soil matrix rather than by the mechanical properties of the fiber-reinforced composite material
- A critical confining pressure at which the governing mode of failure changes from fiber pullout to fiber breakage can be defined using the individual fiber and soil matrix properties.
- The fiber-induced distributed tension is a function of fiber content, fiber aspect ratio, and interface shear strength of individual fibers if the governing mode of failure is by fiber pullout.
- The fiber-induced distributed tension is a function of fiber content and ultimate tensile strength of individual fibers if the governing mode of failure is by fiber breakage.

Figure 29 shows a schematic view of a fiber-reinforced infinite slope. The behavior of the fiber-reinforced soil mass depends on whether the failure mode is governed by pullout or breakage of the fibers. The governing failure mode of the fiber-reinforced soil mass depends on the confinement. A critical normal stress, $\sigma_{n,crit}$, can be defined for comparison with the normal stress σ_n at the base of the veneer. If $\sigma_n < \sigma_{n,crit}$, the dominant mode of failure is the fibers pullout. This is the case for cover system applications. In this case, the fiber-induced distributed tension t_f is defined by (Zornberg 2002):

$$t_f = \eta\, \chi\, c_{i,c}\; c + \eta\, \chi\, c_{i,\phi}\; \tan\phi\, \sigma_n \tag{12}$$

where $c_{i,c}$ and $c_{i,\phi}$ are the interaction coefficients for the cohesive and frictional components of the interface shear strength; η = aspect ratio (length/diameter) of the individual fibers, and χ = volumetric fiber content.

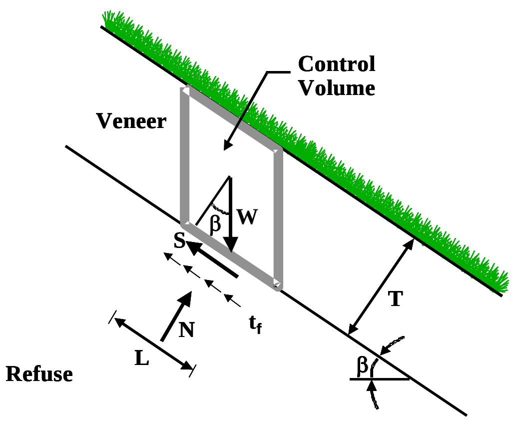


Figure 29: Veneer reinforced with randomly distributed fibers

Similarly, if $\sigma_n > \sigma_{n,crit}$, the dominant mode of failure is fiber breakage. Even though this is not generally the governing mode of failure for cover slopes the solution for this case is presented for completeness. The fiber-induced distributed tension t_f is defined by:

$$t_t = \sigma_{f,ult} \cdot \chi \tag{13}$$

where $\sigma_{f,ult}$ = ultimate tensile strength of the individual fiber.

In a fiber-reinforced veneer, the shear force needed for equilibrium of the control volume equals:

$$S = W \sin\beta - \alpha\, t_f\, L \tag{14}$$

where α is an empirical coefficient that accounts for preferential orientation of fibers. For the case of randomly distributed fibers considered herein α equals one.
From limit equilibrium analysis, the factor of safety for a fiber-reinforced veneer, $FS_{r,f}$:, is given by

$$FS_{r,f} = \frac{\dfrac{c}{\gamma\, T\, \sin\beta} + \dfrac{\tan\phi}{\tan\beta}}{1 - \dfrac{\alpha\, t_f}{\gamma\, T \sin\beta}} \tag{15}$$

Solutions were presented for the case of unreinforced, slope-parallel, horizontally-reinforced and fiber-reinforced veneers. As expected, additional reinforcement always leads to a higher factor of safety while increasing slope inclination would typically lead to decreasing stability. Yet, it is worth noting that increasing soil friction angle leads to increasing stability, when compared to the unreinforced case, only for the case of fiber reinforced slopes. Also, it should also be noted that increasing total height of the slope (or increasing total length) does not affect detrimentally the efficiency of horizontally placed reinforcements and of fiber reinforcement.

CONCLUSIONS

Geosynthetics have great potential to be used as cost-effective solutions for several engineering problems. This paper presented recent advances in geosynthetic products, on the utilization of these materials in reinforced soil structures and in environmental applications. Manufacturing of geosynthetics products allows incorporating recent advances in material sciences. Therefore, the expectation is that innovations in products, types and properties will continue to take place, adding to the already vast range of applications of these materials.

Geosynthetic reinforced soil retaining walls present better performance than traditional retaining walls under dynamic loadings and this has been demonstrated by a number of case histories of prototype structures that have withstood severe earthquakes. Thus, this type of structure can be cost-effective not only under static loading but also in regions where significant seismic activities are expected. New construction methodologies have also broaden the applications of geosynthetic reinforced soil retaining wall, which include new facing units and that reduces the construction time, costs and allow better aesthetic conditions for the final structure.

Investigations on the behaviour of large model reinforced walls built under controlled conditions, monitoring of real structures and theoretical studies have yielded the development of a practical method for the estimate of reinforcement loads, including the case of using cohesive backfill. This method is a significant advance on existing design approaches and will allow the construction of cheaper structures.

The use of geosynthetics has also led to major advances in environmental applications. While geosynthetics has been used in a number of applications in environmental project, this paper has described advances on the use of geosynthetics in landfills. Specifically, simple yet accurate formulations are now available for the design of liquid collection systems, which involve proper quantification of the thickness of liquid within drainage composites. Also, significant advances have taken place regarding the use of reinforcements for stabilization of steep cover systems. Approach include the use of geosynthetic reinforcements parallel to the cover slope, horizontal reinforcements embedded into solid waste, and fiber reinforcement of the cover soils. Overall, the use of geosynthetics has led to major advances towards the construction environmental systems that are cost-effective but that provide enhanced environmental protection.

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ATTACHMENT D

POST-CLOSURE SITE USE

Boston Harbor Islands
IslandCache Program

National Park Service
U.S. Department of the Interior

Site 3: Reconnection and Renewal

N 42º 19.612'   W 070º 59.256'

"Here is exemplified the commendable Old-World thrift, by which useless refuse is converted in prodcuts of value, by the aid of ingenuity and indusry."—M.F. Sweetser

Spectacle Island 101

Prior to European contact in the late 17th century, Spectacle Island had two drumlins connected by a tombolo. From an aerial view, the island greatly resembled a pair of spectacles. The City of Boston purchased the land in 1912, and over the course of forty years, added over 36 acres and over 80 feet of refuse and fill to the island, rendering the land unrecognizable from its original shape and character. You are currently standing on a man-made hill, terraced with retaining walls, roads and vegetation. On a clear day, visitors can see four lighthouses and more than half of the park's islands from the top of the drumlin.

A "Colorful" Island

Often called an "attractive place to conduct less than attractive business," some visitors could argue Spectacle Island has the most colorful history of all the islands in Boston Harbor. The location of Spectacle Island, a quick four miles from the busy port of Boston, made for a great location to conduct some of the island's less than desirable activities prevalent in a major city. In 1717, a quarantine station was erected on Spectacle Island, inspecting immigrants for infectious diseases before they entered the city. Spectacle Island also housed a horse rendering facility owned and operated by Nahum Ward in 1857, which processed more than 2,000 horses a year into hides and glue. Between the 1860s and 1910s, Spectacle also hosted a casino, brothel and a few resort hotels. When the city of Boston purchased the land in 1912, the island was zoned for use as a garbage site, and a grease reclamation plant. In addition to its industrial and commercial uses, Spectacle Island was also home to many families for several generations. To get a taste of what it would have been to live here, you can read about the last resident of Spectacle Island in the visitor center's exhibits.

Reconnecting and the "Big Dig"

A recent construction project—aptly named "the Big Dig"—removed over 15 million cubic yards of soil from the Central Artery corridor in order to generate space for two four-lane tunnels beneath the city. Over 4,400 barges were used to bring the excavated soil to the island, and "cap" off the varied history of the landscape. After laying 5 to 6 feet of top-soil, and planting over 20,000 plants, Spectacle Island stands today as the city's symbol of reconnection and renewal. The island is fully equipped with a state-of-the-art visitor center, which is powered by solar technology. The island also features "zero emissions" electric maintenance vehicles and self-composting toilets. You can reconnect with Spectacle Island by exploring the five miles of hiking trails, and walking along the west-facing beach.

Next Clue: Artifacts excavated during the "Big Dig" have revealed that Native Americans utilized this island long before the European settlers arrived. This evidence was discovered in the form of a midden—a large mound containing shell debris, animal bones, and stone tools—dating back to over 8,000 years ago.

N 42° 19.146'
W 070° 59.153'

United States Environmental Protection Agency

EPA/600/R-14/349 | November 2014 | www.epa.gov/ord

Closed Waste Sites as Community Assets: A Guide for Municipalities, Landfill Owners, and Regulators

Office of Research and Development

EPA/600/R-14/349

Closed Waste Sites as Community Assets: A Guide for Municipalities, Landfill Owners, and Regulators

Waste Management Branch
Land Remediation and Pollution Control Division
National Risk Management Research Laboratory
Office of Research and Development
Cincinnati, OH

EPA/600/R-14/349

Foreword

The US Environmental Protection Agency (US EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, US EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by US EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Cynthia Sonich-Mullin, Director
National Risk Management Research Laboratory

Executive Summary

Though closed landfill sites are often considered a liability to local governments, many communities have explored innovative practices to repurpose these facilities as community assets. Examples include open-space recreational uses such as parks, wildlife areas, and golf courses, as well as more construction-intensive applications such as parking lots and government or commercial buildings. In addition, more landfills are being developed as hubs for energy and materials recovery. Landfill gas is commonly captured for energy at landfills, and there is a growing interest is solar and wind power application at landfill sites. Some communities cluster recycling and materials recovery operations at their landfill sites, while others go so far as to reclaim closed landfill areas to recover buried assets and achieve more efficient site utilization. Since landfills remain a key component of integrated municipal waste management systems for the foreseeable future, communities should begin to consider landfill sites as potential community assets and plan for future community uses as part of facility conception and development.

This document provides an overview of the common approaches to utilize closed landfills as community assets, as well as the environmental and regulatory challenges faced when implementing these projects. All uses for closed landfills must ensure that the integrity of the final cover system is maintained to ensure protection of human health and the environment. Common challenges to the use of closed landfill sites include landfill gas and waste settlement. Landfill gas, which can be both explosive and toxic at elevated levels, must be controlled in a fashion to minimize buildup in enclosed spaces; site uses must not interfere with existing gas collection operation. As waste decomposes, the landfill settles, and this necessitates routine maintenance of any features placed on the landfill surface; building construction must be undertaken with care and consideration of the long-term topographic changes. A series of case studies document the typical challenges and opportunities encountered by communities attempted to utilize closed landfills as a resource.

Many opportunities exist to better utilize closed landfill sites as community resources, especially when they are discussed early in the design and planning stage of the facility. Several options/factors should be considered to enhance use of a landfill site after closure. When selecting a facility location, the proximity to potential facility users, other industries, and utilities should be considered. The

community should be involved in the decision-making process from the beginning. Site infrastructure should be planned from the beginning to accommodate future site uses. Landfill disposal cells and their associated infrastructure should be configured and located to best conform to future uses and to minimize construction requirements in later years. Technical innovations that result in the most efficient utilization of the facility as an asset should be implemented where possible. Operating the landfill as a bioreactor promotes waste stabilization and reduces long-term issues with landfill gas and settlement. Opportunities to maximize future materials recovery should be considered early, even when the material value does not currently merit recovery.

EPA/600/R-14/349

Notice

The US Environmental Protection Agency (US EPA) through the Office of Research and Development funded and managed the research described here under contract order number: EP-C-10-060 to Computer Science Corporation, VA. It has been subject to the Agency's review and has been approved for publication as a US EPA document. Use of the methods or data presented in this manual does not constitute endorsement or recommendation for use. Mention of trade names or commercial products does not constitute endorsement or recommendation.

Contents

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List of Abbreviations, Acronyms, and Initialism

CHP	Combined Heat and Power
CSP	Concentrated Solar Power
GCCS	Gas Collection and Control System
LCRS	Leachate Collection and Removal System
LFG	Landfill Gas
LMOP	Landfill Methane Outreach Program
MSW	Municipal Solid Waste
MW	Megawatt
NMOC	Non-Methane Organic Compound
NREL	National Renewable Energy Laboratory
NSPS	New Source Performance Standards
PCC	Post-Closure Care
PV	Photovoltaic
RCRA	Resource Conservation and Recovery Act
US	United States
US EPA	United States Environmental Protection Agency

1 Introduction

For several decades, sanitary landfills have provided for the bulk of municipal solid waste (MSW) management capacity in the US. Despite a growing migration toward recycling and energy recovery, landfills will remain an integral part of the nation's solid waste infrastructure for the foreseeable future. Landfill owners and operators are required by federal rules to follow location, design, and operational requirements developed to protect human health and the environment. A key component of these regulations includes requirements for properly closing the landfill after waste acceptance ceases, followed by maintaining and monitoring the site for 30 years of post-closure care (PCC).

Landfill owners and surrounding communities often view closed landfills as both an environmental and economic liability, largely due to the required long-term maintenance and monitoring. However, a variety of opportunities exist to utilize closed landfills for productive purposes so the space can be transformed into an asset for the surrounding community. Throughout the US, communities have converted closed landfills into recreational areas, natural habitats, energy recovery parks, and hubs for sustainable materials management operations. The combined experiences of these efforts provide a strong knowledge base for communities to utilize when planning for future productive utilization of their own operating or recently closed landfills.

The likely long-term role of landfills for MSW management, the lessons learned from repurposing closed disposal facilities as community resources, and the desire to manage our nation's waste in a more sustainable fashion all present communities with a new opportunity: planning future waste disposal facilities from the beginning for use as a community asset. To date, decisions regarding closed landfill utilization have occurred toward the end of the facility's operating life or after closure. By this time, multiple opportunities for beneficial utilization of facility component materials or energy have been lost, or at the least, have become more challenging and expensive to capture. Community leaders, planners, engineers, and operators should consider from project conception the opportunities to leverage existing facility requirements to maximize future asset potential.

A major challenge with utilizing waste disposal sites as community assets is balancing the desire to utilize space and materials for productive use with the need to meet the primary requirement of the facility – protection of human health and the environment. The utilization of an MSW landfill after closure can be a complex undertaking; environmental, health and safety, geotechnical, energy and reclamation issues must be considered when evaluating reuse options for a closed landfill site (summarized in Figure 1-1). The earlier that the desired site uses are identified, the more opportunities will be available to strike the necessary balance between site utilization and meeting protective requirements.

The objective of this report is to provide MSW landfill owners, municipal officials, engineers and local residents with an introduction to the considerations associated with using closed MSW landfill sites as community assets, and planning for future asset utilization at new sites. The focus of this report is on MSW landfills only and does not consider other types of property (e.g., brownfields) that may have some similar technical challenges or potential reuse opportunities. Through the presentation of background information, various resource recovery options, and selected case studies, this report can also serve as a first step for communities in the planning process to help leverage spaces and resources at existing and future landfills as assets.

This report discusses guidance and regulations that have been developed throughout the US related to the use of closed landfill sites. The report additionally discusses planning and conceptualizing landfills as community assets from the outset, and includes a description of innovative approaches for more sustainable landfill management such as bioreactor landfills and landfill reclamation. The report identifies the advantages of involving the community at the earliest stages of development and for designing the landfill to be compatible with end uses appropriate for a site's location, layout, environmental controls, structural requirements, and potential for future recovery of disposed waste.

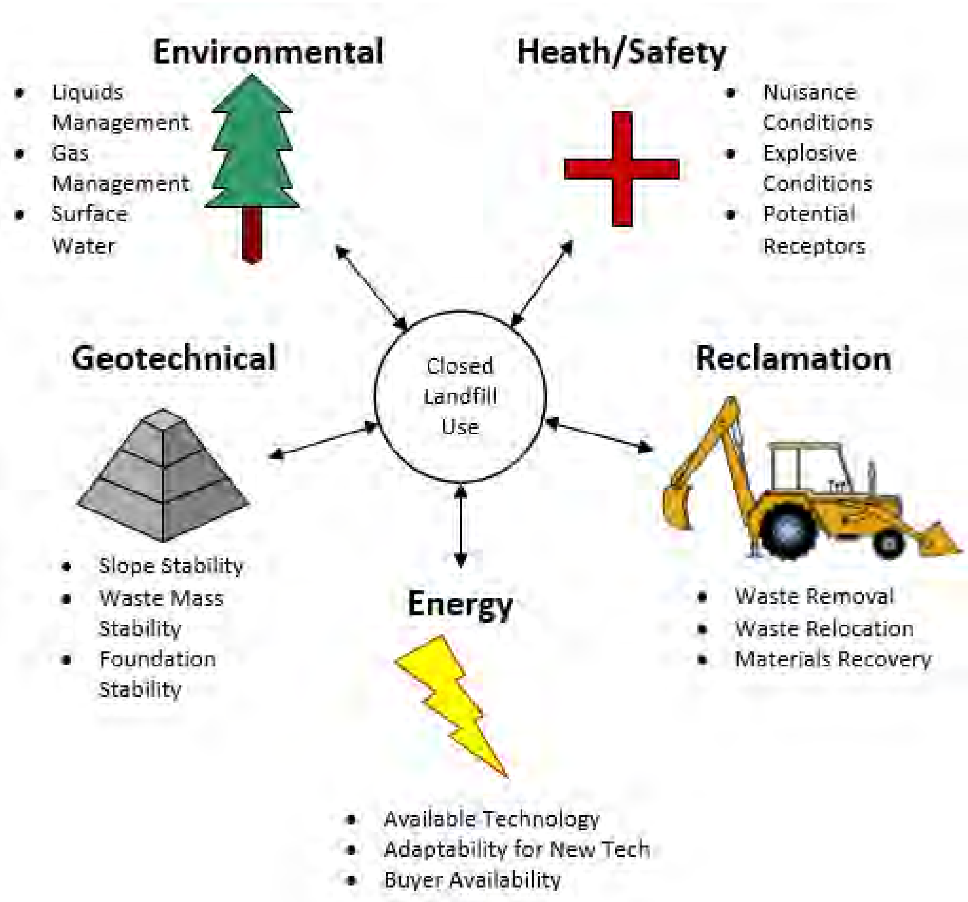

Figure 1-1. Presentation of Major Categorical Considerations Related to the Use of Closed Landfills

The report is organized into six chapters. Chapter 2 provides specific details on the common environmental considerations for project developers, including a specific focus on the regulatory constraints that must be addressed. Chapter 3 focus on highlighting opportunities for successful utilization of closed landfills as assets, both for community uses and for energy and materials recovery as well as the challenges that should be expected with such activities. Chapter 4 presents a series of examples of several projects where closed landfills successfully serve as community assets. Finally, in Chapter 5, the opportunities for maximizing site utilization for community benefit from the early planning and design stages of a project are summarized. References are provided in Chapter 6. Included in Appendix A of this report is a detailed listing of identified resources that planners, developers, engineers and regulators can consult to find additional information related to beneficial utilization of waste disposal sites as community resource.

2 Regulatory and Environmental Considerations

2.1 Overview

MSW Landfills in the US are regulated by the US Environmental Protection Agency (US EPA) through the Resource Conservation and Recovery Act (RCRA), specifically Subtitle D of RCRA, which was developed to provide provisions for landfills to be operated, monitored, and closed to mitigate human health and environmental impacts. Subtitle D rules dictate that facilities must complete a PCC plan that details how the owner or operator will continue to care for the property after the site closes until the post-closure period ends. PCC must be conducted for a minimum of 30 years, but may be decreased or increased (by the state or jurisdiction with regulatory authority over the site) based on the conditions at the site. At a minimum, the typical MSW landfill PCC plan consists of maintenance and monitoring activities that will be performed at the facility, contact information for the responsible entity during the PCC period, the frequencies that maintenance activities will occur, and the planned uses of the property during the post-closure period.

Since the PCC period of a landfill may go on for many years, it is important when evaluating the future use of a closed landfill, or when planning for the new facilities to accommodate later beneficial uses, that the use does not interfere with the required day-to-day care activities of the landfill or create unsafe conditions. Depending on specific site characteristics, a closed MSW landfill is likely to have the following ongoing activities to control or prevent hazards:

- Maintenance of the integrity and effectiveness of the landfill's final cover
- Maintenance and operation of the leachate collection system
- Maintenance and operation of groundwater monitoring system and
- Maintenance and operation of the gas monitoring system.

Even after the PCC period of a landfill ends, there may still be a need to continue maintenance or care based on potential exposure pathways and risks (this is sometimes referred to as custodial care). Ideally, an MSW landfill would be designed with an intended final use planned, so as the appropriate preparation and development of the site accommodates for potential stressors or failures that may occur based on the intended end use (ITRC 2006). If the originally intended end use of a facility is altered, the newly-proposed end use must be evaluated based on any new potential risks or exposures that may result from the use change.

In this chapter, the regulatory and environmental considerations are discussed in greater detail. First, detailed regulatory requirements related to landfill closure and site reuse are described, both in terms of US federal requirements and selected state requirements. Then, environmental considerations that represent the greatest source of concern with respect to landfill sites (leachate, landfill gas, direct exposure) are discussed.
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2.2 Regulations

The key landfill-related regulations for closed MSW landfills in the US, found in RCRA Subtitle D, lay out minimum specifications that must be implemented upon closure and the subsequent PCC period. State governments have either directly adopted the Federal Subtitle D rules, or they have developed more rigorous requirements that provide additional protection beyond Subtitle D. While the Subtitle D rules not specific about PCC uses, some states do provide outline detailed requirements or guidance for the use of closed landfills. In the rest of this chapter, the US federal rules for closure and LFG are briefly summarized, followed by a description of some of the state-specific landfill regulations that address the use of landfills following closure.

US Federal Regulations

Subtitle D requires MSW Landfills to install a final cover system equal to that of the bottom liner system or, if no liner system is present, with a permeability of less than $1x10^{-5}$ cm/sec. The cover system must contain an infiltration and an erosion layer. Figure 2-1 provides a generalized cross section of a typical final landfill cover system. The ultimate goals of the closure criteria are to minimize infiltration and erosion, which will consequently aid in minimizing future environmental impacts (as described later in this chapter).

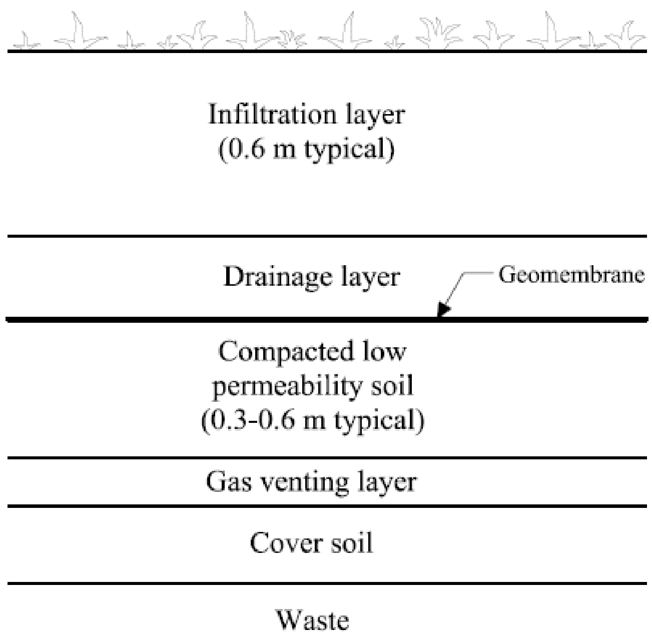

Figure 2-1. Typical Cross Section of a Landfill Cover System Including Major Components

During the PCC period, the Subtitle D regulations dictate that the landfill owner complies with several specific requirements. These requirements are outlined in Table 2-1.

