UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
ENFORCEMENT AND COMPLIANCE ASSURANCE

November 1, 2004

MEMORANDUM

SUBJECT: Transmittal of Average Cost of Investigation Derived from Fund-Lead Superfund Costs, Interim Measures Cost Compendium, and Compendium of Related Guidance Documents

FROM: Susan E. Bromm, Director /s/
Office of Site Remediation Enforcement

TO: RCRA Directors, Regions I - X
RCRA Enforcement Managers, Regions I - X
RCRA Key Contacts, Regions I - X

This memorandum transmits the attached documents entitled "Average Cost of Remedial Investigation Derived from Fund-Lead Superfund Costs" and "Interim Measures Cost Compendium," and "Compendium of Related Guidance Documents." The purpose of the documents is to assist you in evaluating the appropriate level of financial assurance that may be required for a RCRA Facility Investigation (RFI) or for interim measures.

On September 30, 2003, OSRE and OSW jointly transmitted the "Interim Guidance on Financial Responsibility for Facilities Subject to RCRA Corrective Action." That interim guidance provides regulators with guidance on implementing financial responsibility requirements to ensure that hazardous waste treatment, storage, and disposal facility (TSDF) owners and operators provide evidence of financial responsibility for corrective action when necessary.

The September 30, 2003 guidance recommends a flexible, facility-specific approach to requiring financial assurance for corrective action, and in appropriate situations, encourages regulators to require financial assurance earlier in the corrective action process such as for the RFI and/or for significant interim measures.

Enclosed, please find:

- **Average Cost of Remedial Investigation Derived from Fund-Lead Superfund Cost**s

The first document is a table that provides cost values for the remedial investigation (RI) at 28 categories of sites. The cost values are based on the costs of completed fund-lead RI costs from the Superfund program. For each site type category, the number in parentheses indicates the number of sites where cost data was obtained.

Fund-lead RI cost data came from three sources: RACMIS, an Office of Superfund Remediation Technology Innovation (OSRTI) system that tracks and maintains information on work performed by Response Action Contractors; SCORES, an accounting system maintained by the EPA Comptroller's Office; and CERCLIS, an OSRTI system that tracks and maintains information on hazardous waste sites and remedial activities across the nation.

Cost data was assigned to completed RI actions in a hierarchical fashion based on data quality. All available RACMIS cost data was assigned first to completed RI actions. SCORES data was assigned to those completed RI actions that did not already have cost information. Finally, CERCLIS cost data was assigned to any remaining actions where cost data had not already been assigned.

The Superfund and RCRA programs have similar investigation and remediation processes. Superfund RI costs can be used as a proxy for RCRA Facility Investigation (RFI) costs and serve as a general guideline for cost estimating efforts. Although past costs from similar work serve as excellent pricing sources, adjustments will have to be made for dissimilarities which affect prices such as facility type, media, and type and volume of waste. Users of this table can determine the site type category, and then refer to the table to locate a cost estimate for assessing the appropriate amount of financial assurance.

- **Interim Measures Cost Compendium**

The second document is a cost compendium for a variety of interim measures. The costs were developed using the Remedial Action Cost Engineering and Requirements (RACER) cost estimating software which was developed by the US Air Force during the early 1990s for use by its remedial project managers in developing estimates for cleanups related both to RCRA and Superfund. Costs in this software are based on the 2003 Environmental Cost Handling Options and Solutions (ECHOS) cost database which consists of unit prices for materials, labor and equipment that is updated annually through a survey of contractors, suppliers, laboratories, and engineering/consulting firms.

For each interim measure, we included multiple scenarios. For example, costs for groundwater extraction well installation were obtained for four different scenarios. These costs are provided in a chart that allows you to locate the correct extraction and depths to groundwater rates to estimate the installation cost per well. The annual operation and maintenance (O&M) cost per well also are included in the chart.

Facility-specific conditions will govern the type of investigation and interim measures and the level of effort required for any given facility. The range and cost data is provided as a framework for developing cost estimates during preliminary or planning phases, where actual costs are not known. You are encouraged to use the attached documents and adjust cost estimates as more information becomes known.

- **Compendium of Related Guidance Documents**

Also attached is a compendium of Superfund and RCRA remediation guidance documents. The documents address remediation cost estimating tools, procedures and guidelines, and documents related to site investigation and interim measures. The compendium summarizes the guidance documents and includes the internet address for the PDF files (except for two documents available through NTIS).

I appreciate the input my office received from Bob Stewart in EPA Region IV, who helped shape these documents and I want to thank him for his help. For more information regarding the attached documents, please contact Mary Bell at (202) 564-2256.

