United States Environmental Protection Agency

Engineering Controls on Brownfields Information Guide:

How They Work with Institutional Controls; the Most Common Types Used; and an Introduction to Costs

Introduction

Engineering controls (ECs) encompass a variety of engineered and constructed physical barriers (e.g., soil capping, sub-surface venting systems, mitigation barriers, fences) to contain and/or prevent exposure to contamination on a property. In contrast, institutional controls (ICs) are administrative or legal instruments (e.g., deed restrictions/notices, easements, covenants, zoning) that impose restrictions on the use of contaminated property or resources. ICs are also used to identify the presence of ECs and long-term stewardship (LTS) requirements. Long-term stewardship refers to the activities necessary to ensure that ECs are maintained and that ICs continue in force. Additional information regarding LTS can be found at: www.epa.gov/brownfields/tools/lts_fs_04_2008.pdf

The need for ECs and/or ICs is identified as part of selecting a cleanup remedy and will vary depending on a number of factors, including but not limited to, the planned activity and land use for the property, the extent and location of contamination, and the environmental medium impacted. While it is not uncommon to find ICs without ECs, ICs are typically an integral part of EC protectiveness. For example, the most common ICs for brownfield cleanup projects (e.g., deed notices/restrictions, environmental covenants, state registries) provide information or notifications that residual contamination may remain on a property and identify ECs such as caps, mitigation barriers, or fencing, which are intended to restrict access and exposure to contamination, and eliminate further migration of contamination. Over the past several years environmental covenants have become an increasingly popular form of LTS to address activity and land use restrictions and engineering control installation, operation, and maintenance. Environmental covenants provide a mechanism to ensure that land use restrictions, mandated environmental monitoring requirements, and a wide range of common engineering controls designed to control the potential environmental risk of residual contamination will be reflected on the land records and effectively enforced over time as valid real property servitude. Currently 25 states have enacted legislation to adopt a form of the Uniform Environmental Covenants Act (UECA). More information regarding UECA can be found at: www.environmentalcovenants.org/

There are many different types of ECs and they vary from property to property, depending on the contaminants found and the type of media impacted. The following is a list of the more commonly used ECs at brownfield properties.

- **Capping in Place (Asphalt or Concrete)** – The use of paved areas (e.g., parking lots, roadways) and building foundations as surface barriers or caps over contaminated soil. Capping in place involves creating and maintaining a hard surface, usually concrete or asphalt, over contamination. The result is a high strength, low permeability cover that reduces surface water infiltration and stabilizes contaminated soils. As a result, the cap prevents contact with the contaminated soil and contaminant mobility is limited protecting ground water.

Paved areas such as parking lots and roadways can be used as caps over contaminated soil

- **Capping in Place (Clean Fill)** – Placement of defined thickness of clean fill over an area of contaminated soil (e.g., 2-3 feet of soil for non-residential uses, 10 feet for residential uses) to prevent contact with the contaminated soil.

- **Passive Depressurization Systems** – Installation of a passive vapor control system in conjunction with a vapor barrier under buildings to minimize potential migration of volatile contamination to indoor air. A passive depressurization system relies on a natural convection of air to draw air from the soil beneath a building and discharges it to the atmosphere through a series of collection and discharge pipes.
- **Active Depressurization Systems** – Installation of an active vapor control system in conjunction with a vapor barrier under buildings to minimize potential migration of volatile contamination to indoor air. An active depressurization system consists of a fan or blower which draws air from the soil beneath a building and discharges it to the atmosphere through a series of collection and discharge pipes.
- **Ground Water Migration Barriers** (e.g., barrier wall, ground water depression systems) – The use of a vertical impermeable barrier to limit exposure by cutting off the route and preventing migration of contaminated ground water or leachate from a contaminated property.

Engineering Controls Integrated Into Redevelopment

An important consideration for ECs in the context of brownfields redevelopment is the benefit of integrating the implementation and long-term stewardship of the ECs into the redevelopment of a property. In some cases, elements of the redevelopment (e.g., paving, building foundations) can serve as the EC by providing barriers to eliminate potential exposures to soil, ground water, and other environmental media. In cases where ECs are an integral part of the redevelopment, however, it may be difficult to separate the specific cost of the EC from the redevelopment. For example, where a parking lot is used as a cap over contaminated soil, the cost of site preparation and paving would have already been a consideration for the cost of the redevelopment. The cost of the EC would be any incremental costs that would not have been incurred during the paving if the contaminants were not present in the soil.