Table 2-1. PCC Requirements for MSW Landfills under RCRA Subtitle D

PCC Requirement
Maintain the integrity and effectiveness of any final cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and prevent run-on and runoff from eroding or otherwise damaging the final cover
Maintain and operate the leachate collection system.
Monitor the ground water
Maintain and operate the gas monitoring system

Although design requirements for closure and maintenance requirements for closed landfills are specified in Subtitle D, there are no federal standards for specific use of closed landfills. The generalized language in Subtitle D references requirements that must be met for any post-closure "disturbance" to the landfill site:

> *§258.61(c)(3) "…Post-closure use of the property shall not disturb the integrity of the final cover, liner(s), or any other components of the containment system, or the function of the monitoring systems unless necessary to comply with the requirements in this part 258. The Director of an*

> *approved State may approve any other disturbance if the owner or operator demonstrates that disturbance of the final cover, liner or other component of the containment system, including any removal of waste, will not increase the potential threat to human health or the environment."*

The Subtitle D regulations require that MSW landfills monitor for off-site migration of landfill gas and they do require that off-site odor must be controlled; while these regulations do not specifically require the installation and operation of a GCCS, several US rules under the authority of the Clean Air Act require that landfills of a given size and with a given non-methane organic compound (NMOC) emission rate must collect and control LFG. These regulations include the New Source Performance Standards (NSPS) for MSW landfills, the National Emission Standards for Hazardous Air Pollutants, and the Emission Guidelines for MSW landfills. Under these rules, landfills that exceed the designated thresholds must construct and operate a GCCS; the GCCS and landfill surface monitoring described in the previous subchapter are required under the authority of these regulations. Operation of the GCCS must continue until the landfill is closed and a closure report submitted, the GCCS was in operation for a minimum of 15 years, and the calculated emissions of NMOCs are less than targeted thresholds.

State-Specific Conditions for Use of Closed Landfills

Since state environmental regulatory agencies have the option of developing and adopting rules at least as protective as the federal regulations, several state agencies have taken the opportunity to customize and expand regulations for closed landfill use to fit the unique interests and perspectives of their state. For most state departments of environmental protection (at least 75%), however, a nearly identical recitation of the federal regulations are stipulated. Example of state-specific closed landfill use regulations are presented below. The examples highlighted are not intended to be inclusive of all state-specific regulatory requirements, but rather to provide the reader with a distribution of examples from several states in different areas of the country. Developers and landfill owners should always consult the appropriate regulatory agency with jurisdiction over their site to understand all current applicable regulations for their site. References for the regulations below are provided in Chapter 6 as well as in Appendix A of this report.

The few states that provide additional regulatory instruction incorporate language prohibiting specific types of end uses; describe the application and permit requirements for specific end uses; or provide additional conditions that must be met depending on if construction will occur on or near the waste extents of the landfill. For example, Maine, North Dakota and Wisconsin rules provide a list of prohibited activities for closed landfills (MDEP 2013, NDAC 2009, WAC 2013). The types of activities that are restricted include: construction of buildings on top of or within a specific distance of the waste boundary; use for agricultural purposes (haying may be allowed on a site-specific basis in Maine); grazing; or excavation of the final cover or any waste material.

Texas has a thorough subchapter outlining the use of land over closed MSW landfills. Within the subchapter, the process for obtaining clearance for development of an enclosed structure over a closed MSW landfill unit or a closed MSW landfill in post-closure care is provided. A permit modification or amendment application must be submitted and approved by the regulatory agency. Specific operational requirements outlined in the rule must be followed for construction of a structure. Examples of some of the operational requirements include LFG control (LFG monitoring and monthly reporting of methane sampling), meeting air pollution criteria, and providing proper ventilation. Construction of an enclosed area to be occupied by people under the natural grade of the land or under grade of the final cover is prohibited (TAC 2014).

In Pennsylvania, as part of the initial permitting of an MSW landfill, a two-part application process must be fulfilled and approved. Within the second part of the application, a post-closure land use plan is required describing the proposed use of the facility after closure. The application should include "a discussion of the utility and capacity of the re-vegetated land to support a variety of alternative uses, and the relationship of the use to existing land use policies and plans." The application must explain how the proposed use of the landfill will be achieved and what necessary support activities are needed to fulfill the proposed land use. The application should also identify the considerations that have been assessed to ensure that the post-closure land use is consistent with landowner plans and the applicable State and local land use plans and programs (PaCode 1988).

California requires all non-irrigated land uses of sites implementing closure or closed sites to submit proposed uses to multiple government agencies. One agency specifically reviews and approves projects that involve structures near or on top of the waste. The regulations require that construction of structural improvements on top of landfilled areas during post-closure period must meet several conditions including having automatic methane gas sensors, prohibiting enclosed basement construction, mitigation of the effect of gas accumulation and differential settlement, placement of utilities above the low permeability layer of final cover, acceptable piling installation and periodic monitoring of methane gas inside all building and underground utilities. Additional specific design provisions are listed for any construction that occurs within 1,000 feet of the waste disposal area; these conditions are meant to prevent gas migration into building structures (CIWMB 2014).

Massachusetts regulations require the post-closure use of landfills be reviewed and approved by their state regulatory agency. The usage unless otherwise determined by the agency must not alter the final contours of the landfill, disturb the integrity of the final cover, and all erosion and sedimentation control must be maintained. Additionally, if construction occurs during the post-closure care period of the landfill, buildings must be placed above-grade (basements that penetrate the low permeability of the final cover are prohibited), constructed to prevent gas accumulation within the structure (gas monitoring and warning systems are required; an active gas venting system may be needed), and utility connections should be designed with flexible connections (CMR 2014).

Some states have created guidance documents for owners and operators of landfills to assist in landfill use decision-making. Guidance documents typically provide added insight to the environmental considerations of choosing an appropriate use for an old landfill. In Appendix A, references to guidance documents for the following states have been included: Florida, Indiana, New Jersey, Ohio, Texas, and Massachusetts.

2.3 Environmental Drivers

Landfills have the potential to negatively impact water (surface and groundwater) and air resources, thus landfills are required by federal regulations (RCRA) and state regulations to be designed and operated to mitigate these potential negative impacts. During the operational years and throughout the post-closure years of a landfill facility, sites generally have well-established standards to follow to prevent pollution and to control the materials and people that are entering and leaving the facility. When a closed landfill is utilized for another purpose in addition to waste management, the activities at the facility may change, but the ongoing environmental responsibilities of the owner and operator remain. In consideration of these environmental responsibilities, it is important to have a good understanding of the major pathways of environmental risk that must be considered when integrating new activities with a landfill site.

Leachate

Leachate forms as a result of the contact of waste with water. When waste is first disposed of in a landfill, some moisture exists within the waste, but most leachate results when rainwater infiltrates into the landfill. At older landfills with no protective liner systems, leachate migrates from the bottom of the landfill into the groundwater; the Federal Subtitle D landfill regulations outlining design (including liner design), operation, monitoring, and financial assurance requirements for MSW landfills were promulgated in 1991. At sites with engineered liners, the leachate is removed via the leachate collection and recovery system (LCRS) and then properly treated. At some sites, leachate "outbreaks" or "seeps" on the side slopes of the landfill occur and must be appropriately addressed to avoid any environmental contamination or human contact.

Leachate can contain a variety of chemicals as highlighted in Table 2-2. Some of these chemicals occur as a result of the waste decomposition reactions in the landfill, while others originate from products or chemicals disposed of in the landfill. When discharged to surface water, leachate poses an ecological risk. When mixed with a drinking water source (such as an aquifer), the water may become contaminated to levels that are no longer safe to drink.

Table 2-2. Chemical Constituents of Concern in MSW Landfill Leachate, in Order of Most to Least Predominant (adapted from Kjeldsen et al., 2002)

Chemical Constituent Category	Specific Chemicals
Dissolved organic matter	Quantified as biochemical oxygen demand, chemical oxygen demand, total organic carbon, or volatile fatty acids
Inorganic major constituents	Total dissolved solids, calcium, magnesium, potassium, manganese, ammonium, iron, chloride, sulfate, bicarbonate
Trace metals	Arsenic, cadmium, chromium, copper, lead, nickel, zinc
Trace xenobiotic organic compounds	Hydrocarbons, solvents, pesticides, pharmaceutical compounds

Landfill operators use several techniques and operational practices to mitigate the possible environmental and human health effects of leachate; many of these are required by regulation. During operation, leachate production is minimized through a process referred to as run-on control and runoff control. By minimizing the amount of water that infiltrates into the landfill, the amount of leachate ultimately generated is reduced. At a closed landfill site, infiltrating moisture is controlled through the placement of an engineered cap designed to shed stormwater off the landfill. Thus it is very important that regardless of the final use of the landfill site, the integrity of the cap is maintained and that the stormwater management system continues to function as designed.

At lined facilities where leachate is captured by the leachate collection and removal system (LCRS), the operator minimizes potential impact on the environment by removing the leachate in a timely fashion so that the head on the liner is minimized. This requires that pumps be operated and maintained, and the LCRS pipes be routinely inspected and if necessary cleaned. An important component to any leachate operation plan is routine monitoring of leachate volumes (and possible depths). For closed landfills, even though the amount of leachate should be reduced because of the presence of the final cover system, the LCRS and its associated infrastructure must continue to be operated and maintained. Sites in PCC uses must accommodate this infrastructure, keep unauthorized personnel or visitors away from sensitive areas, and provide necessary access for authorized personnel to service and monitor the LCRS as needed.

An additional element for related to leachate issues, at both lined and unlined landfills sites, is a groundwater monitoring system. Groundwater monitoring wells are place at the perimeter of the landfill units, both up-gradient of the landfill (to assess the water before it passes under the landfill) and down-gradient (to assess the water after it passes under the landfill). By measuring the concentration of chemicals in the groundwater on a periodic basis (usually twice per year), the operator can evaluate how well the landfill is performing with respect to leachate minimization and containment, and take actions if needed. Groundwater monitoring will continue at closed sites repurposed for other community uses. Similar to the

LCRS infrastructure, the monitoring wells must be protected and the site must be configured and maintained in a manner to allow access. Also very important is providing careful thought to the location of other infrastructure or activities near monitoring wells that might result in future contamination; some activities at a closed landfill site might by necessity require the use of chemical products, that if spilled, could result in groundwater contamination and diminish the efficacy of the monitoring well network.

LFG

LFG is generated from the decomposition of organic materials in the waste stream (e.g., food, yard waste, paper products) and is predominantly comprised of an approximate 50/50 mix by volume of methane and carbon dioxide (though trace amounts of other gases will also be present). As LFG is generated within the landfill, pressures develop and cause the gas to migrate from the landfill to the lower pressure atmosphere; gas migrates to the top of the landfill, but may also migrate to the side or bottom of the landfill as well.

LFG can prove problematic for landfill sites for several reasons. First, the methane can be explosive when mixed with oxygen in the right proportion; this is a major concern for buildings (or any structure with an enclosed space) that is constructed on or adjacent to a landfill. Second, the trace components (e.g., hydrogen sulfide) contained with LFG are a source of odors and can also be toxic at elevated concentrations. Table 2-3 summarizes issues with methane and one of the more highly cited problem trace gases, hydrogen sulfide. Finally, landfill gas includes different chemicals that are potent greenhouse gases, most notably methane.

Table 2-3. Selected LFG Components of Concern Related to Human Health and Site Safety

LFG Component	Potential Effect
Hydrogen Sulfide	Has a very low odor threshold and nuisance odor (rotten egg); Can cause irritation to the respiratory system, eyes, or skin; Specific gravity greater than air, so gas tends to accumulate in low lying areas or buildings with poor ventilation; At higher concentrations, it can be fatal.
Methane	Accumulated concentrations in the presence of oxygen can create explosive conditions; Increases the risk of injury and damage due to explosion and fire.
NMOC	Contains compounds that can be toxic or otherwise hazardous to humans, may contain odorous compounds

In a similar fashion as described for leachate, operators use a variety of techniques and operational practices to minimize potential issues with LFG. Maintaining proper cover soil placement, along with good run-on and runoff practices, can lessen LFG issues, as soil cover can help attenuate gas migration and additional moisture promotes gas production. Upon closure, the final cover system performs these roles, and thus the importance of maintaining the cover and stormwater controls systems as described for leachate control are equally true for LFG control.

Depending on either regulatory requirements or site-specific objectives, the operator may install a gas collection and control system (GCCS). This will normally consist of vertical and/or horizontal wells placed within the waste that are connected to a piping network. The piping is in turn attached to a mechanized extraction system that applies a vacuum to extract the gas to a flare station or some type of energy recovery system (for older sites, gas wells may be vented to the atmosphere). Integrating the GCCS with other site uses can prove a challenge, as the gas collection infrastructure will be dispersed all over the surface of the landfill, including both extraction points (well heads) and buried collection pipes. Operation of the GCCS will continue for many years after closure, and post-closure sites uses must accommodate the GCCS infrastructure. Unauthorized personnel or visitors must be kept away from sensitive areas, while authorized personnel must be provided sufficient access to service and monitor the GCCS as needed. Any new infrastructure constructed on or near the landfill must factor in the location of the GCCS wells and pipes to avoid damage and potential environmental release.

Finally, regulatory requirements normally necessitate that potential LFG migration outside of the landfill be monitored, both at the surface of the landfill and the perimeter. Surface monitoring involves measuring concentrations at the surface of the landfill using a portable meter by walking the landfill in transects. Perimeter monitoring will be conducted akin to groundwater well monitoring, but the gas monitoring probes will be installed in the unsaturated zone above the groundwater table. Monitoring may also be required in the enclosed spaces of any structures on or adjacent to the landfill. Future site uses must accommodate these monitoring requirements.

Direct Human Exposure

An additional category of possible exposure, one that would less frequently be encountered at closed MSW landfill sites, is direct exposure to wastes (or soils contaminated as a result of waste, leachate or LFG). When a landfill is closed, in addition to the final soil cover layer, the engineered cap will be constructed on top, and thus wastes should remain buried unless later disturbed. Direct exposure is a more common issue at closed hazardous waste sites or brownfield sites, where chemicals may be spilled or purposefully added to the land over time.

Developers and owners of closed MSW landfill sites should still be cognizant of potential direct exposure pathways as a result of waste disturbance. During site maintenance of infrastructure or construction activities, waste materials may be exhumed or exposed, requiring immediate cover and proper disposal if removed from the site. In addition, routine landfill inspection should consider possible waste exposure as a result of severe waste settlement, burrowing animals, or erosion.

3 Opportunities for Community Use of Landfills

3.1 Overview

When considering potential end uses of a closed MSW disposal facility, landfill owners, along with municipal government officials and community planners, have a variety of options that can be explored. Table 3-1 presents an overview of the more common beneficial uses of closed landfill sites. These uses range from those with heavy community interaction (such as a park), to those where the community is benefited through the creation of new energy (placement of solar panels on top of closed landfills). Landfills can serve as an asset to their surrounding community through many avenues. In areas where undeveloped land may be difficult to find, or come at a premium (e.g., densely populated areas with limited green space), the utilization of the open space provides a very tangible benefit to local residents.

Table 3-1. Opportunities of Post-Closure Landfill Usage

Opportunity	Description
Recreation	Recreational opportunities range from less intensive and publicly restricted uses, such as a habitat preserve, to more intensive activities such as a sports complex (e.g., ball field, golf course). Recreational uses may be comprised of primarily open space or they may include amenities such as restrooms, concessions stands or other structures and features.
Agriculture	Agricultural uses (e.g., crops, haying,) can include planting shallow root crops, which may also substitute for the vegetative layer of the closed landfill.
Structural features and buildings	Parking lots, maintenance buildings, retail stores, and other structures have been constructed on old landfills. Most structures built on former waste disposal sites are relatively light in nature, although some projects have involved heavier infrastructure. A landfill site can also serve as a hub for other sustainability-oriented purposes, including environmental educational centers for the community, a location for dropping off recyclables, a center for donating and claiming used or unwanted items, and a drop-off center for household hazardous wastes.
Energy generation	Landfill gas (LFG), a product of waste decomposition, can be collected and utilized as an energy source; this is a relatively common practice at larger landfills. Placement of solar panels and wind turbines has also been recognized as a potential good use for landfill sites depending on the geographic location of the landfill and other factors. Landfills that utilize technologies to create energy can generate revenue and reduce greenhouse gas emissions by offsetting fossil fuel use.
Landfill reclamation	Reclaiming (or mining) a closed landfill provides an opportunity to remove waste from problematic locations, which may otherwise lead to potential risk to human health and the surrounding environment, so that land use can be maximized and may also result in the recovery of potentially valuable materials (e.g., metals, combustibles, soil).

When assessing the utilization of a landfill site as a community resource, either an existing facility or one under planning, some problematic issues will pose a challenge to implementing the desired outcomes and necessitate the implementation of remedial or precautionary measures. Table 3-2 presents a summary of the types of challenges typically encountered. It is important to remember landfills are permitted facilities and any changes to the site will require compliance with permit conditions or a modification of the permit; in cases where a change to the permit is needed, the appropriate regulatory permitting authority must be contacted. Regulatory issues are described in greater detail in the previous chapter. The benefits and challenges of utilizing landfill sites as community assets are discussed throughout the report.

Table 3-2. Listing of Key Challenges of Post-Closure Use of Landfills

Challenge	Description
Maintaining cover system integrity	Closed landfills are required to have an engineered cover system. Regular maintenance activities are required to monitor the condition of the cover system and repair detected

Challenge	Description
	problems. Some beneficial uses might result in cover system damage; inspection and maintenance is required to avoid excess leachate generation, LFG migration, and exposure to waste materials.
Leachate management	Leachate is the liquid that results when water contacts waste. Many landfills will have an operational component for leachate management, such as collection and removal from the landfill and subsequent treatment that must continue after the site has been closed regardless of final use. As leachate represents a potential human health risk when exposure occurs, the leachate system needs to be inspected and maintained to avoid any releases.
LFG management	A gas collection and control system (or a passive LFG venting system) must be operated, maintained, and monitored to minimize migration to LFG and prevent explosive conditions that can arise when LFG accumulates within buildings or confined spaces; this would be a particular concern for any structure built on top of an area of former waste disposal. LFG use in energy recovery applications (particularly those involving direct use) may necessitate treatment of the gas to remove undesirable constituents. The LFG collection, treatment and utilization system must continue to operate until LFG amounts are sufficiently low, regardless of final use.
Groundwater monitoring	Landfills must monitor groundwater until the site's regulatory permit allows this activity to cease. New site uses must still accommodate the presence and access to the groundwater monitoring wells for periodic sampling. Accidental release of chemicals to the ground from other site activities must be prevented.
Stormwater management and erosion control	Appropriate stormwater management and erosion control plans must be followed to prevent damage and wear to the cover system and appropriately convey stormwater to the surface water management system. These activities must continue regardless of final site use and must be integrated into any planned site reconfiguration.
Surface water protection	Similarly to groundwater contamination, surface water quality can be affected by leachate seeps or from inadequate stormwater and erosion controls. Proper monitoring and maintenance of leachate, stormwater conveyance and the cover system are needed to reduce these impacts.
Settlement	Landfill settlement results from waste consolidation and decomposing in the landfill. Settlement can impact the foundation of buildings or other structures, as well as utility connections or other site features, and can damage the cover system and create unsafe conditions at the surface of the landfill. Structures must be designed to accommodate settlement and monitored for the detrimental impacts of settlement (e.g., cracking, depressions).
Landfill infrastructure	Managing some of the previously-detailed issues requires the effective performance of landfill containment and control infrastructure. Landfills have a mix of infrastructure built before (if bottom liner system was included), during, and after waste was placed. Any new activities on the site must not negatively impact these vital components for landfill performance.
Building/structure stability	Building/construction projects on top of the landfill can be a challenge because the structure must be designed to withstand potential settling issues, address potential LFG migration, and address other factors to ensure proper functioning of the closure system (e.g., avoid interference with the cap system).

The development of landfill sites into an area that serves as a community asset can take several forms. Some assets serve as direct benefits to the community, such as making available new land area for community activities, wildlife habitat, commercial ventures, or less direct uses such as energy and materials recovery. This chapter focuses on these uses, providing additional details and considerations regarding typical practices, technical considerations, and unique challenges.

3.2 Recreational Use

The use of old landfills for community recreational purposes provides an opportunity to enhance leisure amenities for the public and potentially improve property values in the surrounding area. These applications are among the most common beneficial uses of closed landfill sites. Benefits with respect to creation of community recreational space include providing desirable green space to heavily urbanized areas, expanding the availability of nature trails and sports activities to promote community health and wellness, and restoring natural habitats and providing an area to host local wildlife educational programs.

Recreational activities range in complexity from serving as primarily open space with no structural amenities to highly-developed sports complexes with numerous structures. Depending on the characteristics of the landfill, and the attributes desired by the community, a repurposed landfill may incorporate one or many different recreational functions at a site. When determining an appropriate recreational use for an old landfill, in addition to addressing the needs of the community, there are many considerations that should be accounted for. The advantages of and concerns with the major types of recreational use projects are elaborated upon below.

Nature Sanctuary/Habitat Creation

The establishment of wildlife habitat areas provides several benefits when compared to the standard closure practice of planting a monoculture of grass on top of the landfill. This practice entails using a variety of vegetation and landscaping features that meet the objectives of the final cover system (minimize infiltration of liquids into the waste and properly controlling stormwater), and in addition provide a more natural setting for wildlife and recreational enjoyment. With the selection of vegetation appropriate to the local climate, including native and/or drought-resistant species, this approach offers potential operational cost savings related to vegetation maintenance. Wildlife habitats created to have a natural appearance should have limited mowing needs in comparison to the grass mowing required with closed landfills only covered in grass. The reduced fertilizer needs of wildlife areas additionally may also result in cost savings (Simmons 1999). Some maintenance controls such as weeding, and inspection and removal of invasive plant species may be necessary to maintain natural habitats.

To successfully launch habitat creation, a pre-development survey should be conducted. These surveys are intended to identify existing species in the area and to characterize the natural prevailing conditions necessary for the habitat. Once the survey has been performed, restoration of the landfill site will normally follow one of three paths (Simmons 1999). In some cases, the natural regeneration of the habitat takes place with little to no human interference. Alternatively, the basic habitat requirements can be first created, including the establishment of vegetation and related landscape features, and then minimal interference takes place during natural development. Lastly, the habitat features can be established and maintained over time to meet desired outcomes.

As with all post-closure landfill uses, care must be taken to maintain the integrity of the cover system functions and to protect both the landfill infrastructure and potential users of the area. Efficiencies and potential cost savings can be realized if closure system components (e.g., GCCS, stormwater drainage structures) are designed in conjunction with the wildlife habitat. If the pre-development survey indicates that wildlife species that inhabit the area might pose a damage risk to the cover system and infrastructure (e.g., burrowing animals damaging geomembrane caps), then provisions such as placement of a stone/cobble above geomembrane should be incorporated into the cover system design to prevent damage to the geomembrane. Similarly, damage to the cap with root penetration should be considered when selection vegetation for closure cap and development of vegetation maintenance plan.

Parks and Sports Complexes

Parks or sports fields that consist of primarily open spaces carry some advantages over more complicated recreational approaches because concerns with accumulation of gases within buildings are eliminated. From a surface water management perspective, the needs of open recreational areas are generally not in conflict with closure standards for landfills; rainfall runoff will need to be drained off regardless and conditions of ponded water should be avoided. Open recreational sites may have picnicking sites, benches and trails, but there are typically no structural buildings. Similar to those concerns identified when constructing open spaces for wildlife habitat, care must be taken in more heavily trafficked recreational areas to protect the cover system and the related infrastructure. More maintenance will certainly be required for these types of activities. The installation of signs or similar features to identify areas that should be off-limit or treated with caution may be warranted.

With more user-intensive recreational development projects, a larger number of occupants and activities may be expected, in addition to the presence of one or more structures. Buildings associated with recreational parks may include administration buildings, storage areas, and restrooms. Lighting systems may be required. Whenever possible, such facilities should be located outside the boundaries of disposed waste, but given the potentially large area of many landfill sites, effective recreational use may require some construction above the waste itself. Foundation requirements for these types of buildings, as well as ancillary components such as playgrounds, pavilions, bleachers and concession stands, may require additional soil be placed as a foundation material or that the existing foundation be stabilized. Issues with constructing buildings on top of waste disposal areas are discussed in greater detail in Section 3.4. The control of LFG and the need to avoid explosive conditions will be a major concern discussed.