Attachments (3)

cc:
Paul Connor, OECA/OSRE
Neilima Senjalia, OECA/OSRE
Ken Patterson, OECA/OSRE
Monica Gardner, OECA/OSRE
Mary Bell, OECA/OSRE
Tracy Gipson, OECA/OSRE
Matthew Hale, OSWER/OSW
Maria Vickers, OSWER/OSW
Dale Ruhter, OSWER/OSW
Christine McCulloch, OECA/RED

Average Cost of Remedial Investigation Derived from Fund-Lead Superfund Costs[1]

(In Millions)

Site Type[2]	Minimum	Median	Mean	Maximum
Agricultural (10)	$51,255	$1,138,254	$1,256,159	$3,048,913
Airports (3)	75,000	784,829	1,045,733	2,277,371
Captive industrial landfill (13)	145,663	610,141	746,927	2,097,604
Captive industrial waste management(4)	65,636	686,947	682,658	1,291,103
Chemical manufacturing (40)	50,816	338,564	667,264	2,150,000
Cleaning operations (4)	100,000	430,315	386,035	583,509
Coal Gasification (1)	793,279	793,279	793,279	793,279
Commercial landfill (10)	87,287	863,307	1,433,410	3,400,455
Commercial landfill: co-disposal (33)	81,136	698,000	1,125,136	14,637,960
Commercial waste management (15)	51,506	210,000	592,627	3,017,000
Dry cleaning facilities (5)	425,000	965,691	843,585	1,198,000

Office of Site Remediation Enforcement
US EPA
August 2004

Site Type	Minimum	Median	Mean	Maximum
Military related operations (2)	800,174	1,076,523	1,076,523	1,352,871
Mining (52)	58,051	674,309	1,052,643	6,316,683
Municipal landfill: co-disposal (21)	110,000	750,000	871,929	2,665,850
Oil refining (6)	126,182	948,319	864,245	1,510,336
Other (5)	200,000	1,183,630	940,820	1,677,045
Other manufacturing (64)	79,206	716,869	1,058,612	6,838,895
Other manufacturing - machinery (17)	105,291	939,129	1,043,474	3,450,000
Other manufacturing – metal (26)	84,004	717,490	1,070,565	4,614,118
Railroads (4)	630,000	1,039,912	1,066,611	1,556,620
Recycling (12)	175,026	911,640	1,190,301	3,753,530
Recycling – batteries (12)	92,777	927,856	1,052,957	3,396,106
Recycling -- degreasing solvents (9)	246,318	1,248,000	1,360,242	3,757,013
Recycling - scrap materials/used oil (21)	131,003	516,510	924,509	3,671,115

Site Type	Minimum	Median	Mean	Maximum
Trucking operations (5)	99,390	212,860	287,736	750,000
Universities (1)	942,345	942,345	942,345	942,345
Warehouses (4)	177,560	572,378	573,473	971,576
Wood preserving (40)	60,595	646,736	785,671	3,852,060
Overall (440)	50,816	690,835	956,389	14,637,960

---

[1] This table provides cost values for the remedial investigation (RI) at 28 categories of sites. The cost values are based on the costs of completed fund-lead RI costs from the Superfund program. Fund-lead RI costs data came from three sources: RACMIS, an OSRTI system that tracks and maintains information on work performed by Response Action Contractors; SCORES, an accounting system maintained by the EPA Comptroller's Office; and CERCLIS, an OSRTI system that tracks and maintains information on hazardous waste sites and remedial activities across the nation.

Cost data was assigned to completed RI actions in a hierarchical fashion based on data quality. All available RACMIS cost data was assigned first to completed RI actions. SCORES data was assigned to those completed RI actions that did not already have cost information. Finally, CERCLIS cost data was assigned to any remaining actions where cost data had not already been assigned.

The Superfund and RCRA programs have similar investigation and remediation processes. Superfund RI costs can be used as a proxy for RCRA Facility Investigation (RFI) costs and serve as a general guideline for cost estimating efforts. Although past costs from similar work serve as excellent pricing sources, adjustments will have to be made for dissimilarities which affect prices such as facility type, media, and type and volume of waste. Users of this table can determine the site type category, and then refer to the table to locate a cost estimate for the remedial investigation.

[2] For each site type category, the number in parentheses indicates the number of sites where cost data was obtained.

Office of Site Remediation Enforcement
US EPA
August 2004

U.S. ENVIRONMENTAL PROTECTION AGENCY

INTERIM MEASURES COST COMPENDIUM

September 28, 2004

Disclaimer

This document is intended solely as a cost evaluation tool. It is not a regulation itself, nor does it change or substitute for requirements in statutes and regulations. This document does not impose legally binding requirements on EPA, States, or the regulated community and does not confer any legal rights. The general description provided here may not apply to a particular situation based upon the circumstances. In a particular situation, parties are free to raise questions and objections about the substance of this document and the appropriateness of the application of this document. EPA and other decisionmakers retain the discretion to adopt approaches on a case-by-case basis that differ from those described in this document where appropriate.

Interim Measures Cost Compendium
Table of Contents

Cost Item | **Page**

General Assumptions and Methodology

This cost compendium contains the costs to implement numerous remediation technologies for use as interim measures at contaminated sites.

Source of Costs

Costs were developed from the Remedial Action Cost Engineering and Requirements (RACER) cost estimating software; costs in this software are based on the 2003 Environmental Cost Handling Options and Solutions (ECHOS) cost database. ECHOS is a joint venture between Talisman Partners, Ltd., experts in environmental restoration cost estimating and technology application, and the R.S. Means Company, Inc., the leading publisher of construction cost information in North America. R.S. Means developed a database of unit prices for materials, labor and equipment that is updated annually through a survey of contractors, suppliers, laboratories, and engineering/consulting firms.

Escalation Factor

Costs were escalated from 2003$ to 2004$ using the RACER-assumed escalation factor of 1.0322.

Area Factor

The RACER thirty city average was used for developing the estimated system costs. Please note that labor, materials, and equipment costs will vary depending on the location. For a full list of area factors refer to RACER.