Although these five ECs are the most commonly used on brownfield redevelopment projects, other types of ECs are also used to reduce exposure to and migration of contamination left on the property. Other ECs used on brownfield properties include, but are not limited to:

- **Security Barriers and Fencing** – Used to restrict access to contaminated and unsafe brownfield properties.
- **Solidification/Stabilization** – Occurs by injecting or mixing cement into contaminated soil to lock contaminants into a structurally sound mass of solid material for disposal.
- **Geotextile Fabric Barriers** – Separate, filter, drain, or reinforce soils.
- **Engineered Caps** – Designed to meet specific performance and containment requirements such as permeability.
- **Leachate Collection Systems** – Direct and collect contaminated leachate, and then transport it offsite for disposal.
- **Permeable Reactive Barriers** – Walls that are built below ground and are composed of materials that remove contaminants from ground water as it flows through the permeable barrier.

In addition, remedial actions such as ground water pump and treat systems, soil vapor extraction systems, and monitored natural attenuation may continue beyond the change in use or redevelopment of a property. In these cases, long-term stewardship similar to engineering controls will be required and can be incorporated into institutional controls such as environmental covenants.

Engineering Control Use at Brownfield Properties

Each brownfield property redevelopment project is different and the need for ECs and/or ICs is based on several factors during the selection of the cleanup strategy. Property specific factors influence the selection of the cleanup remedy and control measures. A list of typical brownfield properties, the general types of contamination found at those properties, and the most common ECs follows.

- Gasoline service stations and auto body repair shops are typically contaminated with petroleum hydrocarbons from underground storage tanks (USTs) and, in some cases, metals associated with motor and hydraulic oils and cleaning solvents. These properties generally use land use and resource restrictions (ICs) along with capping technologies and active/passive depressurization systems to address residual contamination left on the property.
- Industrial properties are typically contaminated with asbestos, heavy metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOC), and polychlorinated biphenyls (PCBs) from manufacturing operations at the property. These properties generally use land use restrictions (ICs) along with capping technologies, active/passive depressurization systems, and security barriers (e.g., fences) to mitigate exposure to contamination left on the property.
- Commercial properties (e.g., dry cleaning operations) are typically contaminated with asbestos, VOCs, polycyclic aromatic hydrocarbons (PAHs), and PCBs from operations at the property. These properties generally use ICs (i.e., land use and resource restrictions) along with capping technologies (e.g., asphalt or clean fill) to address residual contamination left on the property.
- Landfills and dumps are typically contaminated with oils, paints, solvents, corrosive cleaners, batteries, VOCs, PAHs, and PCBs from the waste disposal at the property. These properties generally use ICs (i.e., land use and resource use restrictions) along with capping technologies and ground water mitigation barriers to reduce exposure and migration of contamination from the property.

Engineering Controls and Cleanup

ECs are typically considered a form of cleanup; however, it is important to recognize that there is a distinction between ECs and other forms of cleanup. ECs are often installed during cleanup as a condition of a no further action determination and are generally intended to be in place for long periods of time. In many cases, the presence and long-term stewardship (e.g., O&M) of ECs are defined in environmental covenants, O&M agreements, or other instruments. Other forms of cleanup may reduce or remove contamination in soil, ground water, and other environmental media (e.g., soil removal and disposal, ground water treatment, soil vapor extraction and treatment). These remedial actions are designed to be short term and targeted to meet a defined endpoint (e.g., corrective action goal or risk-based concentration in soil or ground water). While ECs are intended to be in place beyond the no further action determination, cleanups to reduce or remove contamination are typically completed before a no further action determination is made. It is important to note that in some cases, the technology implemented for ECs may be very similar to the technology implemented for reduction or cleanup. For example, a ground water pump and treat system can be used to reduce contamination in ground water or it can be used as an EC to control ground water migration.

Engineering Control Costs

The cost of installing and maintaining ECs is different for each property. In many cases, the costs of installing an EC is an integral part of a property redevelopment (e.g., paving as capping, or a building foundation as a cap) with little additional costs attributable to the EC. The range of costs to install and maintain ECs is, therefore, dependent upon several factors, including but not limited to: construction activities on the property; size of the property; extent and concentration of contamination; size of the building(s) or structure(s) on the property; location of the property; and depth to ground water.

There are three general types of costs associated with ECs: programmatic costs, capital costs, and operation and maintenance costs.

- Programmatic costs are incurred when municipal or local governments develop and implement LTS programs. Programmatic costs include: preliminary costs to develop the program, long-term planning for implementation, public outreach, and developing monitoring and enforcement plans.
- Capital costs are costs incurred for the design, construction, and installation of the EC. Capital costs may include, but are not limited to: mobilization and demobilization; monitoring, sampling, testing, and analysis; site work; design