Golf Courses

Golf courses are one of the more popular end-uses for closed landfills, but a relatively large land area is typically required to develop a full 18-hole golf course. Hurdzan Golf (2013) suggested that at least 175 acres are needed to develop a complete golf course. Figure 3-1 provides an aerial view of a golf course constructed on a closed landfill. Golf courses situated in areas of high demand have been suggested as potential net revenue generators (Gross 1994 and Wallace 2000). One of the most significant costs of building a golf course on a closed landfill is the large amount of soil required to provide the grades that are ideal for golfing, where soil material thicknesses may be 30 ft or more. Developers and landfill owners with a goal of utilizing landfill sites as a golf course should consider integrating these future goals into the waste placement plan for the site; if implemented correctly, this practice could significantly reduce the costs associated with additional soil and minimize disturbance of necessary site infrastructure.

Figure 3-1. Aerial View of Golf Course Constructed on a Closed Landfill (Photo Courtesy of CDM Smith, Inc.)

As discussed earlier, LFG collection is required for a period of time following closure, so the design and operation of any active LFG collection system must be accounted for in the golf course's design. Since the NSPS rules require operational steps such as monitoring of each gas collection well, access to well components must be provided but balanced with the aesthetic needs of the golf course. In addition to the regulatory need to effectively collect LFG, additional issues can arise if LFG is not properly controlled such as impacts to vegetation.

The anticipated settlement of the landfill following golf course construction must be evaluated as well, since differential settlement can cause ponding or surface grades that could negatively impact the golf playing surface (Figure 3-2 provides a close-up view of a green constructed on a golf course in Florida; maintaining appropriate slopes of the playing surface is important). Unlike some recreational uses, irrigation may be very important for golf courses. Considering the goal of the landfill cover system to minimize water infiltration into the landfill, irrigation systems must be planned, designed and operated to work in concert with the overall objectives of the site. Differential settlement can impact the stability of irrigation lines, and this should be accounted for in design. A large, consistent supply of water must be available at the site, which could be a challenge in some locales; opportunities may exist to use treated water from the landfill for irrigation purposes.

Figure 3-2. Golf Course Constructed on an Old Closed Landfill (Photo Courtesy of Innovative Waste Consulting Services, LLC)

Other Recreational Uses

Other types of recreational uses have been reported for closed landfills, including ski and sledding slopes, ice skating rinks, and archery ranges, though these types of uses are less common when compared with the more traditional types of recreational projects (i.e., parks and sports fields). In some cases, these reuse options may be limited as a result of regulator or developer concerns with risks from a less commonly practiced reuse project. However, if the project is compatible with community needs and meets regulatory requirements, it is likely that creative recreational solutions to landfill reuse will be considered by regulators and community leaders.

3.3 Agricultural Use

Agricultural uses for closed landfill sites have been proposed, including growing hay, grazing animals, growing crops, and silviculture. The two major concerns with agricultural use are avoidance of any contamination of future food sources from landfill emissions and protecting the integrity of the cap from damage as a result of agriculture activities. Most agricultural uses tend to focus on older landfill sites that do not have intensive infrastructure that would interfere with proposed planting, harvesting or grazing requirements.

Properly closed and maintained landfills should not result in transfer of pollutants from within the landfill to plants or animals on the surface; GCCS maintenance and run-on and runoff control would be key. Avoiding damage or interference with the cover system and related landfill infrastructure would largely depend on the depth of the soil cover and whether it is sufficient to keep plants roots, agricultural machinery, or animals away from critical components of the cap (as well as the waste). Infrastructure should be buried to every extent possible, and where a device is located above ground, it must be appropriate flagged and protected.

The US federal regulations do not specifically address the use of closed landfill sites for agriculture, though the closure uses must be consistent with the necessary function of all closed landfills sites (e.g., cover system maintenance, stormwater control). Several state regulatory agencies do address agricultural uses at closed landfills. Several states outright prohibit agricultural use. Other states may approve the activity based on the proposed use and associated design and facility characteristics (e.g., Indiana and Massachusetts). In the case of Indiana, for example, grazing/pasturing, crop production and silviculture are evaluated based on an extensive list of considerations. These considerations a provided in Table 3-3; those considering agricultural use on landfill sites in other locations would most likely need to provide similar information.

Table 3-3. Factors to be Considered when Assessing Potential Agricultural Uses of Closed Landfill Sites in Indiana

Agricultural Use Consideration
Types of crops or cover to be planted
Thickness of additional soils required, including information supporting the adequacy of the depth of soil to support the root zone requirements
Required plowing depths
Planting application rates
Fertilization rates
Time required to establish crop production
Erosion control measures
Equipment required
Storage facilities required and location if on site
Source and amount of irrigation water (if applicable)
Livestock grazing schedules
Soil management plan/crop rotation schedule
Description of the intended land use changes from its current condition

3.4 Construction and Structural Improvements

The construction of buildings and other structures on the top of closed landfills was discussed as part of the recreational use development. The types of buildings associated with these uses are often light-duty and often modular or portable. A location for the construction of large, permanent structures is another possible use for closed landfills. Landfills, however, are far from ideal locations for buildings. The two biggest areas of concern relate to the strength of the foundation that building rests upon and the concerns related to LFG migration. This section summarizes issues related to these types of construction projects.

The types of structures constructed on closed landfills have included buildings (including commercial facilities), parking lots, communication towers, and wind turbines (see Chapter 5). The use of landfill sites for the construction of buildings and similar structures is less common than recreational uses because of the greater hurdles (e.g., regulatory, design, economic, long-term safety) that must be overcome to ensure environmental protection and adequate performance of the structures. The US federal regulations do not specifically address building on closed landfills, but several states do. Texas, California, and Massachusetts, for example, have developed regulations which outline requirements specific to the construction of buildings and structures on closed landfills. Additionally, Indiana and Ohio have prepared guidance documents for construction over landfill project submittal requirements (see Appendix A). For example, Table 3-4 provides the considerations that are evaluated in Indiana when considering building construction on closed landfills.

Table 3-4. Indiana Department of Environmental Management Building/Structure Construction Project Proposal Requirements (IDEM 1998)

Component	Details Included
Description of Proposed Use	• Design plans • Design calculations • Revisions to existing post-closure plans
Demonstration of Maintaining Cover and Liner Integrity	• Need to demonstrate that there will be no increased potential threat to human health and the environment
Geotechnical and Structural Engineering Analysis	• Structural fill requirements for foundation • Requirements for in-place waste densification • Additional soil requirements for installation zones of underground utilities • Demonstration that pilings and foundations will not introduce conduits for contamination to enter the natural substrates
Construction Requirements for Mitigating Effects of LFG	• Vent system or active GCCS • Automatic methane sensors with audible alarm when concentrations detected
Settlement Considerations	• Utility connections with flexible connections and utility collars

The remainder of this section will focus on three primary issues with building on closed landfills: maintaining the integrity of the cover system, protections from LFG, and building foundation issues, including long-term settlement.

Maintaining Cover System Integrity

All proposed uses of closed landfill sites must be compatible with the final cover system and not impede necessary functions such as limiting moisture infiltration, controlling gas, and providing appropriate stormwater drainage. When buildings or similar structures are constructed, the foundation of the building will be placed directly on the landfill surface, thus any potential impact on the cover system components must be considered. Construction permits granted by the regulatory authority will prohibit the penetration or deterioration of underlying barrier layers in the cover system (e.g., geomembranes) and stipulate that added stress to the cover system and drainage layer components be minimized. An additional soil layer or building pad will commonly be required to be placed on top of the final landfill cover; this should be constructed to avoid interference with the site's stormwater drainage system. If future building construction is planned during active landfill operation (waste disposal), the design of the final waste placement topography and the cover system configuration can incorporate features to minimize future construction disturbance associated with building construction.

Controlling LFG

As described in Chapter 3, LFG is problematic because it is both explosive and potentially harmful because of the chemicals it contains. Buildings must not only be constructed to avoid interference with the facility's GCCS, but their design and maintenance must include extra precautions to ensure that explosive or toxic conditions do not develop within the enclosed spaces of buildings. A common practice is to require the installation of a geomembrane between the slab of the building and the subgrade. A permeable layer (e.g., 12 inches of clean aggregate) is then placed between the geomembrane and the subgrade to serve as a venting layer. The venting layers will typically contain perforated pipes that vent to a location outside the building, and may be connected to an induced draft exhaust system. Any penetrations through the foundation (e.g., utilities) will require some form of seal be placed to prevent gas intrusion.

Another common requirement for buildings constructed on landfills is some form of continuous or periodic gas monitoring. Methane gas sensors, for example, can be placed within the building or integrated into the foundation venting system under the building and set to provide an alarm when a specific threshold (e.g., 25% of lower explosive limit) is reached. Similar devices could be installed for other problematic gases (e.g., hydrogen sulfide) if these were viewed as a potential concern at the site. Accompanying a continuous gas sensor and alarm should be a safety and evacuation plan for the building. Additional gas monitoring may include collection of periodic samples for later analysis in the laboratory; this monitoring step would allow for a much wider array of chemical constituents to be evaluated.

Building Foundation and Settlement

Landfills are not ideal surfaces for building construction; compacted wastes do not have the same strength as provided by soil. Engineering and construction techniques are available, however, that allow buildings to be constructed on lower quality foundation materials. When designing a building foundation for landfill surface, two issues that must be considered are the bearing capacity of the landfill surface and the potential for long term settlement. The bearing capacity describes a foundation's ability to support the loads applied to the ground surface by the placement of a structure. When designing a building foundation, a geotechnical engineer will estimate the foundation's bearing capacity based on the properties of the underlying soil and design a suitable foundation. For construction projects on the top of closed landfills, depending on the thickness of type of soil overlying the waste, additional soil fill may be required.

While bearing capacity addresses a near-term evaluation of whether the soil (landfill) surface can support the weight of a building, a longer-term and more problematic issue relates to landfill settlement. The surface of a landfill settles as a result of changes within the waste over time that produce a decrease in waste volume (and waste height). Settlement in an MSW landfill can be attributed to several processes: physical and mechanical (e.g., reorientation of particles, movement of fine materials into larger voids, and collapse of void space); chemical processes (e.g., oxidation); dissolution processes (dissolving soluble substances by percolating liquids and subsequent formation of leachate); and biological decomposition (organics in the waste degrade over time controlled by temperature, humidity, and percentage of organics and nutrients in the waste) (Sharma and Anirban 2007). Settlement typically occurs within two phases; the primary phase occurs as the initial settlement of the landfill due to physical and mechanical processes and typically occurs within the first few months after the waste is placed. Secondary settlement occurs over a much longer period of the time and results from physicochemical and biochemical decay and occurs under constant load after the completion of primary settlement.

Different methods have been developed to predict MSW landfill settlement over time, which is an important consideration when determining the end use of the landfill property. Typically, an older landfill will have fewer issues with settlement than a newer landfill that may still be undergoing self-weight settlement. When developing over a landfill, predicted settlement maps and a monitoring plan should be prepared to facilitate the design and create an effective operation and maintenance plan. Long-term settlement from self-weight and external loads can result in differential settlement that can result in tilting of building support system, ponding of water in parking lots, cracking of slabs supported on the ground, breakage in utility lines and down-drag forces on piles that support heavy building loads. Figure 3-3 shows a parking lot constructed on a closed landfill and the resulting settlement that has caused water ponding.

Figure 3-3. Parking Lot Constructed on a Closed Landfill (Photo Courtesy of Innovative Waste Consulting Services, LLC)

For constructed surfaces such as parking lots, settlement can be accommodated by including larger slopes. For structures, building foundations should be designed to accommodate settlement. This can be accomplished with the use of mat foundations (which better distribute the load), flexible connections and utility collars. Soil strengthening or soil stabilization is often used to prepare soft soils for building construction, but this may be limited for landfills because of the need to maintain integrity of the cap. One step that the operator can undertake during operation of the landfill is the purposeful enhancement of waste stabilization and landfill settlement through operation of the landfill as a bioreactor; this technique is described in greater detail in Chapter 5.

3.5 Energy and Resource Recovery Oriented Use

Another use of a closed landfill site as a community asset takes the form of using the site as an energy generation project. Energy projects at landfills could possibly be coupled with other uses such as recreation (appropriate restrictions and safety precautions would be needed), but in cases where the landfill is only utilized as an energy project, the risk to potential receptors is typically less since the people accessing the site are approved personnel.

Many landfills around the US now utilize LFG as an energy source; the same methane that represents an explosive gas risk when captured can be converted to electricity (or used in other fashions). In addition to LFG use, the deployment of solar panels or wind turbines at landfills represents another potential renewable energy opportunity. The production of energy at a landfill could provide a series of benefits to the site and the community, including offset of all or part of the electricity needs for the site, offsetting of non-renewable energy resources, and providing further incentive for increased LFG collection, which can have ancillary environmental benefits such as greenhouse gas emission reductions and reduction of potential nuisance emissions.

This section details information regarding the three aforementioned renewable energy project types (LFG to energy, solar, and wind) and key considerations related to implementing one or more of these technologies at a closed landfill. It also includes a discussion of possible resource recovery from reclamation (mining) of the landfilled waste. Reclamation has the potential to enhance a landfill's value as a community asset through the more efficient use of site space, the recovery of resources, and possibly the recovery of a fuel for energy production.

LFG Recovery

As described earlier, the primary components of LFG are methane and carbon dioxide. When LFG is extracted through a facility's GCCS, the gas is ultimately either burned in a flare or utilized as an energy source. In its raw form, LFG can be used as a fuel to produce electricity with minimal processing requirements. It can also be cleaned up to increase the energy content for other applications. A summary of the major LFG energy conversion technologies is provided in Table 3-5.

Table 3-5. Summary of LFG Beneficial Use Technologies

Technology	Description
Cogeneration (Combined heat and power, CHP)	Generate thermal energy and electricity from steam or heated water. Can be installed to recapture heat losses from turbines and engines thus increasing the processes overall efficiency to up to 80% (US EPA 2008).
Combined Cycle Engine	This system utilizes both gas and steam turbines. The gas turbine provides the heat needed to generate steam that is then fed to the steam turbine. Combined cycles are utilized for scales larger than most internal combustion projects.
Gas Turbine	Can operate at lower gas concentrations; gas turbines typically require larger amounts of gas for economic feasibility. More resistant to damage than other systems. Electrical efficiencies range from 40% to 80% (Dudek et al. 2010).
Internal Combustion Engine	A common type of electricity generation technology, efficiencies typically range from 25 to 35%.
Microturbine	Smaller scale combustion turbines. These turbines are employed in areas with smaller gas flow rates. Pretreatment of LFG to remove moisture is necessary in addition to the usage of activated carbon to remove as much impurities as possible due to damage these impurities cause to the combustion chamber. Microturbines can operate at low gas concentrations. Efficiency for this system ranges from 20% to 30% (Dudek et al. 2010).
Boiler/Steam Turbine	LFG is directly used by combusting it to a large boiler to generate steam that is to be fed to a steam turbine. This system is not commonly used for LFG electricity applications (Dudek et al. 2010).
Stirling Engine	An external combustion engine which mixes air and fuel within the cylinder of the unit to facilitate combustion. Pretreatment of LFG is not needed because of the engine's high tolerance for siloxanes and other such impurities. An average electrical efficiency obtained is 30% (Dudek et al. 2010).
Fuel Cell Technology	Fuel cell technology for LFG involves the fuel (i.e., LFG) entering into a compartment where it reacts to produce electrons, air enters another compartment where it reacts to consume atmospheric oxygen and the electrons produced by the fuel (Messenger 2013). The technology's potential for LFG to energy projects is contingent on gas quality, high levels of methane and low concentrations of diluents or trace contaminants are considered ideal for fuel cell conversion (Spiegel and Preston 2003; Messenger 2013).

The amount of energy that can be harvested from LFG depends on numerous site factors including landfill size, waste age, GCCS coverage and efficiency, and the type of technology used to convert the collected LFG to energy. The US EPA's Landfill Methane Outreach Program (LMOP) estimates that over 600 operational LFG to energy projects are currently active in the US producing a total of approximately 2,000 MW of power. LMOP also estimates another 450 candidate landfills in the US with potential for implementation of a LFG to energy infrastructure. The economic viability of a LFG-to-energy project most often depends on the amount of LFG produced, local availability of direct use applications, the price at which electricity will be purchased for, and the availability of other incentives such as tax benefits or renewable energy credits.

LFG capture for energy is well developed in the US and a common stage in the operating life of large landfill facilities; it may start during the operational years of the landfill and will continue long after the landfill is closed. Landfill owners and operators can take several steps to enhance the asset value of a LFG-to-energy system through early planning. As will be discussed in greater detail in Chapter 5, gas can be captured early in a landfill's operating if the proper steps are implemented, and technologies such as bioreactor landfill operation can enhance the rate at which gas is collected during the peak operational years of the facility (and leave less gas as an issue to deal with after closure). Early planning of the GCCS with respect to other future site beneficial uses (e.g., planning for other power generation, integrated GCCS infrastructure with other site uses) would allow for greater overall site utilization as a community asset.

Solar

The potential for landfills as a host for solar energy projects has gained interest in recent years as the cost of solar systems has decreased. Landfills inherently have large open spaces that may not have other uses (often referred to as marginal lands), and they often are equipped with electricity distribution infrastructure as a result of LFG projects (Millbrandt et al. 2013). Solar energy panels utilize radiant heat and light from the sun and convert the energy into usable electricity. The two major types of solar power technologies are photovoltaics (PV) and concentrated solar power (CSP). PV uses semiconductors to create an electrical charge through the PV effect while CSP uses lenses and mirrors to focus and concentrate sunlight. PV systems are the most commonly utilized solar technology (US EPA 2012). The placement of solar panels can be accomplished through fixed systems (e.g., mounted in a fixed configuration) or the panels can be applied to the surface of a landfill such as on geomembrane panels. Figure 3-4 shows a solar energy system at a facility in the Southeast US consisting of flexible panels mounted on the landfill side slope. Messics (2009a) suggested that placement of solar panels on flat areas or south-facing direction was desirable. Tansel et al. (2013) reported that construction difficulties and potentially increased costs are associated with constructing solar panels on side slopes and can create complexities with stormwater management systems.

Several factors must be considered when evaluating a landfill site as a candidate for solar energy production. First and foremost is the amount of available solar energy available in the region of interest. The National Renewable Energy Laboratory (NREL) has developed Solar Radiation Resource Maps which display the average annual solar radiation on a daily basis across the US. Figure 3-5 presents the NREL solar radiation map corresponding to data from 1998 through 2009. Additional factors include the policy and economic incentives, relationship with the local electrical utility, site logistics for power transmission, and site security. Table 3-6 summarizes many of the considerations that go into determining the feasibility of a solar project at a landfill site (as described by Messics (2009)).

Figure 3-4. Flexible Panel Solar System Installed on an MSW Landfill (Photo Courtesy of Carlisle Energy Services Inc, http://bit.ly/XCI6q2)

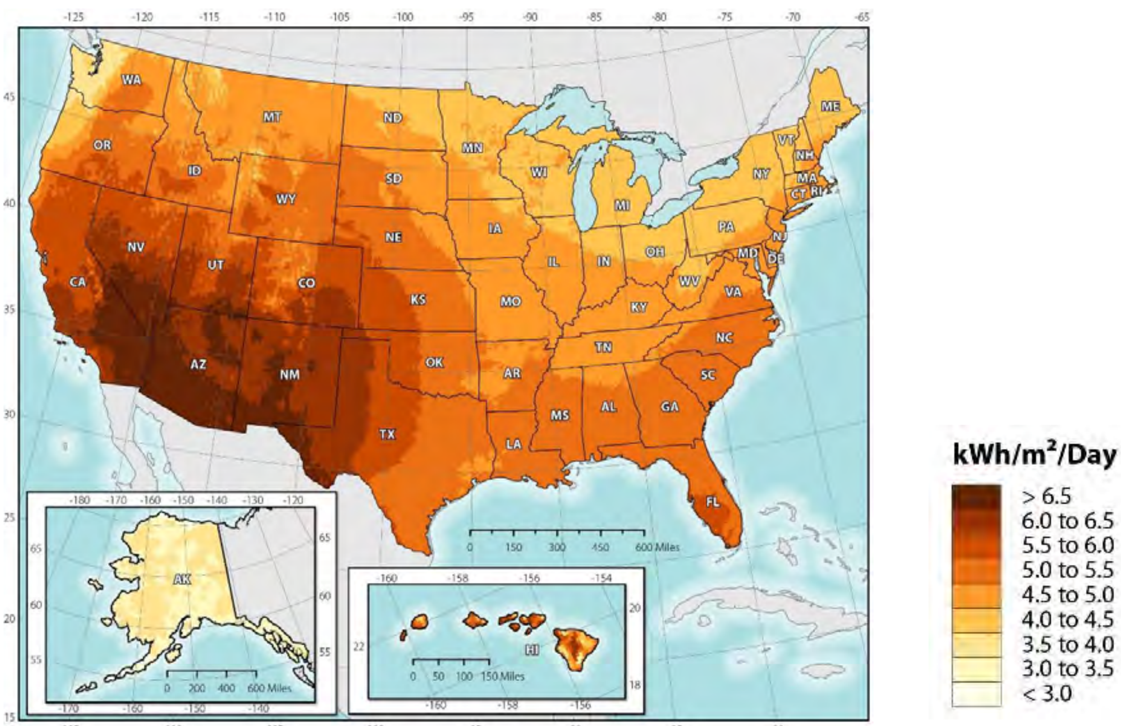

Figure 3-5. PV Solar Resource Map - Annual Average Based on Data from 1998 to 2009 [Photo Courtesy of NREL (2012)]

The construction of a solar system on top of a closed landfill would need to be constructed in a manner that did not interfere with the final cover system and other closure components. For ground mounted solar panels, the excavation into the cover system and placement of structural supports would need to avoid any damage to the cap and thus may require a different design than used for typical soils. The placement of the panels would need to avoid interference with the GCCS or the stormwater management system, and allow landfill personnel sufficient access for monitoring and maintenance.

Table 3-6. Summary of Factors Influential to Solar Project Development at Closed Landfills

Influencing Factor	Desirable Features
Energy Policy	Locations that provide energy policy incentives for solar power. Examples include standard requiring 2% or higher of region's electricity mix to be from solar; multiplier credits for solar energy.
Financial incentives	Grants, tax credits or incentives, customers willing to pay more for solar power (e.g., colleges, corporations, government)
Landfill Location	Location in an areas with a high solar potential (from solar resource maps) and unobstructed sunlight
Site Security	Completely fenced; panels out of danger zone (e.g., out of rock-throwing reach)
Project economics	Credit-worthy counterparties; labor cost control flexibility; high visibility (for marketing purposes)
Power logistics	An existing connection to the power grid through an existing LFG to energy system, as well as an access road and a landfill cap of at least 2 ft thick (for trenching of electric lines); a cooperative electric company to help facilitate reasonable costs and schedules.
Topography	Flat topography is generally preferred for mounting. South facing slopes can be used if necessary; however mounting is more difficult, and requires increased stormwater and erosion control efforts.

Wind

Similar to solar energy projects, wind power projects have garnered growing interest in recent years as a potential option for closed landfill sites (wind power projects also need large areas of land). Wind turbines convert wind energy into a usable form and can either be grouped together in a wind farm or used individually. The presence of sufficient wind resources is a prerequisite for a feasible project. NREL has developed wind resource maps that can be used as a preliminary guide to determine whether a landfill location should be preliminarily considered for a wind-power project (Figure 3-6). Site specific studies can also be conducted at the proposed location to provide a greater degree of certainty with respect to design decisions and financial feasibility. As an example, a 12-month wind assessment study was conducted as part of evaluating the feasibility of wind turbines at the Frey Farm Landfill, Pennsylvania, which allowed for the acquisition of actual wind speed data and other performance metrics (Figure 3-7 presents an image of the two wind turbines at this site).