Markups

RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, and prime and sub contractor markup and profit.

Design Factors

RACER design factors are also included in the cost estimates when appropriate. The "Assumptions and Limitations" section in each technology provides the range of design factors included in the technology costs. The design factor is dependent on the type of remedial action technology and may not be applicable in all cases. For example, investigation technology costs (i.e., groundwater monitoring) typically do not include design factors. RACER assumes percentage factors based on the type of remedial action and the total remedial action capital cost. The types of remedial action are divided into seven categories:

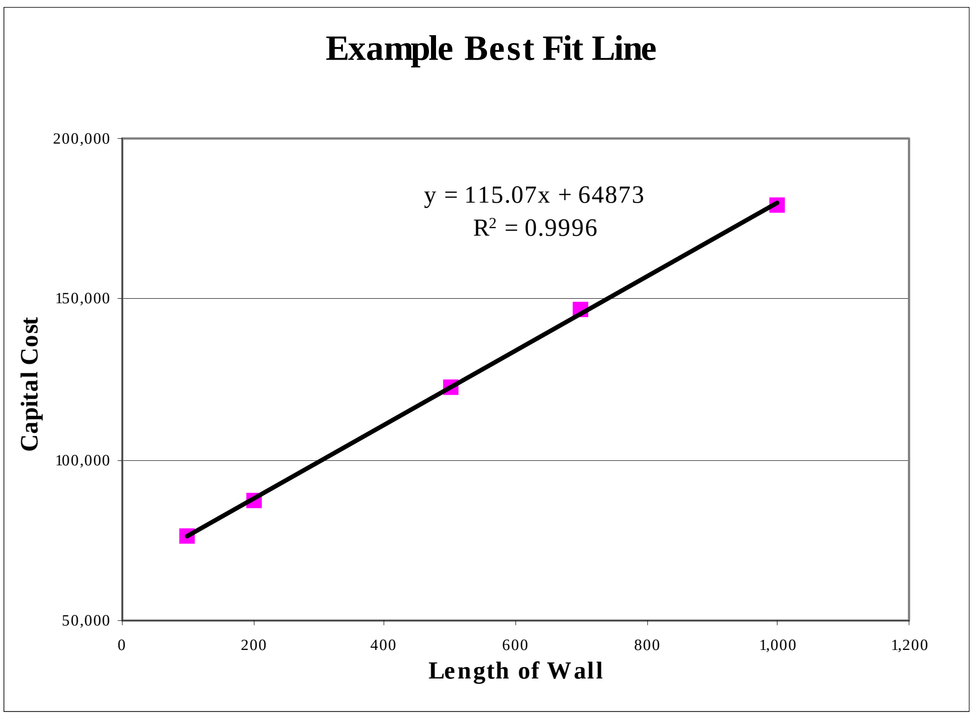
- In-situ treatment,

- In-situ containment;
- Ex-situ: removal/performance-based on-site treatment or disposal;
- Ex-situ: removal/detailed design on-site treatment or disposal;
- Ex-situ: removal/off-site treatment or disposal;
- Natural attenuation; and
- Ordnance and explosive waste.

The design factors range from 2.5 to 15 percent.

Cost Equations

Cost equations are included in the technology descriptions to estimate costs for volumes or sizes of systems not specified in the cost tables. The cost equations are trend line representations of the technology costs estimated using RACER. That is, a cost equation is the best fit line to represent the costs of a range of system sizes (see the following figure). The cost equation can be used instead of linear interpolation for system sizes not estimated using RACER. The cost equations will not exactly reproduce the costs presented in the tables; however, the cost equations will reasonably approximate the RACER cost estimates. In applications where the system size is close (e.g., within five percent) to a system size presented in the cost table, use the RACER cost estimates presented in the tables. In all other cases, use the cost equation. The cost equation is applicable for sizes extending from the low to the high system size presented in the cost table. In all cases, using the specified variable unit for each cost equation will calculate a dollar value for capital costs and a dollar per year value for O&M costs.



Soil and Vegetative Cap

Application

The capital and O&M costs and cost equations were developed using incremental cap areas ranging from 0.5 acres to 50 acres. Cap areas beyond the range of 0.5 to 50 acres will depart from the estimated costs and are not verifiable. However, the cost equation trend line is linear with little to no deviation from the estimated costs for the cap areas. Therefore, the cost equation is assumed to be applicable to any size cap area.

Two cost equations were developed for each scenario, capital costs and general O&M (e.g., mowing, reseeding, fertilizing).

Assumptions and Limitations.

1. The soil and vegetation cap consists of 36 inches of soil and a geotextile fabric. The top 6 inches of on-site soil will be graded and leveled prior to the cap installation. A geotextile fabric is lain on the soil and covered with 30 inches of soil, compacted in 6 inch lifts. A vegetation layer composed of 6 inches of topsoil is placed on the top.

2. Two cost scenarios were developed for covers constructed using either on-site soil or off-site fill. Off-site fill includes purchase, delivery, spreading, and compaction costs. On-site soil includes spreading and compaction costs. The on-site soil costs do not include excavation and the soil is assumed to be already stockpiled (i.e., already excavated) for use. Topsoil was assumed to be purchased from off-site sources in both scenarios. If on-site borrowed soil is used for the cap, additional costs for excavation need to be added.

3. General O&M includes cap inspection, mowing six times a year, fertilizing twice a year, and seeding of one-third of the cap area per year. The costs are presented as annual O&M costs.

4. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment (PPE), permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 7 to 12% of the capital costs.

Costs - 2004$

	Soil and Vegetative Cap Constructed Using On-site Stockpiled Soil		**Soil and Vegetative Cap Constructed Using Off-site Fill**	
Area (acre)	Capital Costs	Annual O&M Costs	Capital Costs	Annual O&M Costs
0.5	$101,800	$3,046	$105,743	$3,046
1	$188,769	$4,815	$197,074	$4,815
3	$530,681	$10,867	$548,626	$10,867
5	$856,545	$16,551	$897,104	$16,551
10	$1,676,046	$28,842	$1,754,453	$28,842
50	$8,163,659	$122,771	$8,539,251	$122,771

Cost Equations - 2004$

Soil and Vegetative Cap Constructed Using On-site Stockpiled Soil
Capital Cost
= ($162,630 × area) + $35,785
General O&M per year
= ($2,395 × area) + $3,404

Soil and Vegetative Cap Constructed Using Off-site Fill
Capital Cost
= ($170,144 × area) + $36,207
General O&M per year
= ($2,395 × area) + $3,404

area = capping area in acres.

Composite Cap for Hazardous Waste (Subtitle C)

Application

The capital costs, O&M costs and cost equations were developed using incremental cap areas ranging from 0.5 acres to 50 acres. Cap areas beyond the range of 0.5 to 50 acres will depart from the estimated costs and are not verifiable. However, the cost equation trend line is linear with little to no deviation from the estimated costs for the cap areas. Therefore, the cost equation is assumed to be applicable to any size cap area. 2003 CFR 40 Sections 264.301 and 264.310 were used to determine the requirements for capping of hazardous waste materials.

Three cost equations were developed, capital costs, general O&M (e.g., mowing, reseeding, fertilizing), and miscellaneous O&M. Miscellaneous O&M is comprised of repairs to the cap due to erosion, settling, or other unforseen circumstances.

Assumptions and Limitations

1. The Subtitle C composite cap consists of 36 inches of clay, a geotextile fabric, a 40 mil HPDE liner, 18 inches of soil, and 6 inches of topsoil. The top 6 inches of on-site soil will be graded and leveled prior to the cap installation. Three feet of compacted clay is placed on the graded fill, followed by the 40 mil HDPE liner and then the geotextile fabric. The geotextile fabric is covered with 18 inches of soil, compacted in 6 inch lifts, and the vegetation layer composed of 6 inches of topsoil is the last layer. Two scenarios were developed as follows:

   a.. On-site source compacted clay layer: six inch grading of onsite soil, three foot on-site clay layer, 40 mil HPDE liner, geotextile fabric, 18 inches of off-site fill, six inches of off-site topsoil, and vegetation.
   b. Off-site source compacted clay layer: six inch grading of onsite soil, three feet of off-site clay layer, 40 mil HPDE liner, geotextile fabric, 18 inches of off-site fill, six inches of off-site topsoil, and vegetation.

2. General annual O&M includes cap inspection, mowing six times a year, fertilizing twice a year, and seeding of one-third of the cap area once a year. Miscellaneous annual O&M is comprised of repairs to the cap due to erosion, settling, or other unforseen circumstances or damage to the cap.

3. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment (PPE), travel and per diem, permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup, profit, and design. RACER design factors are also included, ranging from 7 to 12% of the capital costs.
4. The cost equations tend to overestimate costs by up to 20% for smaller cap areas (i.e.,

areas less than 1.5 acres).

Cost - 2004$

	Subtitle C Composite Cap Constructed Using On-site Clay for Compacted Clay Liner			**Subtitle C Composite Cap Constructed Using Off-site Clay for Compacted Clay Liner**		
Area (acre)	Capital Costs	General O&M Costs ($/year)	Miscellaneous O&M Costs ($/year)	Capital Costs	General O&M Costs ($/year)	Miscellaneous O&M Costs ($/year)
0.5	$241,304	$2,146	$4,699	$257,745	$2,146	$5,078
1	$467,052	$3,658	$9,315	$499,278	$3,658	$10,078
3	$1,346,813	$8,836	$26,529	$1,442,862	$8,836	$28,714
5	$2,238,885	$13,514	$42,862	$2,398,966	$13,515	$46,403
10	$4,466,237	$24,958	$83,685	$4,786,398	$24,958	$90,614
50	$22,049,323	$111,516	$402,116	$23,635,305	$111,516	$435,530

Cost Equations - 2004$

Subtitle C Composite Cap Constructed Using On-site Clay for Compacted Clay Liner
Capital
= ($440,427 × area) + $33,324
General O&M per year
= ($2,195 × area) + $2,013
Miscellaneous O&M per year
= ($8,007 × area) + $2,117
Subtitle C Composite Cap Constructed Using Off-site Clay for Compacted Clay Liner
Capital
= ($472,128 × area) + $34,609
General O&M per year
= ($2,195 × area) + $2,013
Miscellaneous O&M per year
= ($8,673 × area) + $2,274

area = capping area in acres.

Excavation

Application

The RACER software has a fixed total excavation range of 1 to 999,999 cubic yards. The excavation width and length is limited to 9,999 feet and the depth is limited to 40 feet.