Type of EC	Range of Capital Costs	Activities included in Capital Costs	Range of O&M Costs*	Activities included in O&M Costs
Capping in Place *(Asphalt or Concrete)*	• Clearing: $5,000 to $7,500 per acre • 1" Sub-base: $2.50 to $7.00 per square yard • 1.5" Surface: $12.00 to $20.00 per square yard • Swale: $15.00 to $25.00 per linear foot	• Site clearing • Equipment mobilization • Initial surface compaction • Design and engineering • Surface preparation • Hard surface cap layer placement • Edge drainage swale preparation • CQA program	• $1,000 annually	• Long-term inspections • Repair of damages • Site supervision • Security • Site quality assurance and health and safety
Capping in Place *(Clean Fill)*	• Excavation: $15 to $30 per cubic yard • Placement: $50 to $75 per cubic yard • Surface preparation and Hydro-Seeding: $100 to $200 per 1,000 square feet	• Site clearing • Equipment mobilization • Initial surface compaction • Design and engineering • Surface preparation • Cap layer placement • Edge drainage swale preparation • CQA program • Irrigation system	• $5,000 annually (vegetative cover)	• Long-term inspections • Repair of damages • Watering/irrigation system (to maintain vegetative cover) • Mowing • Utilities • Site supervision • Security • Site quality assurance and health and safety
Passive Depressurization Systems	• $2,000 to $5,000**	• Equipment mobilization • Design and engineering • Trenching and backfilling • Vent piping • Passive barrier installation • Compaction and restoration • GeoEngineer oversight	• $1,000 to $5,000 annually	• Long-term oversight and inspections • Repair of damages • Site supervision • Site quality assurance and health and safety
Active Depressurization Systems	• $5,000 to $20,000**	• Equipment mobilization • Design and engineering • Trenching and backfilling • Vent piping • Passive barrier installation • Mobilize and install active system • Compaction and restoration • GeoEngineer oversight	• $1,000 to $10,000 annually	• Long-term oversight and inspections • Performance and site Monitoring • Utilities • Repair of damages • Site supervision • Site quality assurance and health and safety
Ground Water Migration Barriers	• Trench barrier: $200 to $1,000 per linear foot of trench*** • Ground water depression: $50,000 to $500,000***	• Equipment mobilization • Design and engineering • Migration wall construction and installation • GeoEngineer oversight	• Trench barrier: $3,000 to $10,000 annually **** • Ground water depression: $5,000 to $35,000 annually ****	• Long-term oversight and inspections • Repair of damages • Site supervision • Site quality assurance and health and safety

Assumes length of post-closure care is 20-30 years.

** *Assumes average building size of 4,000 square feet.*

*** *The capital costs of ground water migration barriers are dependent on the type of barrier installed, the depth of the barrier and other site-specific conditions. The capital costs provide a range of costs considering the variability in these characteristics. Trenching assumes a maximum depth of 20 feet below the ground surface. Ground water depression assumes pumping rate of 1 to 10 gpm and that extracted water will be treated prior to discharge.*

**** *Assumes periodic ground water monitoring for trench barrier. Assumes periodic ground water monitoring and inspection and maintenance of pumping and treatment systems.*

Note that the EC examples identified in the table do not include capital and operating costs associated with designing, installing, and operating a ground water monitoring program that may be required. Additional information regarding EC and IC costs can be found in An Introduction to the Cost of Engineering and Institutional Controls at Brownfield Properties at: www.epa.gov/brownfields/tools/lts_cost_fs.pdf

and engineering; construction and installation; off-site treatment and disposal; construction quality assurance (CQA); and project and construction management.

- Operation & Maintenance (O&M) costs associated with ECs should be considered throughout the lifecycle of property cleanup and post-cleanup care. O&M activities are conducted at a property after ECs are in place, to ensure that the action is effective and operating properly, and may include, but are not limited to: performance inspections and site monitoring; operating remediation systems, including sampling and analysis, preparing reports, and recordkeeping; maintaining caps and system maintenance; and site supervision.

The following table provides a range and list of costs for the more common ECs implemented on brownfield properties. The examples provided below only include site-specific capital and O&M costs incurred when designing, implementing, and monitoring ECs. The table does not include the programmatic cost to a municipality or local government to develop and implement a LTS program. In addition, each EC design and implementation will incur indirect and variable costs. These indirect and variable costs are not listed in the table and may include, but are not limited to: project management, vendor selection, permit preparation and fees, regulatory interaction, and contingencies.

Local Government Planning Tool to Calculate IC/EC Costs for Brownfield Properties

The cost calculator is designed as a voluntary guide for municipal or local governments to assist in calculating their expected costs of implementing and conducting LTS of ICs and ECs at brownfield properties. In general, primary responsibility for maintaining ICs and ECs rests with the property owner and others responsible for cleanup. The state response program often plays a large role in selecting, implementing, and monitoring ICs and ECs; however, local governments, as controllers of local land use and zoning, often have responsibilities associated with ICs and ECs and LTS at brownfield properties. Each of these separate entities may have different roles, responsibilities and costs. It is important to calculate the full cost of LTS for ICs and ECs, both short- and long-term to ensure adequate resources are available for their management over time. Additional information on the institutional and engineering control costs calculating tool can be found in the Local Government Planning Tool to Calculate Institutional and Engineering Control Costs for Brownfield Properties at: www.epa.gov/brownfields/tools/tti_lucs.htm.