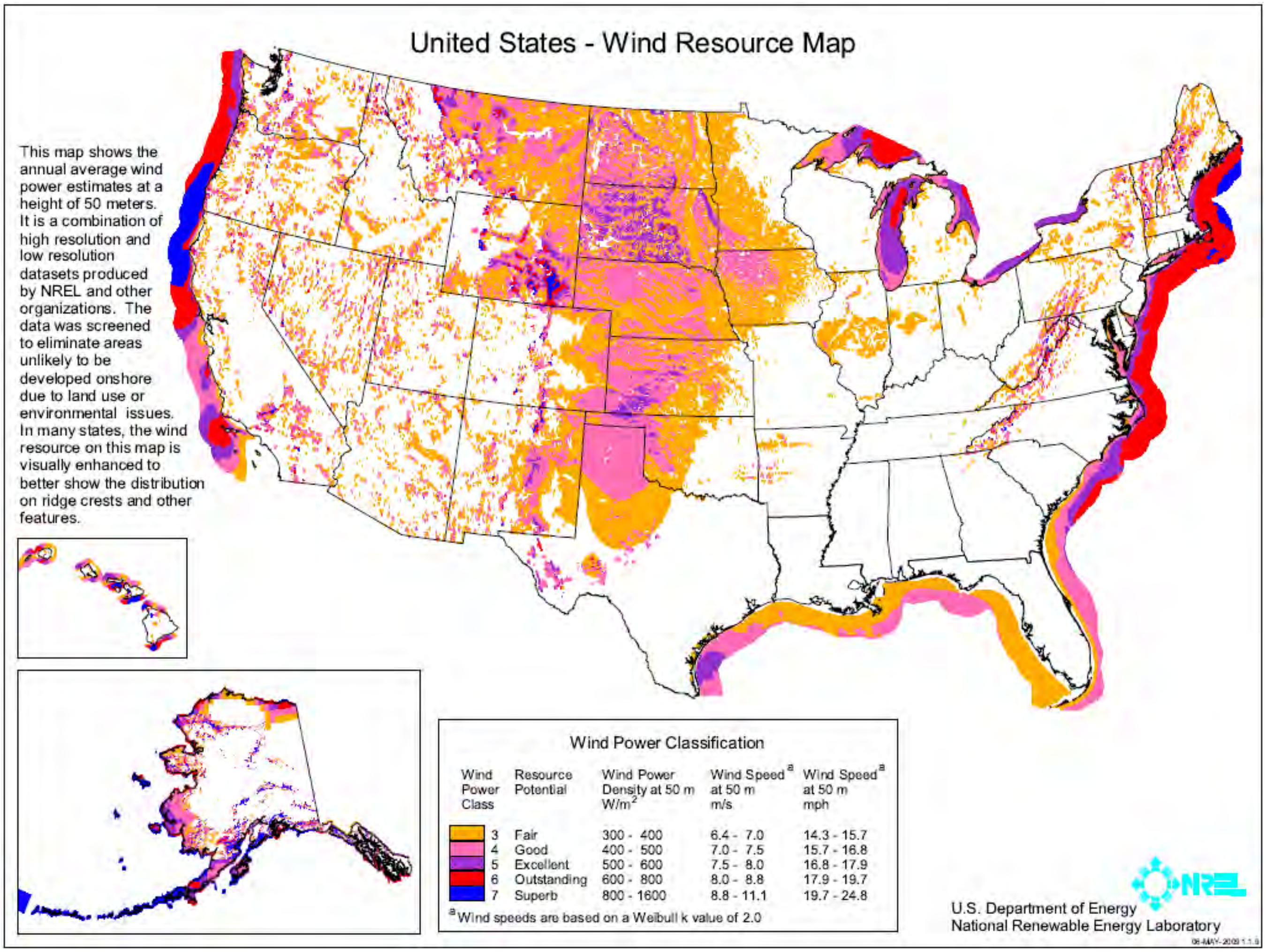

Figure 3-6. Wind Power Resource Map in the US [Photo Courtesy of NREL (2009)

Figure 3-7. Turkey Point Wind Project at LCSWMA's Frey Farm Landfill in Conestoga, PA (Photo Courtesy of www.lcswma.org)

The siting of wind turbines at landfills is less well-documented than solar project siting. The US EPA (2014) reported 336.0 MW of installed power capacity for wind projects on marginal lands (more than double the solar capacity), but most of the installed capacity was on brownfields or similar contaminated sites (not municipal landfills). A few wind turbines have, however, been located on closed landfills, including in Massachusetts and Pennsylvania.

One geotechnical consideration when constructing wind turbines on closed landfills is the foundational stability of the turbine base and the rotational motion associated with the turbine blade. Geotechnical properties of interest include soil bearing capacity, electrical resistivity of the soil, subgrade characteristics (Yun et al. 2011, Miceli 2012). Installation of the necessary foundation for a wind turbine would require site specific borings and sample collection, and a detailed geotechnical engineering design. The foundation may require some placement with in the landfilled waste, and thus the cover system and geomembrane cap (if present) would need to be modified to make sure that cover system integrity was maintained. Grounding of wind systems and generators is also very important; 35 annual turbine related fires were reported for California alone, attributable to short circuiting and lightning. Safety features, such as mitigation relays, can be installed which allow the immediate shut off of turbines and reduce the chance of system damage and risk to personnel and environment (Panetta, 2010).

Landfill Reclamation

Landfill reclamation is a term used to describe the excavation and removal of waste from a landfill; it is also commonly referred to as landfill mining. In many cases, the waste is processed via screening and ferrous metals are often removed using magnets. Landfill reclaiming is included as another option for utilizing closed landfill sites as community assets because of the opportunity it provides to remove waste from problematic locations (so that desired land use can be maximized) and to recover potentially valuable materials (e.g., metals, combustibles, soil). Figure 3-8 shows a landfill reclamation project at a municipal landfill in Florida. More details on landfill mining activities at this site can be found elsewhere (Jain et al. 2013).

At closed landfill sites where waste has been disposed of over large areas often at relatively shallow depths, landfill reclamation provides an opportunity to recover useful land for other applications and to avoid the problems associated with construction on top of waste as described before. In this process, some of the mined materials can be recycled (primarily ferrous metals) and the screened soil can be used to replace virgin soil in other landfill operations or potentially elsewhere as part of final site construction (e.g., grading for golf courses). Once the soil (which includes biodegraded organic matter) is screened out, much of the remaining material consists of combustible material (e.g., wood, plastic), and there is growing interest in using this material as engineered fuel in industrial units such as cement kilns. Finally, when employing technologies to operate the waste as a bioreactor, landfill reclamation offers an opportunity to recover treated waste. The potential concerns with landfill reclamation project include odor, dust, and litter control, unearthing of hazardous waste and other waste materials that are not permitted (by the prevailing regulations) for disposal in landfills, and leachate and stormwater run-off control.

Figure 3-8. View of Screening Waste Materials at a Landfill Reclamation Project in Florida (Photo Courtesy of Innovative Waste Consulting Services, LLC)

4 Examples of Successful Asset Utilization

Building upon the information presented in the previous chapter, this section provides five case studies of closed landfills that have been converted to a community asset. Case study sites were selected based on a review of available information, literature, and further data regarding site details, landfill reuse system design, and information on accomplishments and challenges associated with the site development and subsequent use. These case studies highlight many of the challenges and opportunities that have been discussed this far, and are intended to provide the reader with a good sense of the steps that different entities have undertaken to transform a closed MSW landfill into a community resource. For the most part, planning for final use of these sites did not occur until after the landfills were either closed or near closure. In the following chapter, considerations for planning final site use from the very beginning of site conception are discussed.

4.1 Cesar Chavez Park

In 1991 the Cesar Chavez Park (formerly North Waterfront Park) in Berkeley, California was established on top of the city's former landfill. The facility is located on a peninsular tract of land that extends north along the coastline between the San Francisco Bay and the North Basin. The landfill was originally formed by filling in and diking a portion of the Bay with rip rap, clay and mud to form the landfill. The landfill accepted approximately 1.75 million tons of mostly household waste up until the early 1980s. The landfill was closed in phases between 1981 and 1990 and was capped according to California regulations at the time. Since the closure of the landfill in 1991, the park has been open for public use. The total footprint of the park is 90 acres which includes picnicking areas, hiking trails, shoreline and wetland areas, a seventeen acre off-leash dog area, and wildlife sanctuary. The park hosts various events throughout the year including an annual kite festival. Figures 4-1 and 4-2 show views from Cesar Chavez Park.

When the landfill was closed, it was capped with one foot of clay and a minimum of four feet of topsoil. To construct the park, approximately 500,000 tons of topsoil were brought to the site to create a series of hills and a surface water management system. The landfill also includes an active LFG collection system including approximately 65 individual collection wells that route gas to a continuously-operated flare station. The quantity of LFG collected decreased over time necessitating routine adjustments to the operational conditions of the flare station.

Although no structural facilities were constructed on the landfill itself, the potential for LFG to migrate through the soil into the foundation of a nearby hotel located 300 feet south of the site was a concern. To evaluate LFG concentrations (particularly methane), a series of approximately 10 probes were installed around the hotel perimeter to continuously monitor methane levels. The site's operational procedures also include routine monitoring of leachate seepage on the landfill surface and surrounding areas.

The location of the site on the San Francisco Bay additionally subjects the landfill to natural wear due to tidal action. This scenario, coupled with waste settling, has over time eroded and sloughed off some of the originally-placed armor rock therefore necessitating maintenance. Another maintenance issue has been burrowing wildlife such as ground squirrels and pocket gophers that cause damage to the cover system and stormwater drainage structures. Public feeding of the rodents has increased their population and in turn increased damage due to their burrowing. There has been great public opposition to the proposed removal and trapping of the animals and for the effect it may have on Western Burrowing Owls (a species of concern within the state of California) which utilize ground squirrels as source of food and for their abandoned burrows. Options are currently being explored to address the challenges of balancing the site's unique ecosystem with the environmental protection responsibilities of the landfill.

Figure 4-1. Overlooking a scenic view to the north of Cesar Chavez Park (Photo Courtesy of Daniel Ramirez, Flickr, http://bit.ly/1mGwTQi)

Figure 4-2. View of the trails at Cesar Chavez Park (Photo Courtesy of Daniel Ramirez, Flickr, http://bit.ly/1kSSQVq)

4.2 Cross State Site

The Cross State Site is a 74-acre former landfill site located in Palm Beach County, Florida. Solid waste was disposed of at the landfill from 1938 until 1976. During this time, 2.5 million cubic yards of garbage, including household waste, wood and construction and demolition debris, was accepted at the facility. The site also housed an adjacent ten-acre junk yard and twelve-acre asphalt batching operation. The total waste footprint of the site is 54 acres. Based on its centralized location in the county, the potential land purchase savings, and benefits to the surrounding community, the two owners of the properties, the Solid Waste Authority of Palm Beach County and Palm Beach County, redeveloped the site into four parcels: a concrete and asphalt recycling facility, a vegetative waste recycling facility, a fire rescue training and administration complex, and a Sheriff's driver training pad.

The Sheriff's driver training pad areas and the eastern portion of the fire rescue training facilities, including a four story burn building, a vehicle extraction area, various other light structures, roads and pavements, are located within the footprint of the landfill. During construction, efforts were made to avoid disturbing the cover of the landfill and to supplement as needed with fill to provide an effective sub-base for the roads and driving courses. For minor structures, mat foundations were installed to provide a system where the mat could move with the consolidation of the landfill and also provide a surface to distribute the loads over a larger area while creating an impervious surface for the collection of fire water to avoid point infiltration issues.

To avoid settlement issues with the fire rescue training building (a more substantial structure), waste material was excavated and then backfilled with acceptable material to provide a more stable base for the structure. Flexible paving systems were an important consideration for the driving pad areas that would likely be affected by settlement over time. The site used a minimum of twelve inches of recycled asphalt material available from the adjacent recycling operations with a stabilized sub-base fill as an inexpensive and easy method of maintaining the driving courses. Repairs are made by filling depressions with recycled asphalt material.

The site was sufficiently old at the time of the redevelopment project and therefore significant LFG generation was not expected. A methane gas screening survey was conducted to detect combustible gas just below the surface of the landfill in areas with proposed structures. There were detectable levels of methane, however for open air training purposes, it was determined that the low levels of methane would not interfere with use of the site. Appropriate methane exclusion methods such as under-drain piping in gravel beds to intercept and release gas and sealing off conduits as utilities enter buildings or exterior transformers and panels were still necessary precautions (and retrofits) for buried utilities and enclosed structures.

Additional design aspects of the project that have contributed to the success of the site include an integrated stormwater management design that improved flooding protection; an open stormwater conveyance system that avoided using buried pipes that could be damage due to settling; and using high density polyethylene sanitary force mains servicing the landfill structures to provide maximum piping flexibility.

Since the Cross State Landfill ceased operations prior to landfill design requirements and was not required to undergo closure permitting, the project was given more regulatory flexibility than would be expected with current design regulations; however the project still necessitated the cooperation from multiple agencies and stakeholders to successfully complete the project.

4.3 Millennium Park

The Gardner Street Landfill served as an MSW disposal facility in West Roxbury, a neighborhood of Boston, Massachusetts. The 85-acre landfill is located on a 98-acre parcel of land. In 1997, a post-closure plan was developed by citizen's advisory committee working with the public works department; the goal was to develop a plan for revitalizing the landfill to provide public access. In order to properly close the landfill for the proposed post-closure use, the landfill needed to be re-graded, shaped, and capped. Construction soils largely consisted of soils excavated from a major construction project nearby. An active gas collection system, as well as a clay cutoff trench, was also installed, and the adjacent brook was remediated. Site investigations including waste delineation, electromagnetic terrain conductivity survey, and site sampling; these were necessary in order to address potential risks in order to ensure public health and safety through the use of the landfill as a park for the city of Boston.

A traditional closure cap as described by Massachusetts regulations was deemed acceptable for closure, along with the construction of an active gas collection system for long-term closure. The landfill cap consisted of (in order of bottom to top) a gas venting layer, a low permeability barrier layer, a drainage layer, and a vegetative support and protection layer. The active GCCS for the landfill was constructed of 58 extraction wells and included more than 8 km of header and lateral piping. Gas was routed to an enclosed flare. The state approved the installation of seven groundwater monitoring wells and required semi-annual monitoring for a period of 30 years post-closure.

Following the landfill closure, the facility reopened as Millennium Park in 2000. Millennium Park consists of approximately 100 acres of trails, fields, and nature areas. It also includes six miles of walking paths that circle the former landfill, three paved walking loops, and in between the walking paths, 26 acres of playing fields and a playground. Figure 4-3 show the walking trails and picnicking areas at Millennium Park. A small amphitheater was also constructed. One of the highlights of the park is a canoe launch on the Charles River that provides accessible to the public to enter the river in their canoes and kayaks (shown in Figure 4-4).

Figure 4-3. Millennium Park Paved Trails and Picnic Tables (Photo Courtesy of Dan Brody, www.newtonconservators.org)

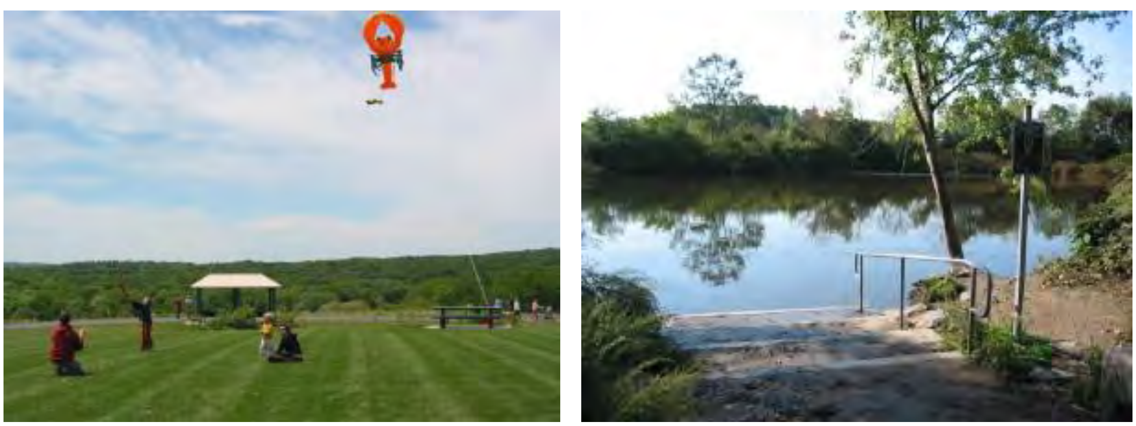

Figure 4-4. Millennium Park Kite Festival and Canoe Launch (Photo Courtesy of Dan Brody, www.newtonconservators.org)

4.4 Colma Landfill

The Junipero Serra (Colma) Landfill is a solid waste landfill located in San Mateo County, California. In 1983, the landfill was closed after reaching waste depths of 130 feet in some areas (E^2 2007). Ten years following the closing of the Colma Landfill, the site was slated to be developed as a Home Depot (Figure 4-5 shows a view of the big-box store that was built on the landfill). Due to its proximity to San Francisco, the landfill property was an excellent location for commercial business. In the Bay Area of California, deep foundations are necessary due to the soft Bay mud. A total of 710 steel H piles were driven into the landfill, spanning up to 181 feet in length traversing the depth of the landfill (Fittinghoff 2014). The piles were designed to transfer the structural loads to the bearing soils located below the landfill. The Colma Landfill was able to utilize pilings to stabilize and support the structure because it was an older, unlined landfill, and thus there was no liner to damage. The pilings were driven into the bedrock underneath the landfill. Estimates of expected settlement were conducted based on empirical observations and numerical models.

To accommodate for settling, gas wells and collection lines were constructed with flexible piping. A total of nine extraction wells, eight extraction trenches, and 1,850 ft of gas collection header piping were placed below the foundation of the building (McLaughlin and Miller). A geomembrane was placed beneath the building, as was a gas venting system to prevent LFG migration into the structure. When the barrier layer was interrupted for utilities to enter the building, the penetrations were sealed using butyl tape, polyurethane sealant, or special boots (E^2 2007). As an added measure, methane monitors were placed within the building and programmed to set off an alarm when methane concentrations reach 1%. Ramps on the parking structure and connecting features were constructed with hinges, designed to handle some settlement before repairs are necessary. Over time, facility components have required maintenance, including bringing more soil into the site to fill in low areas, repairing the ramps, and keeping the gas system working.

Figure 4-5. View of a Big-Box Store Built on the Colma Landfill (Photo Courtesy of CalRecycle, http://bit.ly/1yheajY)

4.5 Los Alamos County Landfill

The Los Alamos County Landfill began accepting waste in 1974; it accepted local MSW and waste from the Los Alamos National Laboratory until 2008 (Wheeler 2007). Closure was initiated in 2008, although minimal waste filling occurred from 2008 to 2012 (to bring the site to final closure elevation) (Nagawiecki et al., 2013). The site is unlined, outfitted with substantial final cover material. Upon closure, the County placed solar panels on the landfill and transfer station for waste and recyclables was constructed adjacent to the closed landfill (Nagawiecki et al., 2013).

Los Alamos County Landfill is located in an area with high energy generation potential according to US NREL (2012) solar resource maps. Final cover was installed incorporating consideration of the PV system (Shaw 2011). Panels were mounted on a unique modular tray system and electrical wiring connecting to each panel was connected above the landfill surface, making it possible to complete the project on the newly closed landfill, conforming to contours on the site surface and allowing for disconnection and landfill maintenance (Rafael De LaTorre, personal communication, 2014; see Figure 4-6). Table 4-1 provides an overview of how many of the challenges to site permitting, construction and operation were addressed.

Figure 4-6. Los Alamos Landfill Site (Photo Courtesy of Los Alamos Department of Public Utilities

Table 4-1. Aspects of the Los Alamos Landfill Site and Associated Environmental Controls

Project Aspect	Description of Closure Plans and Environmental Controls
Solar panel system (14.7 acres)	The PV system plateau was installed with a unique racking system to avoid puncturing the landfill cap. The following layers provided protection when mounting the panels: 12-inch intermediate soil cover, geosynthetic clay liner, 18-inch protective soil layer and 6-inch gravel.
Recycling park (8.5 acres)	The facility processes concrete, tires, metal, manure, and compost; a protective cover system (similar to what was installed for the solar panel system) including asphalt millings was installed to prevent puncturing the landfill cap.
Transfer station (TS)	The TS building was green building certified and an active GCCS was installed below the TS to intercept migrated LFG.
Side slopes (12.0 acres)	Side slopes were formed at 4:1 to 3:1 ratios with an evapotranspiration cover system to decrease rain infiltration.
Stormwater and erosion	Terraced berms, riprap down chutes, and sloping the landfill plateau by approximately 4% were methods used to accommodate drainage and prevent erosion.
Gas collection	Gas is passively vented since the total waste mass landfilled is below NSPS LFG requirements and dry climatic conditions are not likely to produce excessive LFG.
Groundwater monitoring	Unnecessary because distance to the water table is 1,200 ft below the land surface
Leachate detection	Because the landfill is unlined, precautionary detection piezometers were installed.
Geotechnical considerations	Battery storage for the PV system were located on virgin land to minimize variables related to lead acid and sodium sulfur batteries.

5 Pre-Planning Waste Sites as Community Assets

As discussed in the introduction to this report, most planning for the beneficial utilization of closed landfill sites occurs after the landfill has been closed, or during the period just prior to closure. Many of the issues that must be addressed when assessing reuse options for a closed waste site would be easier to manage if thought was given to them during the earlier planning, design and operational stages of facility life. A waste site developed alongside an intended end use should allow a more efficient use of resources to transition the facility to a community asset. Such upfront planning would also likely provide opportunities that would otherwise not exist for achieving additional site benefits. With the likely long-term role of landfills for MSW management and the lessons learned from repurposing closed disposal facilities as community resources, landfill owners and their associated communities have the opportunity to plan future waste disposal facilities from the beginning for use as a community asset.

Building upon the information already presented, this final chapter of the report explores aspects of the waste site design with respect to how pre-planning a waste site with an intended reuse can benefit the community and provide effective waste management: site location, site layout, community involvement, technical design and future reuse. Not all of the approaches are currently practiced or permitted, but they are presented to challenge developers, planners, landfill owners, design engineers, regulators, and community leaders to potentially expand and explore additional future uses or approaches for managing closed or closing waste sites.

5.1 Location

Most landfills are located far from population centers because of concerns regarding odor, traffic, noise and environmental contamination. While siting waste management facilities in such locations may be the politically palatable course of action, other factors merit consideration when developing plans for a future community asset. The future use of some recreational activities might be enhanced if the facility were sited in a more convenient location for community use. Environmental concerns are largely addressed by following current regulatory requirements for landfills, and issues such as odor, traffic and noise can be minimized with proper planning, design and operational controls. The expenditure of some additional resources up front to make a facility more compatible with local residents and businesses could pay off later years in the creation of a facility that provides more benefit to the entire community.

Location is also important in consideration of energy and resource recovery. The feasibility or profitability of a LFG-to-energy system might be much more enhanced if the landfill were located adjacent to a specific industry or an industrial park where direct use of LFG could occur, or if a natural gas transmission line were located nearby. LFG-to-energy, solar power, and wind power would all benefit from proximity to electrical transmission infrastructure. Locating a landfill next to other industries or utilities that could benefit from co-location would increase overall asset utilization. For example, if a landfill were located near a wastewater treatment facility, the landfill's leachate could be more effectively managed and the treatment plant's biosolids could be placed in the landfill and later captured as methane and converted to energy. Manufacturing facilities that rely on recycled materials as feedstock would benefit from close proximity to the landfill, and the community would benefit from a greater diversion of materials from disposal.

5.2 Site Layout

A number of benefits should be achievable by planning the layout of a landfill facility with future use options in mind. Site roadways and access points should factor in desired uses, as should the location of the landfill units and their associated support infrastructure. Community use for some areas of the site might be possible much earlier if the site is configured appropriately. For example, if a portion of the site closes first and is ready be developed into a community asset (e.g., a recreational area), the site layout should allow public access to this area of the site while still providing appropriate control and limits from restricted areas of the operational part of the facility.

Planning for the location of utilities and roads that will be needed in the future should prevent costly retrofits or re-designs in later years. The landfill cells should be designed with desired final use in mind. For example, if a golf course is planned, the waste filling sequence and cell locations (and associated grades and elevations) can be constructed in a manner to minimize the volume of soils and additional materials that will be required, and lessen the degree of infrastructure modification needed (e.g., relocated gas and leachate lines). If solar or wind power is desired, waste cells should be placed in an optimum configuration to capture these resources. If buildings are to be constructed, specific areas may require more soil fill, or wastes less likely to settle (e.g., brick, rubble, ash) could be disposed of in that location.

The location of leachate and gas infrastructure should be located with final site configuration in mind. At some landfill locations, desired site uses have been limited because expensive reconfiguration and movement of leachate and gas infrastructure have been required.