Assumptions and Limitations

1. Soils are grouped as gravel/sand and silt/clay. Gravel and sand soils are assumed to have no cohesion and require sloping at excavation depths greater than one foot. For excavation depths between 1 and 5 feet, a slope of 1:1 is assumed. For depths from five feet to approximately 15 feet, a slope of 1:2 is assumed. For depths greater than 15 feet, steel shoring is assumed. For silt and clay soils, no sloping is assumed for excavation depths up to five feet. For depths greater than 5 to 15 feet, a slope of 1:1 is assumed. For depths greater than 15 feet, steel shoring is assumed.

2. Shoring costs include installation, removal, and salvage of the steel sheeting.

3. Costs are developed for the nominal excavation volumes. The total (nominal) excavation volume is determined by using the area and depth of the contaminated soil to be excavated, not including side stabilization sloping excavation volumes.

4. Different bucket volume crawler-mounted, hydraulic excavators are assumed for different excavation volumes as follows:

Total Excavation Volume Range (cy)	**Bucket Volume (cy)**	**Assumed Excavation Volume Representing Range (cy)**
<500	1	250
500 to <4,000	2	2,000
4,000 to <13,000	3	8,000
13,000 or more	4	15,000 and 30,000

5. Excavated material is stockpiled on site and covered by plastic laminate. Silt/clay soils are assumed to bulk more than gravel/sand soils, requiring a larger area of plastic laminate. RACER default factors were used for the bulking factors.

6. The crawler-mounted, hydraulic excavator will be decontaminated once during the excavation operations.

7. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment (PPE), travel and per diem, permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup, profit, and design. RACER design factor are not included since this factor is dependent on the final corrective action (e.g., on-site or off-site treatment or disposal). Design factors typically range from 3.5 to 15%, depending on the management method and total.

<u>Costs</u> - 2004$

Excavation Volume (cy)	**Excavation Depth (ft)**	**Gravel/Sand Soil Total Excavation Cost**	**Silt/Clay Soil Total Excavation Cost**
250 (<500 Range)	1	$2,875	$2,938
2,000 (500 to <4,000 Range)	1	$13,318	$13,808
8,000 (4,000 to <13,000 Range)	1	$43,114	$44,959
15,000 (>13,000 Range)	1	$88,093	$91,492
250 (<500 Range)	5	$3,505	$2,938
2,000 (500 to <4,000 Range)	5	$14,555	$13,808
8,000 (4,000 to <13,000 Range)	5	$45,231	$44,959
15,000 (>13,000 Range)	5	$91,497	$91,492
30,000 (>13,000 Range)	5	$174,848	$180,607

Excavation Volume (cy)	Excavation Depth (ft)	Gravel/Sand Soil Total Excavation Cost	Silt/Clay Soil Total Excavation Cost
250 (<500 Range)	10	$5,021	$5,008
2,000 (500 to <4,000 Range)	10	$19,385	$16,628
8,000 (4,000 to <13,000 Range)	10	$56,899	$52,150
15,000 (>13,000 Range)	10	$105,599	$100,584
30,000 (>13,000 Range)	10	$194,528	$189,731
250 (<500 Range)	20	$31,006	$30,945
2,000 (500 to <4,000 Range)	20	$85,878	$86,333
8,000 (4,000 to <13,000 Range)	20	$188,495	$190,282
15,000 (>13,000 Range)	20	$286,265	$289,615
30,000 (>13,000 Range)	20	$441,721	$448,329

<u>Cost Equations</u> - 2004$

Gravel/Sand Soils

1 foot excavation depth	Total cost = ($5.71 × cy) + $809
5 foot excavation depth	Total cost = ($5.78 × cy) + $2,056
10 foot excavation depth	Total cost = ($6.35 × cy) + $6,099
20 foot excavation depth	Total cost = $1,378.7 × $(cy)^{0.5536}$

Silt/Clay Soils

1 foot excavation depth	Total cost = ($5.99 × cy) + $560
5 foot excavation depth	Total cost = ($5.99 × cy) + $560
10 foot excavation depth	Total cost = ($6.23 × cy) + $3,983
20 foot excavation depth	Total cost = $1350.2 × $(cy)^{0.557}$

cy = The nominal excavation volume in cubic yards. The nominal volume represents the volume to be excavation not including excavation area necessary for slope stabilization.

Backfill

Application

The RACER software has a backfill application range of 1 to 999,999 cubic yards. The backfill width and length are limited to 9,999 feet, and the depth is limited to 40 feet.

Assumptions and Limitations

1. The unit cost is for unclassified fill from an off-site or on-site source, placed in six inch lifts. Costs include delivery (if applicable), spreading, and compaction.

2. No costs for a gravel, asphalt, or concrete final cover are included. The unclassified fill is left exposed as the final cover.

3. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment (PPE), travel and per diem, permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup, profit, and design. RACER design factor are not included since this factor is dependent on the final corrective action (e.g., on-site or off-site treatment or disposal). Design factors typically range from 3.5 to 15%, depending on the management method and total.

4. The cost equations will tend to underestimate costs for backfill costs for volumes less than 250,000 cubic yards.

Costs - 2004$

Volume (cy)	Backfill Obtained From On-site Source	Backfill Obtained From Off-site Source
9	$139	$298
93	$816	$1,739
926	$7,555	$15,400
9,259	$69,977	$141,642
92,592	$1,004,442	$1,741,341
925,926	$7,339,287	$13,860,868

Cost Equations - 2004$

On-site fill source cost = $\$7.96 \times cy$
Off-site fill source cost = $\$15.01 \times cy$

cy = The nominal excavation volume in cubic yards. The nominal volume represents the volume to be excavation not including compaction or settling factors.