Sources for Estimating Costs and Additional Resources

EC capital and O&M cost estimates can be generated from several sources. Cost-estimating software and databases can be used to calculate the capital and O&M costs of ECs. The majority of available software tools are designed to estimate the cost for all or selected cost elements of an EC. Below is a list of several sources for estimating costs of ECs.

- **Cost Estimating Guides/References** – Provide costs for a wide variety of construction activities, including those related to property cleanup. Some guides are specifically customized to estimate costs for environmental remediation projects. Cost data in guides or references are often broken down into labor, equipment, and material categories, and may or may not include contractor markups. Costs are typically provided on a national average basis for the year of publication of the reference.
- **Vendor or Contractor Quotes** – Provide costs that are more site-specific in nature than costs taken from standard guides and references. These quotes usually include contractor markups and are typically provided as a total cost rather than categorized as labor, equipment, or materials. If possible, more than one vendor quote should be obtained. Quotes from multiple sources can be averaged, or the highest quote can be used in the cost estimate if the collected quotes seem to be at the low end of the industry range.
- **Experience with Similar Projects** – Engineering judgment should be exercised if cost data from another project need to be adjusted to take into account site- or technology-specific parameters. In addition, sources of actual cost data from government remediation projects are maintained by various federal agencies.

- **Cost Estimating Software/Databases/Reports** – The majority of available software tools are designed to estimate the cost for all or selected cost elements of an alternative.
- **Remedial Action Cost Engineering Requirements (RACER)** – A cost estimating system originally developed by the U.S. Air Force. The system uses a patented methodology for generating location-specific program cost estimates. RACER calculates quantities for each technology; localizes unit costs for materials, equipment, and labor; adjusts unit prices for safety and productivity losses; and applies markups to account for indirect costs. It uses current multi-agency pricing data, and is researched and updated annually to ensure accuracy. This software is available for purchase at: www.frtr.gov/ec2/ecracersystem.htm
- **CostPro** – A software program developed by EPA to estimate costs for closure and post-closure plans prepared by Treatment, Storage, and Disposal Facilities (TSDFs) regulated under the Resource Conservation and Recovery Act (RCRA). Under RCRA, owners or operators of interim status and permitted TSDFs must prepare and annually update a cost estimate for closure and post-closure (if applicable) and provide corresponding financial assurance. CostPro uses data from RS Means and ECHOS for specific cost items. EPA limits free distribution of the software only to EPA and state personnel. Others interested in obtaining the software must pay a licensing fee to RS Means and ECHOS that provides the right to use the data incorporated into this software. To obtain further information about CostPro or how to obtain the software: contact Bob Maxey, EPA Headquarters, at (703) 308-7273 or maxey.robert@epa.gov.
- **Micro Computer Aided Cost Engineering System (MCACES)** – A program used by the U.S. Army Corps of Engineers that is linked to the Unit Price Book (UPB) database. www.hnd.usace.army.mil/traces/
- **Federal Remediation Technology Roundtable (FRTR)** – FRTR makes data more widely available on real experiences and lessons learned in selecting and implementing treatment and site characterization technologies to clean up soil and ground water contamination. The remediation case study reports describe the performance and cost of technology applications at full-scale and large-scale demonstration projects. www.frtr.gov/costperf.htm
- **Innovative Treatment Technologies** – Provides information about characterization and treatment technologies for the hazardous waste remediation community. It offers technology selection tools and describes programs, organizations, publications for federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens. www.epa.gov/tio/remed.htm
- **EPA's Cleanup Information (CLU –IN)** – Provides information about innovative treatment technologies and acts as a forum for all waste remediation stakeholders. www.clu-in.org/remediation/
- **A Guide to Developing and Documenting Cost Estimates During Feasibility Study (July 2000)** – This guide provides capital and O&M cost categories and details steps in calculating costs of ECs. www.epa.gov/superfund/policy/remedy/pdfs/finaldoc.pdf
- **Florida Department of Environmental Protection Engineering Controls Report (1999)** – This document considers the adequacy of ECs available for use at contaminated properties; summarizes the types of ECs currently available; evaluates the effectiveness of ECs in protecting human health, and the environment; and evaluates the ability of ECs to achieve risk-based corrective action criteria at contaminated properties. www.dep.state.fl.us/waste/quick_topics/publications/wc/csf/focus/engineer.pdf

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For additional information regarding ECs/ICs and LTS, please visit the EPA Brownfields Program at www.epa.gov/brownfields or contact Ann Carroll at (202) 566-2748 or carroll.ann@epa.gov.