5.3 Community Involvement

Allowing the input on potential utilization options, particularly at the planning phase, is another way to expand the potential scope of possibilities, and potentially source innovative ideas (similar to the idea of crowd-funding). This concept was illustrated several of the case studies reviewed in this report, where municipalities involved residents in evaluating use options after the landfill closed. Extending this to the entire life of a waste management facility, the community should be integrated into the decision-making process with regard to use of the site after closure. The community needs to be involved early in the decision process and kept informed through the operation of facility, especially as important milestones are reached. Key players and partners should be identified. Such outreach could result in finding partners that would actively participate in a true integrated materials management hub (e.g., industry, manufacturers, recyclers, end users). Advice from the regulatory agency community should be sought early and often to avoid future conflicts or unforeseen limitations.

5.4 Technical Design

Retrofitting closed landfills to accommodate desired end uses involves addressing complicated issues of settlement, LFG migration and leachate generation. A site that is able to control these aspects at an earlier time in the life of the site instead of waiting until the landfill has been built out, is more likely to avoid costly long-term maintenance repairs and monitoring costs. For instance, a building on top of a landfill with stabilized waste is less prone to suffer from settlement issues and structural damage. The facility will have to deal with less concern with regard to LFG migration into enclosed spaces over the life of the building.

A bioreactor landfill is an MSW landfill that is designed and operated in a manner to promote the stabilization of the waste. Components such as food waste, yard trash, and paper biodegrade in a landfill (which produces LFG and causes settlement). This process can occur slowly over many decades and thus presents operational problems many years after closure. Experience has shown, however, that if the landfill is operated under certain conditions, the rate of waste stabilization can be greatly enhanced. The most common approach used at bioreactor landfills is to add liquids to the waste, either leachate collected from the LCRS, or some other source of moisture. Some facilities also practice the addition of air in the same fashion as is done with a compost pile. While the implementation of bioreactor technology requires careful planning and implementation to make sure that it is performed in a manner that meets all of environmental protection objectives of the landfill, it can provide for landfills with much fewer problems with LFG and waste settlement in the years after closure when the landfill will be most used as a community asset.

The site developer has many options to better integrate LFG management into waste asset planning. Many landfill designers make the mistake of not considering future LFG collection as part of the original design and construction of the landfill liner system. By implementing aggressive practices for collecting LFG, more gas can be collected earlier in the life of the site, thus making gas recovery economics more feasible and reducing sources of odor and related emissions. For example, the GCCS can be integrated into the LCRS (which is often a significant source of LFG) early on in the construction of a landfill. Innovative practices such as exposure geomembrane caps can allow greater gas collection efficiency earlier in the life of the landfill. The GCCS can be readily designed to accommodate a variety of future landfill configurations and uses, and thus potential impacts on GCCS infrastructure (a common issue observed in the case studies) can be minimized. The GCCS can be designed to avoid interference with the aesthetics of the site or get in the way of the end use (e.g., gas wells sticking out of a landfill golf course).

5.5 Planning for Future Recovery

Depending on a variety of factors (e.g., poor market, prohibitive distance to recycler), there may instances when a landfill facility does not have the means to recycle or use a waste product, but has the foresight to plan for the future recovery of the material at time when it is more economically viable. Materials that are accepted in bulk and arrive at a disposal facility separate of other waste materials (e.g., water treatment sludge, concrete) are candidate materials for future recycling or beneficial use applications because of their large quantity which can make their recovery more economical and because the waste does not have to be sorted which avoids the additional expense of processing.

Facilities that identify a material as a potential future commodity and prepare and design their landfill filling around recovering these materials at a later day in the future, position themselves to take advantage of situations that may improve recycling circumstances. Ideally, the facility employing such a strategy would set aside a portion of the landfill and dedicate it solely to this particular material so as not to blend it with other contaminants that would depreciate its value. The location of the material must be accurately documented to avoid disturbing areas unnecessarily and tracking the quantity of material is essential in determining the right time at which there is sufficient material that has accumulated and the economics of excavating and recovering the material is justified. This type of approach is already common at landfills that accept special wastes such as asbestos, so basic principles and practices for dedicated disposal areas of likely (or potentially) higher-value materials would not be an unknown to many site owners and operators. Reclaiming waste materials increases available landfill air space, it can be an additional source of revenue for the facility and the environmental advantages of recycling/reusing waste materials are all potential benefits of planning the future recovery of waste materials.

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7 Appendix A

7.1 Resources for Further Reading

Resource	Description
FDEP (2011). Guidance for Disturbance and Use of Old Closed Landfills or Waste Disposal Areas in Florida. Department of Environmental Protection Solid Waste Section, Tallahassee, FL http://www.dep.state.fl.us/waste/quick_topics/publications/shw/solid_waste/Dump-Guidance-03Feb11.pdf	Describes the expectations of the Florida Department of Environmental Protection when an old site is disturbed or used including when construction is to occur near or over waste-filled areas. Provides Department contact information; summary of landfill permit, closure and long-term care requirements;
Martin, W. L., and Tedder, R. B. (2002). Use of Old Landfills in Florida. Proceedings of the 16th GRI Conference, Geosynthetic Institute Philadelphia, PA, USA, December 16-17, 2002. http://www.dep.state.fl.us/waste/quick_topics/publications/shw/solid_waste/USEOFOLDLFsINFL-totalPaper.pdf	Four case studies of landfill use in Florida (all projects included construction over or near the landfill) and the lessons learned from their experiences.
IDEM (1999). Post-Closure Uses of Solid Waste Disposal Facilities. Indiana Department of Environmental Management Office of Land Quality, Indianapolis, IN, WASTE-0026-NPD. http://www.in.gov/idem/files/nrpd_waste-0026.pdf	Guidance document developed by Indiana Department of Environmental Management for the beneficial post-closure use of landfill including agricultural, recreational and industrial activities.
MassDEP (2009) Landfill Post-Closure Use Permitting Guidelines June 2009. Massachusetts Department of Environmental Protection. http://www.mass.gov/eea/agencies/massdep/recycle/approvals/landfill-post-closure-use-permitting-guidelines.html (website) http://www.mass.gov/eea/docs/dep/recycle/laws/lfpcguid.pdf (document)	The Massachusetts permitting process and requirements (for facilities that have not obtained previous permits or permissions for the end use) for major and minor post-closure uses.
NJDEP (2014) Guidance Documents. http://www.nj.gov/dep/sage/so-	New Jersey guidance documents that discuss determining sites best

Resource	Description
guidancedocs.html Accessed 16 April 2014. NJDEP (2012) Solar Siting Analysis. New Jersey Department of Environmental Protection Sustainability and Green Energy, October 2012. NJDEP (2013) Guidance for Installation of Solar Renewable Energy Systems on Landfills in New Jersey (Updated January 8, 2013). New Jersey Department of Environmental Protection.	suited for developing solar energy projects and how to apply for permits, permissions and the issues with installing a solar renewable energy system on a landfill.
Ohio EPA (2010). Considerations for Development On or Adjacent to a Closed Solid Waste Landfill. Ohio EPA, Division of Solid and Infectious Waste Management, Columbus, Ohio, Guidance Document 1003, March 2010. http://www.epa.ohio.gov/portals/34/document/guidance/gd_1003.pdf	Ohio Environmental Protection Agency discusses environmental considerations when developing on or adjacent to a closed solid waste landfill.
TCEQ (2014) Use of Land Over Closed Municipal Solid Waste Landfills. Texas Commission on Environmental Quality, https://www.tceq.texas.gov/permitting/waste_permits/msw_permits/msw_closeduse.html Accessed 16 April 2014.	The state of Texas' applicable regulations; application procedures for permitting or registration for development of land over a closed MSW landfill (2005); questions and answers for developing on land over an MSW landfill (2010).
US EPA (2005) Guidance for evaluating landfill gas emissions from closed or abandoned facilities. EPA -600/R-05/123a, September 2005. http://www.epa.gov/nrmrl/pubs/600r05123.html	A guidance document for superfund remedial project managers that provides background information relevant to closed MSW landfills including: LFG basics, exposure risks and problems and LFG collection and control systems.
US EPA and NREL (2013) Best Practices for Siting Solar Photovoltaics on Municipal Solid Waste Landfills. NREL/TP-7A30-52615, February 2013. http://www.epa.gov/oswercpa/docs/best_practices_siting_solar_photovoltaic_final.pdf	A technical guidance document addressing challenges of siting photovoltaics (PV) on MSW landfills. Discusses the types of PV technology and considerations related to feasibility, design, construction, and operation and maintenance of PV. Includes a summary of best practices for siting PV.
US EPA (2014) Handbook on Siting Renewable Energy Projects While	Discusses reusing contaminated sites for renewable energy projects and

Resource	**Description**
Addressing Environmental Issues. U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response's Center for Program Analysis, http://www.epa.gov/oswercpa/docs/handbook_siting_repowering_projects.pdf Accessed 16 April 2014.	includes evaluating the renewable energy potential of a site and integrating renewable energy development into cleanup processes.
US EPA and NREL (2014) Screening Sites for Solar PV Potential. http://www.epa.gov/oswercpa/docs/solar_decision_tree.pdf Accessed 16 April 2014.	This document is a decision tree to assist state and local governments and stakeholders screen sites (including landfills) for redevelopment with solar PV energy. The document describes the processes of pre-screening, site screening and financial screening.
US EPA and NREL (2014) Screening Sites for Wind Energy Potential. http://www.epa.gov/oswercpa/docs/wind_decision_tree.pdf Accessed 16 April 2014.	This document is a decision tree to assist state and local governments and stakeholders screen sites (including landfills) for redevelopment with wind energy. The document describes the processes of pre-screening, site screening and financial screening.
US EPA (1997) Landfill Reclamation. Solid Waste and Emergency Response, EPA530-F-97-001, July 1997. http://www.epa.gov/osw/nonhaz/municipal/landfill/land-rcl.pdf	This document describes the basics of the reclamation process and project planning and also touches on its benefits and drawbacks and provides case studies of successful projects.
US EPA (2001) Reusing Superfund Sites: Recreational Use of Land Above Hazardous Waste Containment Areas http://www.epa.gov/superfund/programs/recycle/pdf/recreuse.pdf	This document describes the technical considerations of designing recreational facilities as superfund cleanups where some of the hazardous waste is retained on site; case studies of successful projects are included.
US EPA (2003) Reusing Cleaned Up Superfund Sites: Golf Facilities Where Waste is Left on Site http://www.epa.gov/superfund/programs/recycle/pdf/golf.pdf	This document describes the elements of planning, designing, operations and maintenance related to developing a golf course facility on a superfund site; case studies of successful projects are included.
US EPA (2002) Reusing Superfund Sites: Commercial Use Where Waste is Left on Site	This document describes site configurations, remediation approaches, and design considerations when planning to reuse a superfund site for commercial purposes; case studies of successful projects are included.

Resource	Description
http://www.epa.gov/superfund/programs/recycle/pdf/c_reuse.pdf	

ATTACHMENT E

STORMWATER AND FLOODPLAIN EFFECTS

Industrial Stormwater

Fact Sheet Series

Sector L: Landfills and Land Application Sites

U.S. EPA Office of Water
EPA-833-F-06-027
December 2006

What is the NPDES stormwater permitting program for industrial activity?

Activities, such as material handling and storage, equipment maintenance and cleaning, industrial processing or other operations that occur at industrial facilities are often exposed to stormwater. The runoff from these areas may discharge pollutants directly into nearby waterbodies or indirectly via storm sewer systems, thereby degrading water quality.

In 1990, the U.S. Environmental Protection Agency (EPA) developed permitting regulations under the National Pollutant Discharge Elimination System (NPDES) to control stormwater discharges associated with eleven categories of industrial activity. As a result, NPDES permitting authorities, which may be either EPA or a state environmental agency, issue stormwater permits to control runoff from these industrial facilities.

What types of industrial facilities are required to obtain permit coverage?

This fact sheet specifically discusses stormwater discharges from landfills and land application sites. Facilities and products in this group fall under the following categories, all of which require coverage under an industrial stormwater permit:

- Landfills
- Land application sites
- Open dumps that receive or have received industrial waste

These include sites subject to regulation under Subtitle D of the Resource Conservation and Recovery Act (RCRA) including municipal solid waste landfills (MSWLFs), industrial solid nonhazardous waste landfills, and industrial waste land application sites.

What does an industrial stormwater permit require?

Common requirements for coverage under an industrial stormwater permit include development of a written stormwater pollution prevention plan (SWPPP), implementation of control measures, and submittal of a request for permit coverage, usually referred to as the Notice of Intent or NOI. The SWPPP is a written assessment of potential sources of pollutants in stormwater runoff and control measures that will be implemented at your facility to minimize the discharge of these pollutants in runoff from the site. These control measures include site-specific best management practices (BMPs), maintenance plans, inspections, employee training, and reporting. The procedures detailed in the SWPPP must be implemented by the facility and updated as necessary, with a copy of the SWPPP kept on-site. The industrial stormwater permit also requires collection of visual, analytical, and/or compliance monitoring data to determine the effectiveness of implemented BMPs. For more information on EPA's industrial stormwater permit and links to State stormwater permits, go to **www.epa.gov/npdes/stormwater** and click on "Industrial Activity."

What pollutants are associated with activities at my facility?

Pollutants conveyed in stormwater discharges from landfills and land application sites will vary. There are a number of factors that influence to what extent industrial activities and significant materials can affect water quality.

- Geographic location
- Topography
- Hydrogeology
- Extent of impervious surfaces (e.g.,, concrete or asphalt)
- Type of ground cover (e.g., vegetation, crushed stone, or dirt)
- Outdoor activities (e.g., material storage, loading/unloading, vehicle maintenance)
- Size of the operation
- Type, duration, and intensity of precipitation events

Factors such as these will interact to influence the quantity and quality of stormwater runoff. At landfill and land application sites, runoff carrying suspended sediments and the commingling of runoff with uncontrolled leachate are the two primary sources of pollutants in stormwater. In addition, sources of pollutants other than stormwater, such as illicit connections, spills, and other improperly dumped materials, may increase the pollutant loading discharged into receiving waters. Other potential sources of pollutants at landfills and land application sites include those from ancillary areas and areas which are not directly associated with landfill or land application activities (e.g., vehicle maintenance, truck washing). These activities may be subject to permit requirements separate from those required of landfills and land application sites.

Municipal Solid Waste Landfills (MSWLFs). The wastes disposed of in MSWLFs are variable and may include household waste (including household hazardous waste which is excluded from RCRA hazardous waste regulation), nonhazardous incinerator ashes, commercial wastes, yard wastes, tires, white goods, construction wastes, municipal and industrial sludges, asbestos, and other industrial wastes. Industrial process wastes represent a small percent of the total wastestream (although most MSWLFs currently or have previously accepted industrial wastes and are therefore subject to stormwater permitting requirements). MSWLFs that operated prior to the implementation of RCRA hazardous waste management requirements in 1980 may have received wastes that would have been classified as hazardous wastes under current RCRA requirements.

Industrial landfills, most of which are privately owned, only receive wastes from industrial facilities such as factories, processing plants, and manufacturing sites. These facilities may also receive hazardous wastes from very small quantity hazardous waste generators. Included in these waste streams are some PCB contaminated wastes. The Toxic Substances Control Act PCB disposal regulations allow limited categories of PCB materials to be disposed of in RCRA Subtitle D landfills. Because wastes generated by industrial facilities vary considerably, both between and within industries, the wastes disposed of at industrial landfills can be highly variable. For example, the industrial nonhazardous waste category includes wastes from the pulp and paper industry, the organic chemical industry, the textile manufacturing industry, and a variety of other industries. Consequently, these waste streams may vary in chemical composition and/or physical form.

Land application sites receive wastes (primarily wastewaters and sludges) from facilities in virtually every major industrial category. Similar to landfills, the variability in types of waste that are land applied precludes any general characterization of the materials that may be exposed to stormwater. Typically, individual land applications will only dispose of wastes with specific characteristics. However, the criteria for selection are site-specific depending on type of process used and the soil characteristics. Waste application techniques are dependent on waste characteristics, cover crop and soil characteristics.

Stormwater discharges from landfills and land application sites often contain high TSS levels because of the extensive land disturbance activities associated with landfill operations. Suspended solids can adversely affect fisheries by covering the bottom of a stream or lake with a blanket of material that may destroy spawning grounds or the bottom fauna upon which fish feed. In addition, while they remain in suspension, suspended solids can increase turbidity, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

The activities, pollutant sources, and associated pollutants detailed in Table 1A and 1B are commonly found at landfills and land application sites. It is important to note that the occurrence and levels of pollutants other than TSS in stormwater discharges are dependent on the types of wastes deposited/applied and facility design and operation (including use of stormwater management/treatment practices).

Table 1A. Common Activities, Pollutant Sources, and Associated Pollutants at Landfills

Activity	Pollutant Source	Pollutant
Cover crop management	Applied chemicals	Fertilizers, pesticides, and herbicides
Outdoor chemical storage	Exposure of chemical material storage areas to precipitation	Various chemicals stored
Waste transportation	Waste tracking on-site and haul road, solids transport on wheels and exterior of trucks or other equipment	TSS, total dissolved solids (TDS), turbidity, floatable
Leachate collection	Uncontrolled leachate (commingling of leachate with runoff or run-on)	Iron, TSS, biochemical oxygen demand (BOD), ammonia, alpha terpineol, benzoic acid, p-Cresol, phenol, zinc, pH
Landfill operations	Exposure of waste at open face	BOD, TSS, TDS, turbidity
Exposed soil from excavating cells/trenches	Erosion	TSS, TDS, turbidity
Exposed stockpiles of cover material		
Inactive cells with final cover but not finally stabilized		
Daily or intermediate cover placed on cells or trenches		
Haul roads (including vehicle tracking of sedimentation)		
Vehicle/equipment maintenance	Fueling activities	Diesel fuel, gasoline, oil
	Parts cleaning	Solvents, oil, heavy metals, acid/alkaline wastes
	Waste disposal of oily rags, oil and gas filters, batteries, coolants, degreasers	Oil, heavy metals, solvents, acids
	Fluid replacement including hydraulic fluid, oil, transmission fluid, radiator fluids, and grease	Oil and grease, arsenic, lead, cadmium, chromium, chemical oxygen demand (COD), and benzene

Table 1B. Common Activities, Pollutant Sources, and Associated Pollutants at Land Application Sites

Activity	Pollutant Source	Pollutant
Cover crop management	Applied chemicals	Fertilizers, pesticides, and herbicides
Outdoor chemical storage	Exposure of chemical material storage areas to precipitation	Various chemicals stored
Waste transportation	Waste tracking on-site and haul road, solids transport on wheels and exterior of trucks or other equipment	TSS, total dissolved solids (TDS), turbidity, floatable

Table 1B. Common Activities, Pollutant Sources, and Associated Pollutants at Land Application Sites (continued)

Activity	Pollutant Source	Pollutant
Vehicle/equipment maintenance	Fueling activities	Diesel fuel, gasoline, oil
	Parts cleaning	Solvents, oil, heavy metals, acid/alkaline wastes
	Waste disposal of oily rags, oil and gas filters, batteries, coolants, degreasers	Oil, heavy metals, solvents, acids
	Fluid replacement including hydraulic fluid, oil, transmission fluid, radiator fluids, and grease	Oil and grease, arsenic, lead, cadmium, chromium, chemical oxygen demand (COD), and benzene

What BMPs can be used to minimize contact between stormwater and potential pollutants at my facility?

A variety of BMP options may be applicable to eliminate or minimize the presence of pollutants in stormwater discharges from landfills and land application sites. You will likely need to implement a combination or suite of BMPs to address stormwater runoff at your facility. Your first consideration should be for pollution prevention BMPs, which are designed to prevent or minimize pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. Prevention BMPs can include regular cleanup, collection and containment of debris in storage areas, and other housekeeping practices, spill control, diversions, and employee training. It may also be necessary to implement treatment BMPs, which are engineered structures intended to treat stormwater runoff and/or mitigate the effects of increased stormwater runoff peak rate, volume, and velocity. Treatment BMPs are generally more expensive to install and maintain and include oil-water separators, sedimentation ponds, and proprietary filter devices.

BMPs must be selected and implemented to address the following:

Good Housekeeping Practices

Good housekeeping is a practical, cost-effective way to maintain a clean and orderly facility to prevent potential pollution sources from coming into contact with stormwater. It includes establishing protocols to reduce the possibility of mishandling materials or equipment and training employees in good housekeeping techniques. Good housekeeping practices must include a schedule for regular pickup and disposal of waste materials such as oils and fluids and routine inspections of drums, tanks, and containers for leaks and structural conditions. Practices also include containing and covering garbage, waste materials, and debris. Involving employees in routine monitoring of housekeeping practices has proven to be an effective means of ensuring the continued implementation of these measures.

Specific good housekeeping practices for landfills and land application sites include providing protected storage areas for pesticides, herbicides, fertilizers, and other significant materials, vehicle maintenance areas, and recycled materials areas if present. Additionally, a preventative maintenance program should be developed that addresses:

- The maintenance of containers used for outdoor chemical/significant materials/recyclables storage to prevent leaking
- All elements of leachate collection and treatment systems to prevent exposure of leachate to stormwater
- The integrity and effectiveness of any intermediate or final cover

Minimizing Exposure

Where feasible, minimizing exposure of potential pollutant sources to precipitation is an important control option. For landfills and land application sites, this measure is again most applicable to areas other than the active disposal/application sited although minimizing disturbance in these areas is important as well. Minimizing exposure prevents pollutants, including debris, from coming into contact with precipitation and can reduce the need for BMPs to treat contaminated stormwater runoff. It can also prevent debris from being picked up by stormwater and carried into drains and surface waters. Examples of BMPs for exposure minimization include covering materials or activities with temporary structures (e.g., tarps) when wet weather is expected or moving materials or activities to existing or new permanent structures (e.g., buildings, silos, sheds).

Erosion and Sediment Control

BMPs must be selected and implemented to limit erosion on areas of your site that are likely to experience erosion, such as access roads, application areas, and active and recently reclaimed landfill areas. Erosion control BMPs such as seeding and mulching prevent soil from becoming dislodged and should be considered first along with diverting uncontaminated surface flows away from disturbed areas. Sediment control BMPs such as silt fences, sediment ponds, and stabilized entrances trap sediment after it has eroded. Sediment control BMPs should be used to back-up erosion control BMPs.

Landfill construction creates constant changes in the contours of the facility resulting in changing patterns of stormwater run-on and runoff. Controlling erosion of landfill slopes is among the primary concerns of the landfill operator. Practices generally include a combination of temporary controls (straw bales, silt fences, etc.) in active disposal areas and permanent controls (recontouring, revegetation, etc.) in areas where waste disposal has been completed.

Specific sediment and erosion practices for landfills and land application sites include providing temporary stabilization and placing geotextiles on the inactive portions of stockpiles. This should be done for:

- Materials stockpiled daily for immediate and final cover
- Inactive areas of the landfill or open dump
- Any landfill or open dump area with final covers but where vegetation has yet to establish itself
- Where waste application has been completed at land application sites but final vegetation has not yet been established

Management of Runoff

Your SWPPP must contain a narrative evaluation of the appropriateness of stormwater management practices that divert, infiltrate, reuse, or otherwise manage stormwater runoff so as to reduce the discharge of pollutants. Appropriate measures are highly site-specific, but may include, among others, vegetative swales, collection and reuse of stormwater, inlet controls, snow management, infiltration devices, and wet retention measures.

A combination of preventive and treatment BMPs will yield the most effective stormwater management for minimizing the offsite discharge of pollutants via stormwater runoff. Though not specifically outlined in this fact sheet, BMPs must also address preventive maintenance records or logbooks, regular facility inspections, spill prevention and response, and employee training.

All BMPs require regular maintenance to function as intended. Some management measures have simple maintenance requirements, others are quite involved. You must regularly inspect all BMPs to ensure they are operating properly, including during runoff events. As soon as a problem is found, action to resolve it should be initiated immediately.