In-Situ Solidification/Stabilization

Application

The costs are based on areas of 1,000 to 100,000 square feet (sf) and depths of 10 to 50 feet below ground surface. The total volume of waste/contaminated soil is assumed to be the volume calculated by multiplying the assumed surface area in square feet by the depth in feet. Three sets of costs were developed for soil types of gravel/gravel-sand or sand/gravelly sand, sand-silt/sand-clay, and silt/silty-clay. The gravel/gravel-sand and sand/gravelly sand soil types generated the same cost for in-situ solidification/stabilization.

In-situ solidification/stabilization, is an in-situ process where chemical reagents are mixed with waste/contaminated soil to make use of complex chemical and physical reactions to improve physical properties and reduce contaminant solubility, toxicity, and/or mobility.

In solidification, a reagent is added to transform a sludge, sediment, or soil into a solid form. Solidification, immobilizes the contaminants within a crystalline structure of the solidified material, thus reducing the contaminant leaching potential. In stabilization, a reagent is added to transform the material so that the hazardous constituents are in their least mobile or toxic form.

Stabilization/solidification is used to solidify or immobilize inorganic compounds, volatile and non-volatile metals, PCBs (depending on concentration), asbestos, and radionuclides. Solidification/stabilization may have limited effectiveness against semi-volatile organic compounds (SVOCs) and pesticides and no expected effectiveness against volatile organic compounds (VOCs).

Assumptions and Limitations

1. All waste/contaminated soil is a solid and not a sludge, therefore, not able to be pumped.

2. Waste/contaminated soil does not have a high concentration of organics or other miscellaneous materials (i.e., oil and grease, loess, peat, highly plastic clays) that may inhibit the effectiveness of this technology.

3. The personal protection safety level for on-site staff is Level C.

4. Costs include additives based on RACER defaults. These defaults are provided by RACER only to estimate the additive costs. Actual additives and mix ratios are highly waste-specific and should be determined by bench and pilot testing. The RACER defaults assume the following ratios:

   Cement:Waste - 0.150:1
   Water:Cement - 0.400:1
   Proprietary Chemcials:Waste - 0.010:1

5. The cost to conduct a treatability study or bench testing were estimated separately. This bench testing/treatability study is assumed only to determine the appropriate additives to use, the correct additive mix ratio, and the effectiveness of the technology on the waste/contaminated soil. The bench testing assumes the removal of a 1 cy sample of waste from the site, performing ex-situ soldification/stabilization, and analytical testing for metals to determine if the contaminants have been effectively immobilized. The cost for this treatability study was determined to be $64,000.

6. No stabilization/solidification is assumed to be conducted below the water table. If stabilization/solidification was desired to be completed below the water table, dewatering may be required.

7. Solidification/stabilization may increase the volume of waste/contaminated soil present. This increase in volume may raise the ground surface of the site if the treated material is left in place. Costs for grading and capping or disposal of excess waste are not included.

8. Costs for post treatment groundwater monitoring or waste sampling are not included.

9. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 4 to 6% of the capital costs.

Costs - 2004$

Area (ft^2)	Depth (ft)	Volume (ft^3)	In-Situ Solidification of Gravel/Gravel-Sand to Sand/Gravelly-Sand Soil	In-Situ Solidification of Sand-Silt/ Sand-Clay Soil	In-Situ Solidification of Silt/Silty-Clay Soil
Capital Costs Year 2004$					
5,000	10	50,000	$421,200	$529,300	$602,600
5,000	30	150,000	$953,600	$1,137,800	$1,425,600
5,000	50	250,000	$1,754,700	$2,258,000	$3,336,600
10,000	10	100,000	$727,100	$792,900	$1,018,600
10,000	30	300,000	$1,788,900	$2,094,500	$2,678,700
10,000	50	500,000	$3,399,800	$4,343,600	$6,461,000
50,000	10	500,000	$2,860,500	$3,399,800	$4,343,600
50,000	30	1,500,000	$8,108,200	$9,718,500	$12,618,800
50,000	50	2,500,000	$15,976,500	$20,935,400	$31,574,400
100,000	10	1,000,000	$5,438,800	$6,512,300	$8,534,000
100,000	30	3,000,000	$15,962,400	$19,167,400	$25,061,100
100,000	50	5,000,000	$31,776,500	$41,694,300	$63,052,400

Cost Equations - 2004$

Treatability Study/Bench Testing: $64,000

Gravel/Gravel-Sand and Sand/Gravelly-Sand

10ft Deep: Capital Cost = ($52 × area in square feet) + $196,378
30ft Deep: Capital Cost = ($158 × area in square feet) + $193,512
50ft Deep: Capital Cost = ($316 × area in square feet) + $184,420

Sand-Silt/Sand-Clay

10ft Deep: Capital Cost = ($415 × area in square feet) + $186,535
30ft Deep: Capital Cost = ($190 × area in square feet) + $200,124
50ft Deep: Capital Cost = ($63 × area in square feet) + $197,073

Silt/Silty-Clay

10ft Deep: Capital Cost = ($629 × area in square feet) + $175,807
30ft Deep: Capital Cost = ($249 × area in square feet) + $185,439
50ft Deep: Capital Cost = ($83 × area in square feet) + $181,440

Ex-Situ Solidification/Stabilization

Application

The costs are based on volumes of sludge, soil, or incinerator ash of 1,000 to 100,000 cubic yards (cy).

In solidification, a reagent is added to transform a sludge, sediment, or soil into a solid form. Solidification, immobilizes the contaminants within a crystalline structure of the solidified material, thus reducing the contaminant leaching potential. In stabilization, a reagent is added to transform the material so that the hazardous constituents are in their least mobile or toxic form.

Stabilization/solidification is used to solidify or immobilize inorganic compounds, volatile and non-volatile metals, PCBs (depending on concentration), asbestos, and radionuclides. Solidification/stabilization may have limited effectiveness against semi-volatile organic compounds (SVOCs) and pesticides and no expected effectiveness against volatile organic compounds (VOCs).

Assumptions and Limitations

1. Waste/contaminated soil does not have a high moisture content or high concentration of organics or other miscellaneous materials (i.e., oil and grease, loess, peat, highly plastic clays) that may inhibit the effectiveness of this technology.

2. The personal protection safety level for on-site staff is Level C.

3. Handling of non-homogenous materials (i.e., rock, debris, etc.) may require sorting or crushing. These costs are not included in this estimate.

4. Soils or solid wastes have a maximum moisture content of 30 percent, the cost estimates assume an initial moisture content of 15 percent. Sludges are assumed to have a moisture content between 30 and 70 percent and is capable of being pumped or dredged, the cost estimates assume an initial moisture content of 60 percent for sludges. The cost estimates assume an initial moisture content of 20 percent for incinerator ashes.

5. Solids are assumed to have a density of 100 pounds per cubic foot (pcf). Sludges are assumed to have a density of 80 pcf. Incinerator ash is assumed to have a density of 52 pcf.

6. Costs include additives based on RACER defaults. These defaults are provided by RACER only to estimate the additive costs. Actual additives and mix ratios are highly waste-specific and should be determined by bench and pilot testing. The RACER default mix ratios for each waste type are presented in the following table.

	Incinerator Ash	Solids/Soils	Sludges
Cement : Waste	1.000:1	0.150:1	0.400:1
Water : Cement	0.400:1	0.400:1	0.000:1
Proprietary Chemicals : Waste	0.001:1	0.010:1	0.100:1

7. Solidification/stabilization will increase the volume of waste present. Costs do not include disposal or backfill of treated material. The following table presents the waste volumes after treatment based on the default mix ratio used to generate the cost estimates.

Initial Waste Volume (cy)	Waste Volume After Treatment (cy)		
	Incinerator Ash	Solids/Soils	Sludges
500	605	635	669
1,000	1,210	1,270	1,337
5,000	6,049	6,349	6,685
10,000	12,097	12,697	13,371
15,000	18,146	19,046	20,056
20,000	24,194	25,395	26,742
30,000	36,292	38,092	40,113
50,000	60,486	63,487	66,855
100,000	120,970	126,970	133,700

8. Costs for post treatment groundwater monitoring or waste sampling are not included.

9. The cost equations are not valid for waste volumes less than 1,000 cy. If the cost equation is used to estimate costs for waste volumes under 1,000 cy the cost estimates will be over estimated by 30 to 60 percent.

10. Four batch plant sizes are used in the cost estimates: 2 cy, 5 cy, 10 cy, and 15 cy. The size of the batch plant affects the duration of the site work and the associated labor hours expended for operation of treatment system. The batch plant sizes assumed are provided in the cost table below.

11. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 3 to 6% of the capital costs.

Costs - 2004$

Waste Volume (cy)	**Assumed Batch Plant Size**	**Ex-Situ Solidification of Incinerator Ash**	**Ex-Situ Solidification of Solids/Soils**	**Ex-Situ Solidification of Sludges**
500	2	$82,000	$93,700	$115,700
1,000	2	$142,900	$160,200	$198,800
5,000	5	$355,600	$527,100	$760,200
10,000	10	$516,600	$918,100	$1,424,100
15,000	10	$757,000	$1,362,500	$2,124,100
20,000	10	$1,006,600	$1,811,500	$2,821,100
30,000	15	$1,308,400	$2,577,500	$4,153,200
50,000	15	$2,171,700	$4,288,200	$6,863,500
100,000	15	$4,317,100	$8,509,500	$13,616,000

Cost Equations - 2004$

Incinerator Ash:
Capital Cost = ($42 × volume in cubic yards) + $104,672

Solids and Soils:
Capital Cost = ($84 × volume in cubic yards) + $82,767

Sludges:
Capital Cost = ($136 × volume in cubic yards) + $77,989

Soil Washing

Application

The cost equations are based on a waste quantity range of 5,000 to 100,000 loose cubic yards (cy) of soil. Three cost equations were developed for soil washing plants with capacities of 25, 50, and 100 tons per hour (TPH). Choice of plant capacity depends on the quantity of waste produced per hour. The 100 ton per hour plant is least expensive per ton of soil for large soil quantities.