Implement BMPs, such as those listed below in Table 2 for the control of pollutants at landfills and land application sites, to minimize and prevent the discharge of pollutants in stormwater. Identifying weaknesses in current facility practices will aid the permittee in determining appropriate BMPs that will achieve a reduction in pollutant loadings. BMPs listed in Table 2 are broadly applicable to landfills and land application sites; however, this is not a complete list and you are recommended to consult with regulatory agencies or a stormwater engineer/consultant to identify appropriate BMPs for your facility.

Table 2A. BMPs for Potential Pollutant Sources at Landfills and Land Application Sites

Pollutant Source	BMPs
Application of fertilizers, pesticides, and herbicides	❑ Observe all applicable Federal, State, and local regulations when using these products. ❑ Strictly follow recommended application rates and methods (i.e., do not apply in excess of vegetative requirements). ❑ Have materials such as absorbent pads easily accessible to clean up spills. ❑ Inspect and maintain all containers used to prevent leaking. ❑ Implement employee training program for proper application and spill prevention. ❑ Store drums and containers indoors when possible.
Chemical material storage areas	❑ Store drums, including empty or used drums, in secondary containment with a roof or cover (including temporary cover such as a tarp that prevents contact with precipitation). ❑ Provide secondary containment, such as dikes or portable containers, with a height sufficient to contain a spill (the greater of 10 percent of the total enclosed tank volume or 110 percent of the volume contained in the largest tank). ❑ Locate material storage areas away from high traffic areas and surface waters. ❑ Inspect storage tanks and piping systems (pipes, pumps, flanges, couplings, hoses, and valves) for failures or leaks and perform preventive maintenance. ❑ Clearly label drums with their contents. ❑ Maintain an inventory of fluids to identify leakage. ❑ Properly dispose of chemicals that are no longer in use. ❑ Store and handle reactive, ignitable, or flammable liquids in compliance with applicable local fire codes, local zoning codes, and the National Electric Code. ❑ Provide drip pads/pans where chemicals are transferred from one container to another to allow for recycling of spills and leaks. ❑ Have materials such as absorbent pads easily accessible to clean up spills. ❑ Develop and implement spill plans or spill prevention, containment, and countermeasure (SPCC) plans, if required for your facility. ❑ Train employees in spill prevention and control and proper materials management.
Exposure of waste at open face (Landfills only)	❑ Minimize the area of exposed open face as much as is practicable. ❑ Divert flows around open face using structural measures such as dikes, berms, swales, or pipe slope drains. ❑ Maintain the integrity and effectiveness of any intermediate or final cover (including repairing the cover as necessary to minimize the effects of settlement, sinking, and erosion). ❑ Regularly inspect erosion and sediment controls.

Table 2A. BMPs for Potential Pollutant Sources at Landfills and Land Application Sites (continued)

Pollutant Source	BMPs
Waste tracking and solids transport on wheels and exterior of trucks or other equipment from on-site/offsite or haul roads.	❑ Clean wheels and exterior of trucks or other equipment as necessary to minimize waste tracking (but contain any wash waters). ❑ Establish procedures such as rumble strips and gravel apron to minimize offsite tracking
Uncontrolled leachate	❑ Divert flows around site using structural measures such as dikes, berms, or swales. ❑ Frequently inspect leachate collection system and landfill for leachate leaks. ❑ Maintain landfill cover and vegetation. ❑ Maintain leachate collection system. ❑ Maintain all elements of leachate collection and treatment systems to prevent commingling of leachate with stormwater.
Erosion from: Excavating cells/ trenches Stockpiles of cover material Inactive cells with final cover but not finally stabilized Daily or intermediate cover placed on cells or trenches Haul roads	❑ Implement structural controls such as dikes, swales, silt fences, filter berms, sediment traps and ponds, outlet protection, pipe slope drains, check dams, and terraces to convey runoff, to divert stormwater flows away from areas susceptible to erosion, and to prevent sediments from entering water bodies. ❑ Confine stockpiling to areas outside of drainage pathways and away from surface waters ❑ Stabilize soils with temporary seeding, mulching, and placing geotextiles on the inactive portions of stockpiles ❑ Leave vegetative filter strips along streams. ❑ Keep as much vegetation as possible when building roads and seed as necessary and appropriate. ❑ Construct vegetated swales along road. ❑ Stabilize haul roads and entrances to landfill with gravel or stone. ❑ Clean wheels and body of trucks or other equipment as necessary to minimize sediment tracking (but contain any wash waters). ❑ Frequently inspect all stabilization and structural erosion control measures and perform all necessary maintenance and repairs.
Vehicle/equipment fueling	Stationary fueling areas ❑ Conduct fueling operations (including the transfer of fuel from tank trucks) on an impervious or contained pad or under a roof or canopy where possible. Covering should extend beyond spill containment pad to prevent rain from entering. ❑ When fueling in uncovered area, use a concrete pad (asphalt is not chemically resistant to the fuels being handled). ❑ Use drip pans where leaks or spills of fuel can occur and where making and breaking hose connections. ❑ Use fueling hoses with check valves to prevent hose drainage after filling. ❑ Use spill and overflow protection devices. ❑ Keep spill cleanup materials readily available. Clean up spills and leaks immediately. ❑ Minimize/eliminate run-on onto fueling areas with diversion dikes, berms, curbing, surface grading or other equivalent measures. ❑ Collect stormwater runoff and provide treatment or recycling.

Table 2A. BMPs for Potential Pollutant Sources at Landfills and Land Application Sites (continued)

Pollutant Source	BMPs
Vehicle/equipment fueling (continued)	Stationary fueling areas (continued) ❑ Use dry cleanup methods for fuel area rather than hosing the fuel area down. Follow procedures for sweeping up absorbents as soon as spilled substances have been absorbed. ❑ Regularly inspect and perform preventive maintenance on storage tanks to detect potential leaks before they occur. ❑ Inspect the fueling area for leaks and spills. ❑ Provide curbing or posts around fuel pumps to prevent collisions during vehicle ingress and egress. ❑ Discourage "topping off" of fuel tanks. Mobile fueling areas ❑ Use drip pan under the transfer hose. ❑ Use fueling hoses with check valves to prevent hose drainage after filling. ❑ Ensure the fueling vehicle is equipped with a manual shutoff valve. ❑ Do not allow topping off of the fuel in the receiving equipment. ❑ Train personnel on fueling BMPs.
Vehicle/equipment maintenance	Good Housekeeping ❑ Eliminate floor drains that are connected to the storm or sanitary sewer; if necessary, install a sump that is pumped regularly. Collected wastes should be properly treated or disposed of by a licensed waste hauler. ❑ Use drip plans, drain boards, and drying racks to direct drips back into a fluid holding tank for reuse. ❑ Drain all parts of fluids prior to disposal. Oil filters can be crushed and recycled. ❑ Promptly transfer used fluids to the proper container; do not leave full drip pans or other open containers around the shop. Empty and clean drip pans and containers. ❑ Dispose of greasy rags, oil filters, air filters, batteries, spent coolant, and degreasers properly. ❑ Store batteries and other significant materials inside. ❑ Label and track the recycling of waste material (e.g., used oil, spent solvents, batteries). ❑ Maintain an organized inventory of materials. ❑ Eliminate or reduce the number of hazardous materials used and amount of waste by substituting nonhazardous or less hazardous materials. ❑ Clean up leaks, drips, and other spills without using large amounts of water. ❑ Prohibit the practice of hosing down an area where the practice would result in the exposure of pollutants to stormwater. ❑ Clean without using liquid cleaners whenever possible. ❑ Do all cleaning at a centralized station so the solvents stay in one area. ❑ If parts are dipped in liquid, remove them slowly to avoid spills. ❑ Do not pour liquid waste down floor drains, sinks, outdoor storm drain inlets, or other storm drains or sewer connections. Minimizing Exposure ❑ Perform all cleaning operations indoors or under covering when possible. Conduct the cleaning operations in an area with a concrete floor with no floor drainage other than to sanitary sewers or treatment facilities.

Table 2A. BMPs for Potential Pollutant Sources at Landfills and Land Application Sites (continued)

Pollutant Source	BMPs
Vehicle/equipment maintenance (continued)	Minimizing Exposure (continued) ❑ If operations are uncovered, perform them on a concrete pad that is impervious and contained. ❑ Park vehicles and equipment indoors or under a roof whenever possible where proper control of oil leaks/spills is maintained and exposure to stormwater is prevented. ❑ Watch vehicles closely for leaks and use pans to collect fluid when leaks occur. Management of Runoff ❑ Use berms, curbs, or other diversion measures to ensure that stormwater runoff from other parts of the facility does not flow over the maintenance area. ❑ Collect the stormwater runoff from the cleaning area and provide treatment or recycle the runoff. Discharge vehicle wash or rinse water to the sanitary sewer (if allowed by sewer authority), wastewater treatment, a land application site, or recycle on-site. DO NOT discharge washwater to a storm drain or to surface water. Inspections and Training ❑ Inspect the maintenance area regularly for proper implementation of control measures. ❑ Train employees on proper waste control and disposal procedures.

What if activities and materials at my facility are not exposed to precipitation?

The industrial stormwater program requires permit coverage for a number of specified types of industrial activities. However, when a facility is able to prevent the exposure of ALL relevant activities and materials to precipitation, it may be eligible to claim no exposure and qualify for a waiver from permit coverage.

If you are regulated under the industrial permitting program, you must either obtain permit coverage or submit a no exposure certification form, if available. Check with your permitting authority for additional information as not every permitting authority program provides no exposure exemptions.

Where do I get more information?

For additional information on the industrial stormwater program see **www.epa.gov/npdes/stormwater/msgp**.

A list of names and telephone numbers for each EPA Region or state NPDES permitting authority can be found at **www.epa.gov/npdes/stormwatercontacts**.

References

Information contained in this Fact Sheet was compiled from EPA's past and current Multi-Sector General Permits and from the following sources:

- U.S. EPA, Office of Wastewater Management. *NPDES Stormwater Multi-Sector General Permit for Industrial Activities (MSGP).*
  www.epa.gov/npdes/stormwater/msgp

(2) If the ISOC upholds the appeal in its entirety, the information will be released in accordance with the provisions of paragraph (e) of this section.

(3) If the ISOC denies the appeal, in part or in its entirety, then it will forward the appeal with its recommendation(s) to the Administrator of FEMA, for a final determination. A reply will be forwarded to the requestor enclosing the declassified releasable information if any, and an explanation for denying the request in whole or in part.

(4) Final action on appeals shall be completed within thirty (30) working days of receipt of appeal.

[49 FR 24518, June 14, 1984, as amended at 49 FR 38119, Sept. 27, 1984; 50 FR 40006, Oct. 1, 1985; 51 FR 34605, Sept. 30, 1986]

PART 9—FLOODPLAIN MANAGEMENT AND PROTECTION OF WETLANDS

AUTHORITY: E.O. 11988 of May 24, 1977. 3 CFR, 1977 Comp., p. 117; E.O. 11990 of May 24 1977, 3 CFR, 1977 Comp. p. 121; Reorganization Plan No. 3 of 1978, 43 FR 41943, 3 CFR, 1978 Comp., p. 329; E.O. 12127 of March 31, 1979, 44 FR 19367, 3 CFR, 1979 Comp., p. 376; E.O. 12148 of July 20, 1979, 44 FR 43239, 3 CFR, 1979 Comp., p. 412, as amended.; E.O. 12127; E.O. 12148; 42 U.S.C. 5201.

SOURCE: 45 FR 59526, Sept. 9, 1980, unless otherwise noted.

§ 9.1 Purpose of part.

This regulation sets forth the policy, procedure and responsibilities to implement and enforce Executive Order 11988, Floodplain Management, and Executive Order 11990, Protection of Wetlands.

§ 9.2 Policy.

(a) FEMA shall take no action unless and until the requirements of this regulation are complied with.

(b) It is the policy of the Agency to provide leadership in floodplain management and the protection of wetlands. Further, the Agency shall integrate the goals of the Orders to the greatest possible degree into its procedures for implementing NEPA. The Agency shall take action to:

(1) Avoid long- and short-term adverse impacts associated with the occupancy and modification of floodplains and the destruction and modification of wetlands;

(2) Avoid direct and indirect support of floodplain development and new construction in wetlands wherever there is a practicable alternative;

(3) Reduce the risk of flood loss;

(4) Promote the use of nonstructural flood protection methods to reduce the risk of flood loss;

(5) Minimize the impact of floods on human health, safety and welfare;

(6) Minimize the destruction, loss or degradation of wetlands;

(7) Restore and preserve the natural and beneficial values served by floodplains;

(8) Preserve and enhance the natural values of wetlands;

(9) Involve the public throughout the floodplain management and wetlands protection decision-making process;

(10) Adhere to the objectives of the Unified National Program for Floodplain Management; and

(11) Improve and coordinate the Agency's plans, programs, functions and resources so that the Nation may attain the widest range of beneficial uses of the environment without degradation or risk to health and safety.

§ 9.3 Authority.

The authority for these regulations is (a) Executive Order 11988, May 24, 1977, which replaced Executive Order

11296, August 10, 1966, (b) Executive Order 11990, May 24, 1977, (c) Reorganization Plan No. 3 of 1978 (43 FR 41943); and (d) Executive Order 12127, April 1, 1979 (44 FR 1936). E.O. 11988 was issued in furtherance of the National Flood Insurance Act of 1968, as amended (Pub. L. 90–488); the Flood Disaster Protection Act of 1973, as amended (Pub. L. 93–234); and the National Environmental Policy Act of 1969 (NEPA) (Pub. L. 91–190). Section 2(d) of Executive Order 11988 requires issuance of new or amended regulations and procedures to satisfy its substantive and procedural provisions. E.O. 11990 was issued in furtherance of NEPA, and at section 6 required issuance of new or amended regulations and procedures to satisfy its substantive and procedural provisions.

[45 FR 59526, Sept. 9, 1980, as amended at 48 FR 44543, Sept. 29, 1983]

§ 9.4 Definitions.

The following definitions shall apply throughout this regulation.

Action means any action or activity including: (a) Acquiring, managing and disposing of Federal lands and facilities; (b) providing federally undertaken, financed or assisted construction and improvements; and (c) conducting Federal activities and programs affecting land use, including, but not limited to, water and related land resources, planning, regulating and licensing activities.

Actions Affecting or Affected by Floodplains or Wetlands means actions which have the potential to result in the long- or short-term impacts associated with (a) the occupancy or modification of floodplains, and the direct or indirect support of floodplain development, or (b) the destruction and modification of wetlands and the direct or indirect support of new construction in wetlands.

Administrator means the Administrator of the Federal Emergency Management Agency.

Agency means the Federal Emergency Management Agency (FEMA).

Agency Assistance means grants for projects or planning activities, loans, and all other forms of financial or technical assistance provided by the Agency.

Base Flood means the flood which has a one percent chance of being equalled or exceeded in any given year (also known as a 100-year flood). This term is used in the National Flood Insurance Program (NFIP) to indicate the minimum level of flooding to be used by a community in its floodplain management regulations.

Base Floodplain means the 100-year floodplain (one percent chance floodplain).

Coastal High Hazard Area means the areas subject to high velocity waters including but not limited to hurricane wave wash or tsunamis. On a Flood Insurance Rate Map (FIRM), this appears as zone V1–30, VE or V.

Critical Action means an action for which even a slight chance of flooding is too great. The minimum floodplain of concern for critical actions is the 500-year floodplain, i.e., critical action floodplain. Critical actions include, but are not limited to, those which create or extend the useful life of structures or facilities:

(a) Such as those which produce, use or store highly volatile, flammable, explosive, toxic or water-reactive materials;

(b) Such as hospitals and nursing homes, and housing for the elderly, which are likely to contain occupants who may not be sufficiently mobile to avoid the loss of life or injury during flood and storm events;

(c) Such as emergency operation centers, or data storage centers which contain records or services that may become lost or inoperative during flood and storm events; and

(d) Such as generating plants, and other principal points of utility lines.

Direct Impacts means changes in floodplain or wetland values and functions and changes in the risk to lives and property caused or induced by an action or related activity. Impacts are caused whenever these natural values and functions are affected as a direct result of an action. An action which would result in the discharge of polluted storm waters into a floodplain or wetland, for example, would directly affect their natural values and functions. Construction-related activities, such as dredging and filling operations within the floodplain or a wetland would be another example of impacts caused by an action.

Emergency Actions means emergency work essential to save lives and protect property and public health and safety performed under sections 305 and 306 of the Disaster Relief Act of 1974 (42 U.S.C. 5145 and 5146). See 44 CFR part 205, subpart E.

Enhance means to increase, heighten, or improve the natural and beneficial values associated with wetlands.

Facility means any man-made or man-placed item other than a structure.

FEMA means the Federal Emergency Management Agency.

FIA means the Federal Insurance Administration.

Five Hundred Year Floodplain (the 500-year floodplain or 0.2 percent change floodplain) means that area, including the base floodplain, which is subject to inundation from a flood having a 0.2 percent chance of being equalled or exceeded in any given year.

Flood or *flooding* means a general and temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland and/or tidal waters, and/or the unusual and rapid accumulation or runoff of surface waters from any source.

Flood Fringe means that portion of the floodplain outside of the floodway (often referred to as ''floodway fringe'').

Flood Hazard Boundary Map (FHBM) means an official map of a community, issued by the Administrator, where the boundaries of the flood, mudslide (i.e., mudflow) and related erosion areas having special hazards have been designated as Zone A, M, or E.

Flood Insurance Rate Map (FIRM) means an official map of a community on which the Administrator has delineated both the special hazard areas and the risk premium zones applicable to the community. FIRMs are also available digitally, and are called Digital Flood Insurance Rate Maps (DFIRM).

Flood Insurance Study (FIS) means an examination, evaluation and determination of flood hazards and, if appropriate, corresponding water surface elevations or an examination, evaluation and determination of mudslide (i.e., mudflow) and/or flood-related erosion hazards.

Floodplain means the lowland and relatively flat areas adjoining inland and coastal waters including, at a minimum, that area subject to a one percent or greater chance of flooding in any given year. Wherever in this regulation the term ''floodplain'' is used, if a critical action is involved, ''floodplain'' shall mean the area subject to inundation from a flood having a 0.2 percent chance of occurring in any given year (500-year floodplain). ''Floodplain'' does not include areas subject only to mudflow until FIA adopts maps identifying ''M'' Zones.

Floodproofing means the modification of individual structures and facilities, their sites, and their contents to protect against structural failure, to keep water out, or to reduce effects of water entry.

Floodway means that portion of the floodplain which is effective in carrying flow, within which this carrying capacity must be preserved and where the flood hazard is generally highest, i.e., where water depths and velocities are the greatest. It is that area which provides for the discharge of the base flood so the cumulative increase in water surface elevation is no more than one foot.

Functionally Dependent Use means a use which cannot perform its intended purpose unless it is located or carried out in close proximity to water, (e.g., bridges, and piers).

Indirect Impacts means an indirect result of an action whenever the action induces or makes possible related activities which effect the natural values and functions of floodplains or wetlands or the risk to lives and property. Such impacts occur whenever these values and functions are potentially affected, either in the short- or long-term, as a result of undertaking an action.

Minimize means to reduce to the smallest amount or degree possible.

Mitigation means all steps necessary to minimize the potentially adverse effects of the proposed action, and to restore and preserve the natural and beneficial floodplain values and to preserve and enhance natural values of wetlands.

Mitigation Directorate means the Mitigation Directorate of the Federal Emergency Management Agency.

Natural Values of Floodplains and Wetlands means the qualities of or functions served by floodplains and wetlands which include but are not limited to: (a) Water resource values (natural moderation of floods, water quality maintenance, groundwater recharge); (b) living resource values (fish, wildlife, plant resources and habitats); (c) cultural resource values (open space, natural beauty, scientific study, outdoor education, archeological and historic sites, recreation); and (d) cultivated resource values (agriculture, aquaculture, forestry).

New Construction means the construction of a new structure (including the placement of a mobile home) or facility or the replacement of a structure or facility which has been totally destroyed.

New Construction in Wetlands includes draining, dredging, channelizing, filling, diking, impounding, and related activities and any structures or facilities begun or authorized after the effective dates of the Orders, May 24, 1977.

Orders means Executive Orders 11988, Floodplain Management, and 11990, Protection of Wetlands.

Practicable means capable of being done within existing constraints. The test of what is practicable depends upon the situation and includes consideration of all pertinent factors, such as environment, cost and technology.

Preserve means to prevent alterations to natural conditions and to maintain the values and functions which operate the floodplains or wetlands in their natural states.

Regional Administrator means the Regional Administrator of the Federal Emergency Management Agency for the Region in which FEMA is acting, or the Disaster Recovery Manager when one is designated.

Regulatory Floodway means the area regulated by federal, State or local requirements to provide for the discharge of the base flood so the cumulative increase in water surface elevation is no more than a designated amount (not to exceed one foot as set by the National Flood Insurance Program).

Restore means to reestablish a setting or environment in which the natural functions of the floodplain can again operate.

Structures means walled or roofed buildings, including mobile homes and gas or liquid storage tanks.

Substantial Improvement means any repair, reconstruction or other improvement of a structure or facility, which has been damaged in excess of, or the cost of which equals or exceeds, 50% of the market value of the structure or replacement cost of the facility (including all ''public facilities'' as defined in the Disaster Relief Act of 1974) (a) before the repair or improvement is started, or (b) if the structure or facility has been damaged and is proposed to be restored, before the damage occurred. If a facility is an essential link in a larger system, the percentage of damage will be based on the relative cost of repairing the damaged facility to the replacement cost of the portion of the system which is operationally dependent on the facility. The term ''substantial improvement'' does not include any alteration of a structure or facility listed on the National Register of Historic Places or a State Inventory of Historic Places.

Support means to encourage, allow, serve or otherwise facilitate floodplain or wetland development. Direct support results from actions within a floodplain or wetland, and indirect support results from actions outside of floodplains or wetlands.

Wetlands means those areas which are inundated or saturated by surface or ground water with a frequency sufficient to support, or that under normal hydrologic conditions does or would support, a prevalence of vegetation or aquatic life typically adapted for life in saturated or seasonally saturated soil conditions. Examples of wetlands include, but are not limited to, swamps, fresh and salt water marshes, estuaries, bogs, beaches, wet meadows, sloughs, potholes, mud flats, river overflows and other similar areas. This definition includes those wetlands areas separated from their natural supply of water as a result of activities such as the construction of structural flood protection methods or solid-fill road beds and activities such as mineral extraction and navigation improvements. This definition is intended to be consistent with the definition utilized by the U.S. Fish and Wildlife Service in the publication entitled *Classification of Wetlands and Deep Water Habitats of the United States* (Cowardin, et al., 1977).

[45 FR 59526, Sept. 9, 1980, as amended at 47 FR 13149, Mar. 29, 1982; 50 FR 40006, Oct. 1, 1985; 74 FR 15335, Apr. 3, 2009]

§9.5 Scope.

(a) *Applicability.* (1) These regulations apply to all Agency actions which have the potential to affect floodplains or wetlands or their occupants, or which are subject to potential harm by location in floodplains or wetlands.

(2) The basic test of the potential of an action to affect floodplains or wetlands is the action's potential (both by itself and when viewed cumulatively with other proposed actions) to result in the long- or short-term adverse impacts associated with:

(i) The occupancy or modification of floodplains, and the direct and indirect support of floodplain development; or

(ii) The destruction or modification of wetlands and the direct or indirect support of new construction in wetlands.

(3) This regulation applies to actions that were, on the effective date of the Orders (May 24, 1977), ongoing, in the planning and/or development stages, or undergoing implementation, and are incomplete as of the effective date of these regulations. The regulation also applies to proposed (new) actions. The Agency shall:

(i) Determine the applicable provisions of the Orders by analyzing whether the action in question has progressed beyond critical stages in the floodplain management and wetlands protection decision-making process, as set out below in §9.6. This determination need only be made at the time that followup actions are being taken to complete or implement the action in question; and

(ii) Apply the provisions of the Orders and of this regulation to all such actions to the fullest extent practicable.

(b) *Limited exemption of ongoing actions involving wetlands located outside the floodplains.* (1) Executive Order 11990, Protection of Wetlands, contains a limited exemption not found in Executive Order 11988, Floodplain Management. Therefore, this exemption applies only to actions affecting wetlands which are located outside the floodplains, and which have no potential to result in harm to or within floodplains or to support floodplain development.

(2) The following proposed actions that impact wetlands located outside of floodplains are exempt from this regulation:

(i) Agency-assisted or permitted projects which were under construction before May 24, 1977; and

(ii) Projects for which the Agency has proposed a draft of a final environmental impact statement (EIS) which adequately analyzes the action and which was filed before October 1, 1977. Proposed actions that impact wetlands outside of floodplains are not exempt if the EIS:

(A) Only generally covers the proposed action;

(B) Is devoted largely to related activities; or

(C) Treats the project area or program without an adequate and specific analysis of the floodplain and wetland implications of the proposed action.

(c) *Decision-making involving certain categories of actions.* The provisions set forth in this regulation are *not applicable* to the actions enumerated below except that the Regional Administrators shall comply with the spirit of the Order to the extent practicable. For any action which is excluded from the actions enumerated below, the full 8-step process applies (see §9.6) (except as indicated at paragraphs (d), (f) and (g) of this section regarding other categories of partial or total exclusions). The provisions of these regulations do not apply to the following (all references are to the Disaster Relief Act of 1974, Pub. L. 93–288, as amended, except as noted):

(1) Assistance provided for emergency work essential to save lives and protect property and public health and safety performed pursuant to sections 305 and 306;

(2) Emergency Support Teams (section 304);

(3) Unemployment Assistance (section 407);

(4) Emergency Communications (section 415);

(5) Emergency Public Transportation (section 416);

(6) Fire Management Assistance (Section 420);

(7) Community Disaster Loans (section 414), except to the extent that the proceeds of the loan will be used for repair of facilities or structures or for construction of additional facilities or structures;

(8) The following Individual and Family Grant Program (section 408) actions:

(i) Housing needs or expenses, except for restoring, repairing or building private bridges, purchase of mobile homes and provision of structures as minimum protective measures;

(ii) Personal property needs or expenses;

(iii) Transportation expenses;

(iv) Medical/dental expenses;

(v) Funeral expenses;

(vi) Limited home repairs;

(vii) Flood insurance premium;

(viii) Cost estimates;

(ix) Food expenses; and

(x) Temporary rental accommodations.

(9) Mortgage and rental assistance under section 404(b);

(10) Use of existing resources in the temporary housing assistance program [section 404(a)], except that Step 1 (§ 9.7) shall be carried out;

(11) Minimal home repairs [section 404(c)];

(12) Debris removal (section 403), except those grants involving non-emergency disposal of debris within a floodplain or wetland;

(13) Repairs or replacements under section 402, of less than $5,000 to damaged structures or facilities.

(14) Placement of families in existing resources and Temporary Relocation Assistance provided to those families so placed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Public Law 96–510.

(d) For each action enumerated below, the Regional Administrator *shall apply steps 1, 2, 4, 5 and 8* of the decision-making process (§§ 9.7, 9.8, 9.10 and 9.11, see § 9.6). Steps 3 and 6 (§ 9.9) shall be carried out except that alternative sites outside the floodplain or wetland need not be considered. After assessing impacts of the proposed action on the floodplain or wetlands and of the site on the proposed action, alternative actions to the proposed action, if any, and the ''no action'' alternative shall be considered. The Regional Administrator may also require certain other portions of the decision-making process to be carried out for individual actions as is deemed necessary. For any action which is excluded from the actions listed below. (except as indicated in paragraphs (c), (f) and (g) of this section regarding other categories of partial or total exclusion), the full 8-step process applies (see § 9.6). The references are to the Disaster Relief Act of 1974, Public Law 93–288, as amended.

(1) Actions performed under the Individual and Family Grant Program (section 408) for restoring or repairing a private bridge, except where two or more individuals or families are authorized to pool their grants for this purpose.

(2) Small project grants (section 419), except to the extent that Federal funding involved is used for construction of new facilities or structures.

(3) Replacement of building contents, materials and equipment. (sections 402 and 419).

(4) Repairs under section 402 to damaged facilities or structures, except any such action for which one or more of the following is applicable:

(i) FEMA estimated cost of repairs is more than 50% of the estimated reconstruction cost of the entire facility or structure, or is more than $100,000, or

(ii) The action is located in a floodway or coastal high hazard area, or

(iii) The facility or structure is one which has previously sustained structural damage from flooding due to a major disaster or emergency or on which a flood insurance claim has been paid, or

(iv) The action is a critical action.

(e) *Other categories of actions.* Based upon the completion of the 8-step decision-making process (§ 9.6), the Director may find that a specific category of actions either offers no potential for carrying out the purposes of the Orders and shall be treated as those actions listed in § 9.5(c), or has no practicable alternative sites and shall be treated as those actions listed in § 9.5(d), or has no practicable alternative actions or sites and shall be treated as those actions listed in § 9.5(g). This finding will be made in consultation with the Federal Insurance Administration and the Council on Environmental Quality as provided in section 2(d) of E.O. 11988. Public notice of each of these determinations shall include publication in the FEDERAL REGISTER and a 30-day comment period.

(f) *The National Flood Insurance Program (NFIP).* (1) Most of what is done by FIA or the Mitigation Directorate, in administering the National Flood Insurance Program is performed on a program-wide basis. For all regulations, procedures or other issuances making or amending program policy, FIA or the Mitigation Directorate, shall apply the 8-step decision-making process to that program-wide action. The action to which the 8-step process must be applied is the establishment of programmatic standards or criteria, not the application of programmatic standards or criteria to specific situations. Thus, for example, FIA or the Mitigation Directorate, would apply the 8-step process to a programmatic determination of categories of structures to be insured, but not to whether to insure each individual structure. The two prime examples of where FIA or the Mitigation Directorate, does take site specific actions which would require individual application of the 8-step process are property acquisition under section 1362 of the National Flood Insurance Act of 1968, as amended, and the issuance of an exception to a community under 44 CFR 60.6(b). (See also § 9.9(e)(6) and § 9.11(e).)

(2) The provisions set forth in this regulation are not applicable to the actions enumerated below except that the Federal Insurance Administrator or the Assistant Administrator for Mitigation, as appropriate shall comply with the spirit of the Orders to the extent practicable:

(i) The issuance of individual flood insurance policies and policy interpretations;

(ii) The adjustment of claims made under the Standard Flood Insurance Policy;

(iii) The hiring of independent contractors to assist in the implementation of the National Flood Insurance Program;

(iv) The issuance of individual flood insurance maps, Map Information Facility map determinations, and map amendments; and

(v) The conferring of eligibility for emergency or regular program (NFIP) benefits upon communities.

(g) For the action listed below, the Regional Administrator *shall apply steps 1, 4, 5 and 8* of the decision-making process (§§ 9.7, 9.10 and 9.11). For any action which is excluded from the actions listed below, (except as indicated in paragraphs (c), (d) and (f) of this section regarding other categories of partial or total exclusion), the full 8-step process applies (See § 9.6). The Regional Administrator may also require certain other portions of the decision-making process to be carried out for individual actions as is deemed necessary. The references are to the Disaster Relief Act of 1974, Public Law 93–288. The above requirements apply to repairs, under section 402, between $5,000 and $25,000 to damaged structures of facilities except for:

(1) Actions in a floodway or coastal high hazard area; or

(2) New or substantially improved structures or facilities; or

(3) Facilities or structures which have previously sustained structural damage from flooding due to a major disaster or emergency.

[45 FR 59526, Sept. 9, 1980, as amended at 47 FR 13149, Mar. 29, 1982; 49 FR 35583, Sept. 10, 1984; 50 FR 40006, Oct. 1, 1985; 51 FR 39531, Oct. 29, 1986; 66 FR 57347, Nov. 14, 2001]

§ 9.6 Decision-making process.

(a) *Purpose.* The purpose of this section is to set out the floodplain management and wetlands protection decision-making process to be followed by the Agency in applying the Orders to its actions. While the decision-making process was initially designed to address the floodplain Order's requirements, the process will also satisfy the wetlands Order's provisions due to the close similarity of the two directives. The numbering of Steps 1 through 8 does not firmly require that the steps be followed sequentially. As information is gathered throughout the decision-making process and as additional information is needed, reevaluation of lower numbered steps may be necessary.

(b) Except as otherwise provided in § 9.5 (c), (d), (f), and (g) regarding categories of partial or total exclusion when proposing an action, the Agency shall apply the 8-step decision-making process. FEMA shall:

Step 1. Determine whether the proposed action is located in a wetland and/or the 100-year floodplain (500-year floodplain for critical actions); and whether it has the potential to affect or be affected by a floodplain or wetland (see § 9.7);

Step 2. Notify the public at the earliest possible time of the intent to carry out an action in a floodplain or wetland, and involve the affected and interested public in the decision-making process (see § 9.8);

Step 3. Identify and evaluate practicable alternatives to locating the proposed action in a floodplain or wetland (including alternative sites, actions and the ''no action'' option) (see § 9.9). If a practicable alternative exists outside the floodplain or wetland FEMA must locate the action at the alternative site.

Step 4. Identify the potential direct and indirect impacts associated with the occupancy or modification of floodplains and wetlands and the potential direct and indirect support of floodplain and wetland development that could result from the proposed action (see § 9.10);

Step 5. Minimize the potential adverse impacts and support to or within floodplains and wetlands to be identified under Step 4, restore and preserve the natural and beneficial values served by floodplains, and preserve and enhance the natural and beneficial values served by wetlands (see § 9.11);

Step 6. Reevaluate the proposed action to determine first, if it is still practicable in light of its exposure to flood hazards, the extent to which it will aggravate the hazards to others, and its potential to disrupt floodplain and wetland values and second, if alternatives preliminarily rejected at Step 3 are practicable in light of the information gained in Steps 4 and 5. FEMA shall not act in a floodplain or wetland unless it is the only practicable location (see § 9.9);

Step 7. Prepare and provide the public with a finding and public explanation of any final decision that the floodplain or wetland is the only practicable alternative (see § 9.12); and

Step 8. Review the implementation and post-implementation phases of the proposed action to ensure that the requirements stated in § 9.11 are fully implemented. Oversight responsibility shall be integrated into existing processes.

[45 FR 59526, Sept. 9, 1980, as amended at 49 FR 35583, Sept. 10, 1984; 50 FR 40006, Oct. 1, 1985]

§ 9.7 Determination of proposed action's location.

(a) The purpose of this section is to establish Agency procedures for determining whether any action as proposed is located in or affects (1) the base floodplain (the Agency shall substitute the 500-year floodplain for the base floodplain where the action being proposed involves a critical action), or (2) a wetland.

(b) *Information needed.* The Agency shall obtain enough information so that it can fulfill the requirements of the Orders to (1) avoid floodplain and wetland locations unless they are the only practicable alternatives; and (2) minimize harm to and within floodplains and wetlands. In all cases, FEMA shall determine whether the proposed action is located in a floodplain or wetland. In the absence of a finding to the contrary, FEMA may assume that a proposed action involving a facility or structure that has been flooded is in the floodplain. Information about the 100-year and 500-year floods and location of floodways and coastal high hazard areas may also be needed to comply with these regulations, especially § 9.11. The following additional flooding characteristics shall be identified by the Regional Administrator as appropriate:

(i) Velocity of floodwater;

(ii) Rate of rise of floodwater;

(iii) Duration of flooding;

(iv) Available warning and evacuation time and routes;

(v) Special problems:

(A) Levees;

(B) Erosion;

(C) Subsidence;

(D) Sink holes;

(E) Ice jams;

(F) Debris load;

(G) Pollutants;

(H) Wave heights;

(I) Groundwater flooding;

(J) Mudflow.

(c) *Floodplain determination.* (1) In the search for flood hazard information, FEMA shall follow the sequence below:

(i) The Regional Administrator shall consult the FEMA Flood Insurance Rate Map (FIRM) the Flood Boundary Floodway Map (FBFM) and the Flood Insurance Study (FIS).

(ii) If a detailed map (FIRM or FBFM) is not available, the Regional Administrator shall consult an FEMA Flood Hazard Boundary Map (FHBM) . If data on flood elevations, floodways, or coastal high hazard areas are needed, or if the map does not delineate the flood hazard boundaries in the vicinity of the proposed site, the Regional Administrator shall seek the necessary detailed information and assistance from the sources listed below.

SOURCES OF MAPS AND TECHNICAL INFORMATION

Department of Agriculture: Soil Conservation Service
Department of the Army: Corps of Engineers
Department of Commerce: National Oceanic and Atmospheric Administration
Federal Insurance Administration
FEMA Regional Offices/Natural and Technological Hazards Division
Department of the Interior:
Geological Survey
Bureau of Land Management
Bureau of Reclamation
Tennessee Valley Authority
Delaware River Basin Commission
Susquehanna River Basin Commission
States

(iii) If the sources listed do not have or know of the information necessary to comply with the Orders' requirements, the Regional Administrator shall seek the services of a Federal or other engineer experienced in this type of work.

(2) If a decision involves an area or location within extensive Federal or state holdings or a headwater area, and an FIS, FIRM, FBFM, or FHBM is not available, the Regional Administrator shall seek information from the land administering agency before information and/or assistance is sought from the sources listed in this section. If none of these sources has information or can provide assistance, the services of an experienced Federal or other engineer shall be sought as described above.

(d) *Wetland determination.* The following sequence shall be followed by the Agency in making the wetland determination.

(1) The Agency shall consult with the U.S. Fish and Wildlife Service (FWS) for information concerning the location, scale and type of wetlands within the area which could be affected by the proposed action.

(2) If the FWS does not have adequate information upon which to base the determination, the Agency shall consult wetland inventories maintained by the Army Corps of Engineers, the Environmental Protection Agency, various states, communities and others.

(3) If state or other sources do not have adequate information upon which to base the determination, the Agency shall carry out an on-site analysis performed by a representative of the FWS or other qualified individual for wetlands characteristics based on the performance definition of what constitutes a wetland.

(4) If an action is in a wetland but not in a floodplain, and the action is new construction, the provisions of this regulation shall apply. Even if the action is not in a wetland, the Regional Administrator shall determine if the action has the potential to result in indirect impacts on wetlands. If so, all adverse impacts shall be minimized. For actions which are in a wetland and the floodplain, completion of the decision-making process is required. (See §9.6.) In such a case the wetland will be

considered as one of the natural and beneficial values of floodplain.

[45 FR 59526, Sept. 9, 1980, as amended at 47 FR 13149, Mar. 29, 1982; 49 FR 33879, Aug. 27, 1984; 50 FR 40006, Oct. 1, 1985; 51 FR 34605, Sept. 30, 1986]

§ 9.8 Public notice requirements.

(a) *Purpose.* The purpose of this section is to establish the initial notice procedures to be followed when proposing any action in or affecting floodplains or wetlands.

(b) *General.* The Agency shall provide adequate information to enable the public to have impact on the decision outcome for all actions having potential to affect, adversely, or be affected by floodplains or wetlands that it proposes. To achieve this objective, the Agency shall:

(1) Provide the public with adequate information and opportunity for review and comment at the earliest possible time and throughout the decision-making process; and upon completion of this process, provide the public with an accounting of its final decisions (see § 9.12); and

(2) Rely on its environmental assessment processes, to the extent possible, as vehicles for public notice, involvement and explanation.

(c) *Early public notice.* The Agency shall provide opportunity for public involvement in the decision-making process through the provision of public notice upon determining that the proposed action can be expected to affect or be affected by floodplains or wetlands. Whenever possible, notice shall precede major project site identification and analysis in order to preclude the foreclosure of options consistent with the Orders.

(1) For an action for which an environmental impact statement is being prepared, the Notice of Intent to File an EIS is adequate to constitute the early public notice, if it includes the information required under paragraph (c)(5) of this section.

(2) For each action having national significance for which notice is being provided, the Agency shall use the FEDERAL REGISTER as the minimum means for notice, and shall provide notice by mail to national organizations reasonably expected to be interested in the action. The additional notices listed in paragraph (c)(4) of this section shall be used in accordance with the determination made under paragraph (c)(3) of this section.

(3) The Agency shall base its determination of appropriate notices, adequate comment periods, and whether to issue cumulative notices (paragraphs (c)(4), (6) and (7) of this section) on factors which include, but are not limited to:

(i) Scale of the action;

(ii) Potential for controversy;

(iii) Degree of public need;

(iv) Number of affected agencies and individuals; and

(v) Its anticipated potential impact.

(4) For each action having primarily local importance for which notice is being provided, notice shall be made in accordance with the criteria under paragraph (c)(3) of this section, and shall entail as appropriate:

(i) [Reserved]

(ii) Notice to Indian tribes when effects may occur on reservations.

(iii) Information required in the affected State's public notice procedures for comparable actions.

(iv) Publication in local newspapers (in papers of general circulation rather than legal papers).

(v) Notice through other local media.

(vi) Notice to potentially interested community organizations.

(vii) Publication in newsletters that may be expected to reach potentially interested persons.

(viii) Direct mailing to owners and occupants of nearby or affected property.

(ix) Posting of notice on and off site in the area where the action is to be located.

(x) Holding a public hearing.

(5) The notice shall include:

(i) A description of the action, its purpose and a statement of the intent to carry out an action affecting or affected by a floodplain or wetland;

(ii) Based on the factors in paragraph (c)(3) of this section, a map of the area or other indentification of the floodplain and/or wetland areas which is of adequate scale and detail so that the location is discernible; instead of publication of such map, FEMA may state that such map is available for public inspection, including the location at which such map may be inspected and a telephone number to call for information;

(iii) Based on the factors in paragraph (c)(3) of this section, a description of the type, extent and degree of hazard involved and the floodplain or wetland values present; and

(iv) Identification of the responsible official or organization for implementing the proposed action, and from whom further information can be obtained.

(6) The Agency shall provide for an adequate comment period.

(7) In a post-disaster situation in particular, the requirement for early public notice may be met in a cumulative manner based on the factors set out in paragraph (c)(3) of this section. Several actions may be addressed in one notice or series of notices. For some actions involving limited public interest a single notice in a local newspaper or letter to interested parties may suffice.

(d) *Continuing public notice.* The Agency shall keep the public informed of the progress of the decision-making process through additional public notices at key points in the process. The preliminary information provided under paragraph (c)(5) of this section shall be augmented by the findings of the adverse effects of the proposed actions and steps necessary to mitigate them. This responsibility shall be performed for actions requiring the preparation of an EIS, and all other actions having the potential for major adverse impacts, or the potential for harm to the health and safety of the general public.

[45 FR 59526, Sept. 9, 1980, as amended at 48 FR 29318, June 24, 1983]

§ 9.9 Analysis and reevaluation of practicable alternatives.

(a) *Purpose.* (1) The purpose of this section is to expand upon the directives set out in § 9.6, of this part, in order to clarify and emphasize the Orders' key requirements to avoid floodplains and wetlands unless there is no practicable alternative.

(2) Step 3 is a preliminary determination as to whether the floodplain is the only practicable location for the action. It is a preliminary determination because it comes early in the decision-making process when the Agency has a limited amount of information. If it is clear that there is a practicable alternative, or the floodplain or wetland is itself not a practicable location, FEMA shall then act on that basis. Provided that the location outside the floodplain or wetland does not indirectly impact floodplains or wetlands or support development therein (see § 9.10), the remaining analysis set out by this regulation is not required. If such location does indirectly impact floodplains or wetlands or support development therein, the remaining analysis set out by this regulation is required. If the preliminary determination is to act in the floodplain, FEMA shall gather the additional information required under Steps 4 and 5 and then reevaluate all the data to determine if the floodplain or wetland is the only practicable alternative.

(b) *Analysis of practicable alternatives.* The Agency shall identify and evaluate practicable alternatives to carrying out a proposed action in floodplains or wetlands, including:

(1) Alternative sites outside the floodplain or wetland;

(2) Alternative actions which serve essentially the same purpose as the proposed action, but which have less potential to affect or be affected by the floodplain or wetlands; and

(3) *No action.* The floodplain and wetland site itself must be a practicable location in light of the factors set out in this section.

(c) The Agency shall analyze the following factors in determining the practicability of the alternatives set out in paragraph (b) of this section:

(1) Natural environment (topography, habitat, hazards, etc.);

(2) Social concerns (aesthetics, historical and cultural values, land patterns, etc.);

(3) Economic aspects (costs of space, construction, services, and relocation); and

(4) Legal constraints (deeds, leases, etc.).

(d) *Action following the analysis of practicable alternatives.* (1) The Agency shall not locate the proposed action in the floodplain or in a wetland if a practicable alternative exists outside the floodplain or wetland.

(2) For critical actions, the Agency shall not locate the proposed action in the 500-year floodplain if a practicable alternative exists outside the 500-year floodplain.

(3) Even if no practicable alternative exists outside the floodplain or wetland, in order to carry out the action the floodplain or wetland must itself be a practicable location in light of the review required in this section.

(e) *Reevaluation of alternatives.* Upon determination of the impact of the proposed action to or within the floodplain or wetland and of what measures are necessary to comply with the requirement to minimize harm to and within floodplains and wetlands (§ 9.11), FEMA shall:

(1) Determine whether:

(i) The action is still practicable at a floodplain or wetland site in light of the exposure to flood risk and the ensuing disruption of natural values;

(ii) The floodplain or wetland site is the only practicable alternative;

(iii) There is a potential for limiting the action to increase the practicability of previously rejected non-floodplain or wetland sites and alternative actions; and

(iv) Minimization of harm to or within the floodplain can be achieved using all practicable means.

(2) Take no action in a floodplain unless the importance of the floodplain site clearly outweighs the requirement of E.O. 11988 to:

(i) Avoid direct or indirect support of floodplain development;

(ii) Reduce the risk of flood loss;

(iii) Minimize the impact of floods on human safety, health and welfare; and

(iv) Restore and preserve floodplain values.

(3) Take no action in a wetland unless the importance of the wetland site clearly outweighs the requirements of E.O. 11990 to:

(i) Avoid the destruction or modification of the wetlands;

(ii) Avoid direct or indirect support of new construction in wetlands;

(iii) Minimize the destruction, loss or degradation of wetlands; and

(iv) Preserve and enhance the natural and beneficial values of wetlands.

(4) In carrying out this balancing process, give the factors in paragraphs (e)(2) and (3) of this section, the great weight intended by the Orders.

(5) Choose the ''no action'' alternative where there are no practicable alternative actions or sites and where the floodplain or wetland is not itself a practicable alternative. In making the assessment of whether a floodplain or wetland location is itself a practicable alternative, the practicability of the floodplain or wetland location shall be balanced against the practicability of not carrying out the action at all. That is, even if there is no practicable alternative outside of the floodplain or wetland, the floodplain or wetland itself must be a practicable location in order for the action to be carried out there. To be a practicable location, the importance of carrying out the action must clearly outweigh the requirements of the Orders listed in paragraphs (e)(2) and (e)(3) of this section. Unless the importance of carrying out the action clearly outweighs those requirements, the ''no action'' alternative shall be selected.

(6) In any case in which the Regional Director has selected the ''no action'' option, FIA may not provide a new or renewed contract of flood insurance for that structure.

EFFECTIVE DATE NOTE: At 45 FR 79070, Nov. 28, 1980, § 9.9(e)(6) was temporarily suspended until further notice.

§ 9.10 Identify impacts of proposed actions.

(a) *Purpose.* The purpose of this section is to ensure that the effects of proposed Agency actions are identified.

(b) The Agency shall identify the potential direct and indirect adverse impacts associated with the occupancy and modification of floodplains and wetlands and the potential direct and indirect support of floodplain and wetland development that could result from the proposed action. Such identification of impacts shall be to the extent necessary to comply with the requirements of the Orders to avoid floodplain and wetland locations unless they are the only practicable alternatives and to minimize harm to and within floodplains and wetlands.

(c) This identification shall consider whether the proposed action will result in an increase in the useful life of any structure or facility in question, maintain the investment at risk and exposure of lives to the flood hazard or forego an opportunity to restore the natural and beneficial values served by floodplains or wetlands. Regional Offices of the U.S. Fish and Wildlife Service may be contacted to aid in the identification and evaluation of potential impacts of the proposed action on natural and beneficial floodplain and wetland values.

(d) In the review of a proposed or alternative action, the Regional Administrator shall specifically consider and evaluate: impacts associated with modification of wetlands and floodplains regardless of its location; additional impacts which may occur when certain types of actions may support subsequent action which have additional impacts of their own; adverse impacts of the proposed actions on lives and property and on natural and beneficial floodplain and wetland values; and the three categories of factors listed below:

(1) *Flood hazard-related factors.* These include for example, the factors listed in § 9.7(b)(2);

(2) *Natural values-related factors.* These include, for example, the following: Water resource values (natural moderation of floods, water quality maintenance, and ground water recharge); living resource values (fish and wildlife and biological productivity); cultural resource values (archeological and historic sites, and open space recreation and green belts); and agricultural, aquacultural and forestry resource values.

(3) *Factors relevant to a proposed action's effects on the survival and quality of wetlands.* These include, for example, the following: Public health, safety, and welfare, including water supply, quality, recharge and discharge; pollution; flood and storm hazards; and sediment and erosion; maintenance of natural systems, including conservation and long term productivity of existing flora and fauna, species and habitat diversity and stability, hydrologic utility, fish, wildlife, timber, and food and fiber resources; and other uses of wetlands in the public interest, including recreational, scientific, and cultural uses.

§ 9.11 Mitigation.

(a) *Purpose.* The purpose of this section is to expand upon the directives set out in § 9.6 of this part, and to set out the mitigative actions required if the preliminary determination is made to carry out an action that affects or is in a floodplain or wetland.

(b) *General provisions.* (1) The Agency shall design or modify its actions so as to minimize harm to or within the floodplain;

(2) The Agency shall minimize the destruction, loss or degradation of wetlands;

(3) The Agency shall restore and preserve natural and beneficial floodplain values; and

(4) The Agency shall preserve and enhance natural and beneficial wetland values.

(c) *Minimization provisions.* The Agency shall minimize:

(1) Potential harm to lives and the investment at risk from the base flood, or, in the case of critical actions, from the 500-year flood;

(2) Potential adverse impacts the action may have on others; and

(3) Potential adverse impact the action may have on floodplain and wetland values.

(d) *Minimization Standards.* In its implementation of the Disaster Relief Act of 1974, the Agency shall apply at a minimum, the following standards to its actions to comply with the requirements of paragraphs (b) and (c), of this section, (except as provided in § 9.5 (c), (d), and (g) regarding categories of partial or total exclusion). Any Agency action to which the following specific requirements do not apply, shall nevertheless be subject to the full 8-step process (§ 9.6) including the general requirement to minimize harm to and within floodplains:

(1) There shall be no new construction or substantial improvement in a floodway, and no new construction in a coastal high hazard area, except for:

(i) A functionally dependent use; or

(ii) A structure or facility which facilitates an open space use.

(2) For a structure which is a functionally dependent use, or which facilitates an open space use, the following applies. There shall be no construction of a new or substantially improved structure in a coastal high hazard area unless it is elevated on adequately anchored pilings or columns, and securely anchored to such piles or columns so that the lowest portion of the structural members of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level (the 500-year flood level for critical actions) (including wave height). The structure shall be anchored so as to withstand velocity waters and hurricane wave wash. The Regional Administrator shall be responsible for determining the base flood level, including the wave height, in all cases. Where there is a FIRM in effect, it shall be the basis of the Regional Administrator's determination. If the FIRM does not reflect wave heights, or if there is no FIRM in effect, the Regional Administrator is responsible for delineating the base flood level, including wave heights.

(3) *Elevation of structures.* (i) There shall be no new construction or substantial improvement of structures unless the lowest floor of the structures (including basement) is at or above the level of the base flood.

(ii) There shall be no new construction or substantial improvement of structures involving a critical action unless the lowest floor of the structure (including the basement) is at or above the level of the 500-year flood.

(iii) If the subject structure is nonresidential, FEMA may, instead of elevating the structure to the 100-year or 500-year level, as appropriate, approve the design of the structure and its attendant utility and sanitary facilities so that below the flood level the structure is water tight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy.

(iv) The provisions of paragraphs (d)(3)(i), (ii), and (iii) of this section do not apply to the extent that the Federal Insurance Administration has granted an exception under 44 CFR § 60.6(b) (formerly 24 CFR 1910.6(b)), or the community has granted a variance which the Regional Administrator determines is consistent with 44 CFR 60.6(a) (formerly 24 CFR 1910.6(a)). In a community which does not have a FIRM in effect, FEMA may approve a variance from the standards of paragraphs (d)(3)(i), (ii), and (iii) of this section, after compliance with the standards of 44 CFR 60.6(a).

(4) There shall be no encroachments, including fill, new construction, substantial improvements of structures or facilities, or other development within a designated regulatory floodway that would result in any increase in flood levels within the community during the occurrence of the base flood discharge. Until a regulatory floodway is designated, no new construction, substantial improvements, or other development (including fill) shall be permitted within the base floodplain unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the community.

(5) Even if an action is a functionally dependent use or facilitates open space uses (under paragraph (d) (1) or (2) of this section) and does not increase flood heights (under paragraph (d)(4) of this section), such action may only be taken in a floodway or coastal high hazard area if:

(i) Such site is the only practicable alternative; and

(ii) Harm to and within the floodplain is minimized.

(6) In addition to standards (d)(1) through (d)(5) of this section, no action may be taken if it is inconsistent with the criteria of the National Flood Insurance Program (44 CFR part 59 *et seq.*) or any more restrictive Federal, State or local floodplain management standards.

(7) New construction and substantial improvement of structures shall be elevated on open works (walls, columns, piers, piles, etc.) rather than on fill, in

all cases in coastal high hazard areas and elsewhere, where practicable.

(8) To minimize the effect of floods on human health, safety and welfare, the Agency shall:

(i) Where appropriate, integrate all of its proposed actions in floodplains into existing flood warning and preparedness plans and ensure that available flood warning time is reflected;

(ii) Facilitate adequate access and egress to and from the site of the proposed action; and

(iii) Give special consideration to the unique hazard potential in flash flood, rapid-rise or tsunami areas.

(9) In the replacement of building contents, materials and equipment, the Regional Administrator shall require as appropriate, disaster proofing of the building and/or elimination of such future losses by relocation of those building contents, materials and equipment outside or above the base floodplain or the 500-year floodplain for critical actions.

(e) *In the implementation of the National Flood Insurance Program.* (1) The Federal Insurance Administration shall make identification of all coastal high hazard areas a priority;

(2) Beginning October 1, 1981, the Federal Insurance Administration of FEMA may only provide flood insurance for new construction or substantial improvements in a coastal high hazard area if:

(i) Wave heights have been designated for the site of the structure either by the Administrator of FEMA based upon data generated by FEMA or by another source, satisfactory to the Administrator; and

(ii) The structure is rated by FEMA-FIA based on a system which reflects the capacity to withstand the effects of the 100-year frequency flood including, but not limited to, the following factors:

(A) Wave heights;

(B) The ability of the structure to withstand the force of waves.

(3)(i) FEMA shall accept and take fully into account information submitted by a property owner indicating that the rate for a particular structure is too high based on the ability of the structure to withstand the force of waves. In order to obtain a rate adjustment, a property owner must submit to FEMA specific information regarding the structure and its immediate environment. Such information must be certified by a registered professional architect or engineer who has demonstrable experience and competence in the fields of foundation, soils, and structural engineering. Such information should include:

(A) Elevation of the structure (bottom of lowest floor beam) in relation to the Base Flood Elevation including wave height;

(B) Distance of the structure from the shoreline;

(C) Dune protection and other environmental factors;

(D) Description of the building support system; and

(E) Other relevant building details.

Adequate completion of the ''V-Zone Risk Factor Rating Form'' is sufficient for FEMA to determine whether a rate adjustment is appropriate. The form is available from and applications for rate adjustments should be submitted to:

National Flood Insurance Program
Attention: V-Zone Underwriting Specialist
9901–A George Palmer Highway
Lanham, MD 20706

Pending a determination on a rate adjustment, insurance will be issued at the class rate. If the rate adjustment is granted, a refund of the appropriate portion of the premium will be made. *Unless a property owner is seeking an adjustment of the rate prescribed by FEMA-FIA, this information need not be submitted.*

(ii) FIA shall notify communities with coastal high hazard areas and federally related lenders in such communities, of the provisions of this paragraph. Notice to the lenders may be accomplished by the Federal instrumentalities to which the lenders are related.

(4) In any case in which the Regional Director has been, pursuant to § 9.11(d)(1), precluded from providing assistance for a new or substantially improved structure in a floodway, FIA may not provide a new or renewed policy of flood insurance for that structure.

(f) *Restore and preserve.* (1) For any action taken by the Agency which affects the floodplain or wetland and which has resulted in, or will result in, harm to the floodplain or wetland, the Agency shall act to restore and preserve the natural and beneficial values served by floodplains and wetlands.

(2) Where floodplain or wetland values have been degraded by the proposed action, the Agency shall identify, evaluate and implement measures to restore the values.

(3) If an action will result in harm to or within the floodplain or wetland, the Agency shall design or modify the action to preserve as much of the natural and beneficial floodplain and wetland values as is possible.

[45 FR 59526, Sept. 9, 1980, as amended at 46 FR 51752, Oct. 22, 1981; 48 FR 44543, Sept. 29, 1983; 49 FR 33879, Aug. 27, 1984; 49 FR 35584, Sept. 10, 1984; 50 FR 40006, Oct. 1, 1985]

EFFECTIVE DATE NOTE: At 45 FR 79070, Nov. 28, 1980, § 9.11(e)(4) was temporarily suspended until further notice.

§ 9.12 Final public notice.

If the Agency decides to take an action in or affecting a floodplain or wetland, it shall provide the public with a statement of its final decision and shall explain the relevant factors considered by the Agency in making this determination.

(a) In addition, those sent notices under § 9.8 shall also be provided the final notice.

(b) For actions for which an environmental impact statement is being prepared, the FEIS is adequate to constitute final notice in all cases except where:

(1) Significant modifications are made in the FEIS after its initial publication;

(2) Significant modifications are made in the development plan for the proposed action; or

(3) Significant new information becomes available in the interim between issuance of the FEIS and implementation of the proposed action.

If any of these situations develop, the Agency shall prepare a separate final notice that contains the contents of paragraph (e) of this section and shall make it available to those who received the FEIS. A minimum of 15 days shall, without good cause shown, be allowed for comment on the final notice.

(c) For actions for which an environmental assessment was prepared, the Notice of No Significant Impact is adequate to constitute final public notice, if it includes the information required under paragraph (e) of this section.

(d) For all other actions, the finding shall be made in a document separate from those described in paragraphs (a), (b), and (c) of this section. Based on an assessment of the following factors, the requirement for final notice may be met in a cumulative manner:

(1) Scale of the action;

(2) Potential for controversy;

(3) Degree of public need;

(4) Number of affected agencies and individuals;

(5) Its anticipated potential impact; and

(6) Similarity of the actions, i.e., to the extent that they are susceptible of common descriptions and assessments.

When a damaged structure or facility is already being repaired by the State or local government at the time of the Damage Survey Report, the requirements of Steps 2 and 7 (§§ 9.8 and 9.12) may be met by a single notice. Such notice shall contain all the information required by both sections.

(e) The final notice shall include the following:

(1) A statement of why the proposed action must be located in an area affecting or affected by a floodplain or a wetland;

(2) A description of all significant facts considered in making this determination;

(3) A list of the alternatives considered;

(4) A statement indicating whether the action conforms to applicable state and local floodplain protection standards;

(5) A statement indicating how the action affects or is affected by the floodplain and/or wetland, and how mitigation is to be achieved;

(6) Identification of the responsible official or organization for implementation and monitoring of the proposed action, and from whom further information can be obtained; and

(7) A map of the area or a statement that such map is available for public

inspection, including the location at which such map may be inspected and a telephone number to call for information.

(f) After providing the final notice, the Agency shall, without good cause shown, wait at least 15 days before carrying out the action.

[45 FR 59526, Sept. 9, 1980, as amended at 48 FR 29318, June 24, 1983]

§ 9.13 Particular types of temporary housing.

(a) The purpose of this section is to set forth the procedures whereby the Agency will provide certain specified types of temporary housing.

(b) Prior to providing the types of temporary housing enumerated in paragraph (c) of this section, the Agency shall comply with the provisions of this section. For all temporary housing not enumerated below, the full 8-step process (see § 9.6) applies.

(c) The following temporary housing actions are subject to the provisions of this section and not the full 8-step process:

(1) [Reserved]

(2) Placing a mobile home or readily fabricated dwelling on a private or commercial site, but not a group site.

(d) The actions set out in paragraph (c) of this section are subject to the following decision-making process:

(1) The temporary housing action shall be evaluated in accordance with the provisions of § 9.7 to determine if it is in or affects a floodplain or wetland.

(2) No mobile home or readily fabricated dwelling may be placed on a private or commercial site in a floodway or coastal high hazard area.

(3) An individual or family shall not be housed in a floodplain or wetland unless the Regional Administrator has complied with the provisions of § 9.9 to determine that such site is the only practicable alternative. The following factors shall be substituted for the factors in § 9.9 (c) and (e) (2) through (4):

(i) Speedy provision of temporary housing;

(ii) Potential flood risk to the temporary housing occupant;

(iii) Cost effectiveness;

(iv) Social and neighborhood patterns;

(v) Timely availability of other housing resources; and

(vi) Potential harm to the floodplain or wetland.

(4) An individual or family shall not be housed in a floodplain or wetland (except in existing resources) unless the Regional Administrator has complied with the provisions of § 9.11 to minimize harm to and within floodplains and wetlands. The following provisions shall be substituted for the provisions of § 9.11(d) for mobile homes:

(i) No mobile home or readily fabricated dwelling may be placed on a private or commercial site unless it is elevated to the fullest extent practicable up to the base flood level and adequately anchored.

(ii) No mobile home or readily fabricated dwelling may be placed if such placement is inconsistent with the criteria of the National Flood Insurance Program (44 CFR part 59 *et seq.)* or any more restrictive Federal, State or local floodplain management standard. Such standards may require elevation to the base flood level in the absence of a variance.

(iii) Mobile homes shall be elevated on open works (walls, columns, piers, piles, etc.) rather than on fill where practicable.

(iv) To minimize the effect of floods on human health, safety and welfare, the Agency shall:

(A) Where appropriate, integrate all of its proposed actions in placing mobile homes for temporary housing in floodplains into existing flood warning and preparedness plans and ensure that available flood warning time is reflected;

(B) Provide adequate access and egress to and from the proposed site of the mobile home; and

(C) Give special consideration to the unique hazard potential in flash flood and rapid-rise areas.

(5) FEMA shall comply with Step 2 Early Public Notice (§ 9.8(c)) and Step 7 Final Public Notice (§ 9.12). In providing these notices, the emergency nature of temporary housing shall be taken into account.

(e) FEMA shall not sell or otherwise dispose of mobile homes or other readily fabricated dwellings which would be located in floodways or coastal high hazard areas. FEMA shall not sell or otherwise dispose of mobile homes or other readily fabricated dwellings which would be located in floodplains or wetlands unless there is full compliance with the 8-step process. Given the vulnerability of mobile homes to flooding, a rejection of a non-floodplain location alternative and of the no-action alternative shall be based on (1) a compelling need of the family or individual to buy a mobile home for permanent housing, and (2) a compelling requirement to locate the unit in a floodplain. Further, FEMA shall not sell or otherwise dispose of mobile homes or other readily fabricated dwellings in a floodplain unless they are elevated at least to the level of the 100-year flood. The Regional Administrator shall notify the Assistant Administrator for Mitigation of each instance where a floodplain location has been found to be the only practicable alternative for a mobile home sale.

[45 FR 59526, Sept. 9, 1980, as amended at 47 FR 13149, Mar. 29, 1982; 49 FR 35584, Sept. 10, 1984; 50 FR 40006, Oct. 1, 1985]

§ 9.14 Disposal of Agency property.

(a) The purpose of this section is to set forth the procedures whereby the Agency shall dispose of property.

(b) Prior to its disposal by sale, lease or other means of disposal, property proposed to be disposed of by the Agency shall be reviewed according to the decision-making process set out in § 9.6 of this part, as follows:

(1) The property shall be evaluated in accordance with the provisions of § 9.7 to determine if it affects or is affected by a floodplain or wetland;

(2) The public shall be notified of the proposal and involved in the decision-making process in accordance with the provisions of § 9.8;

(3) Practicable alternatives to disposal shall be evaluated in accordance with the provisions of § 9.9. For disposals, this evaluation shall focus on alternative actions (conveyance for an alternative use that is more consistent with the floodplain management and wetland protection policies set out in § 9.2 than the one proposed, e.g., open space use for park or recreational purposes rather than high intensity uses), and on the ''no action'' option (retain the property);

(4) Identify the potential impacts and support associated with the disposal of the property in accordance with § 9.10;

(5) Identify the steps necessary to minimize, restore, preserve and enhance in accordance with § 9.11. For disposals, this analysis shall address all four of these components of mitigation where unimproved property is involved, but shall focus on minimization through floodproofing and restoration of natural values where improved property is involved;

(6) Reevaluate the proposal to dispose of the property in light of its exposure to the flood hazard and its natural values-related impacts, in accordance with § 9.9. This analysis shall focus on whether it is practicable in light of the findings from §§ 9.10 and 9.11 to dispose of the property, or whether it must be retained. If it is determined that it is practicable to dispose of the property, this analysis shall identify the practicable alternative that best achieves all of the components of the Orders' mitigation responsibility;

(7) To the extent that it would decrease the flood hazard to lives and property, the Agency shall, wherever practicable, dispose of the properties according to the following priorities:

(i) Properties located outside the floodplain;

(ii) Properties located in the flood fringe; and

(iii) Properties located in a floodway, regulatory floodway or coastal high hazard area.

(8) The Agency shall prepare and provide the public with a finding and public explanation in accordance with § 9.12.

(9) The Agency shall ensure that the applicable mitigation requirements are fully implemented in accordance with § 9.11.

(c) At the time of disposal, for all disposed property, the Agency shall reference in the conveyance uses that are restricted under existing Federal, State and local floodplain management and wetland protection standards relating to flood hazards and floodplain and wetland values.

§9.15 Planning programs affecting land use.

The Agency shall take floodplain management into account when formulating or evaluating any water and land use plans. No plan may be approved unless it:

(a) Reflects consideration of flood hazards and floodplain management and wetlands protection; and

(b) Prescribes planning procedures to implement the policies and requirements of the Orders and this regulation.

§9.16 Guidance for applicants.

(a) The Agency shall encourage and provide adequate guidance to applicants for agency assistance to evaluate the effects of their plans and proposals in or affecting floodplains and wetlands.

(b) This shall be accomplished primarily through amendment of all Agency instructions to applicants, e.g., program handbooks, contracts, application and agreement forms, etc., and also through contact made by agency staff during the normal course of their activities, to fully inform prospective applicants of:

(1) The Agency's policy on floodplain management and wetlands protection as set out in §9.2;

(2) The decision-making process to be used by the Agency in making the determination of whether to provide the required assistance as set out in §9.6;

(3) The nature of the Orders' practicability analysis as set out in §9.9;

(4) The nature of the Orders' mitigation responsibilities as set out in §9.11;

(5) The nature of the Orders' public notice and involvement process as set out in §§9.8 and 9.12; and

(6) The supplemental requirements applicable to applications for the lease or other disposal of Agency owned properties set out in §9.14.

(c) Guidance to applicants shall be provided where possible, prior to the time of application in order to minimize potential delays in process application due to failure of applicants to recognize and reflect the provisions of the Orders and this regulation.

§9.17 Instructions to applicants.

(a) *Purpose*. In accordance with Executive Orders 11988 and 11990, the Federal executive agencies must respond to a number of floodplain management and wetland protection responsibilities before carrying out any of their activities, including the provision of Federal financial and technical assistance. The purpose of this section is to put applicants for Agency assistance on notice concerning both the criteria that it is required to follow under the Orders, and applicants' responsibilities under this regulation.

(b) *Responsibilities of Applicants*. Based upon the guidance provided by the Agency under §9.16, that guidance included in the U.S. Water Resources Council's *Guidance for Implementing E.O. 11988*, and based upon the provisions of the Orders and this regulation, applicants for Agency assistance shall recognize and reflect in their application:

(1) The Agency's policy on floodplain management and wetlands protection as set out in §9.2;

(2) The decision-making process to be used by the Agency in making the determination of whether to provide the requested assistance as set out in §9.6;

(3) The nature of the Orders' practicability analysis as set out in §9.9;

(4) The nature of the Orders' mitigation responsibilities as set out in §9.11;

(5) The nature of the Orders' public and involvement process as set out in §§9.8 and 9.12; and

(6) The supplemental requirements for application for the lease or other disposal of Agency-owned properties, as set out in §9.13.

(c) *Provision of supporting information*. Applicants for Agency assistance may be called upon to provide supporting information relative to the various responsibilities set out in paragraph (b) of this section as a prerequisite to the approval of their applications.

(d) *Approval of applications*. Applications for Agency assistance shall be reviewed for the recognition and reflection of the provisions of this regulation in addition to the Agency's existing approval criteria.

§ 9.18 Responsibilities.

(a) *Regional Administrators' responsibilities.* Regional Administrators shall, for all actions falling within their respective jurisdictions:

(1) Implement the requirements of the Orders and this regulation. Anywhere in §§ 9.2, 9.6 through 9.13, and 9.15 where a direction is given to the Agency, it is the responsibility of the Regional Administrator.

(2) Consult with the Chief Counsel regarding any question of interpretation concerning this regulation or the Orders.

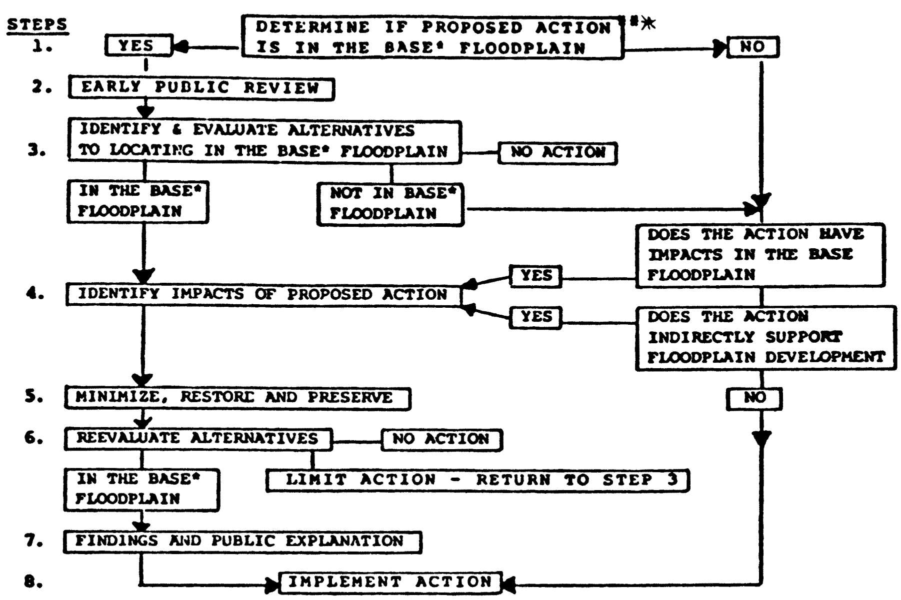
(b) The Heads of the Offices, Directorates and Administrations of FEMA shall:

(1) Implement the requirements of the Orders and this regulation. When a decision of a Regional Administrator relating to disaster assistance is appealed, the Assistant Administrator for Mitigation may make determinations under these regulations on behalf of the Agency.

(2) Prepare and submit to the Office of Chief Counsel reports to the Office of Management and Budget in accordance with section 2(b) of E.O. 11988 and section 3 of E.O. 11990. If a proposed action is to be located in a floodplain or wetland, any requests to the Office of Management and Budget for new authorizations or appropriations shall be accompanied by a report indicating whether the proposed action is in accord with the Orders and these regulations.

[45 FR 59526, Sept. 9, 1980, as amended at 49 FR 33879, Aug. 27, 1984; 74 FR 15336, Apr. 3, 2009]

APPENDIX A TO PART 9—DECISION-MAKING PROCESS FOR E.O. 11988



* FOR CRITICAL ACTIONS SUBSTITUTE "500 YEAR" FOR "BASE" AND FOR WETLANDS DELETE "BASE FLOODPLAIN" AND SUBSTITUTE " WETLANDS".

** FOR WETLANDS "ACTION" INCLUDES "NEW CONSTRUCTION" ONLY.