Soil washing is applicable for media contaminated with volatile organic compounds (VOCs), such as TCE, benzene, toluene, and some fuels. Approximately 90 to 99 percent of VOCs can be removed from contaminated soils by soil washing. Semi-volatile organic compounds (SVOCs) may be removed, but with 40 to 90 percent efficiency. Addition of acids or chelating agents may be required for removal of metals and pesticides, which are more insoluble in water.

Assumptions and Limitations

1. Costs include design, site preparation, mobilization, startup, loading of soils from stockpile, system operation, maintenance, process water, off-site transportation and treatment of process water, surfactant, flocculant, electricity, design, and project management. Costs do not include excessive clearing, utility distribution, analytical sampling, or treatment or disposal of contaminated fines remaining after soil washing.

2. Soil washing plants are assumed to include: vibrating grizzly/screen, rotary feeder module, feed conveyor assembly, trommel washer/deagglomeration unit, cyclone(s), attrition scrubber unit, dense media separation column, dewatering unit, clarifier, filter press, product discharge conveyor, and plant air compressor. All modules are skid-mounted, pre-piped, and pre-wired.

3. The personal protection safety level for on-site staff is Level C.

4. Soil volumes are based on loose cubic yards (e.g., from a stockpile), not in-situ cubic yards. Soil density is assumed to be 1.3 tons per loose cubic yard.

5. Soil washing may not be appropriate for soils with greater than 50 percent clay and silt content because of difficulties in removing contaminants from fine particles. Note that soil washing does not eliminate contaminants – it reduces the volume of contamination into finer fractions for collection and treatment.

6. The total mobilization cost for the soil washing plant is based on an assumed distance from the site of 200 miles. The mobilization cost is also dependent on the number of trailers required to transport the soil washing plant to the site (i.e., 15 trailers for the 25 TPH plant; 20 trailers for the 50 TPH plant; and 30 trailers for the 100 TPH plant).

7. The soil washing plant is assumed to operate 42 weeks per year (80% availability), 5 days per week, 6 hours per day, with 2 hours per day of downtime.

8. The washing agent depends on the type, concentration, and partitioning coefficient of the contaminant. Four pounds of surfactant per ton of feed material is assumed.

9. Feed soils containing more than 35 percent fines by weight are generally poor candidates for soil washing. Typical percent fines for sand and gravel is 4, for sand is 10, and for mixed sandy, silty, clayey soil is 13. Costs are based on mixed sandy, silty, and clayey soil.

10. Water entering the soil washing plant and process water should be at least 55°F. Costs are based on water temperatures of 55°F. Heating would be necessary for water at a lower temperature.

11. Soil washing generally requires 1,000 to 2,000 gallons of water per ton of soil treated. Most of the water can be treated and recycled, leaving the quantity of fresh water needed at 50 to 100 gallons per ton of soil.

12. Soil washing is not appropriate for soils with high explosive potential.

13. Mixtures of contaminants may be difficult to remove by soil washing.

14. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 3 to 4% of the capital costs.

Cost - 2004$

Soil Volume (LCY)	Soil Washing Cost Using a 25 TPH Plant	Soil Washing Cost Using a 50 TPH Plant	Soil Washing Cost Using a 100 TPH Plant
5,000	$1,285,800	$1,156,000	$1,241,300
10,000	$1,807,200	$1,590,300	$1,448,000
25,000	$3,371,600	$2,585,800	$2,265,000
50,000	$5,952,500	$4,450,500	$3,500,000
75,000	$8,548,000	$6,132,400	$4,734,000
100,000	$11,219,800	$7,989,700	$6,133,000

Costs Equations - 2004$

Cost for 25 tons/hour plant = ($104 × LCY) + $757,099

Cost for 50 tons/hour plant = ($71 × LCY) + $830,827

Cost for 100 tons/hour plant = ($51 × LCY) + $957,959

LCY = Loose cubic yards

Soil Vapor Extraction

<u>Application</u>

The costs are based on areas of 5,000 to 500,000 square feet (sf) and depths of 10 to 30 feet below ground surface. Four sets of costs were developed for soil types of gravel/gravel-sand, sand/gravelly sand, sand-silt/sand-clay, and silt/silty-clay.

Soil vapor extraction (SVE) is an in-situ process for removal of volatile organic compounds (VOCs) from unsaturated soil. This process will not remove heavy oils, metals, PCBs, or dioxins.

<u>Assumptions and Limitations</u>

1. Costs are based on vertical wells.

2. Soil vapor extraction is generally not applicable for soil with high clay or moisture content.

3. Costs include vertical vapor extraction wells, air blowers, above-ground piping, two disposable GAC units in series for off-gas treatment, electricity, carbon disposal and replacement, labor, system maintenance, air sampling and analysis for tentative ID compounds (EPA 30/5040/8260), design, project management, and permitting. Costs include markups that decrease with the increasing scale of the project. Costs do not include utility distribution, fencing, monitoring wells, treatment or disposal of drill cuttings, or a building to house the system. Additional permitting costs may be required in some locations.

4. Costs include off-gas treatment. In some locations, direct discharge of off-gas with low vapor concentrations may be allowed.

5. Costs are based on above-ground piping. If below-ground piping is necessary due to site use, significant additional capital costs may be incurred.

6. Costs are based on contaminated soil depths up to 30 feet, which is assumed to be a typical maximum depth of unsaturated soil. Capital costs will increase if contamination extends to greater depths. O&M costs do not change appreciably with depth. Note that soil vapor extraction is not appropriate in saturated soils below the water table. The soil formation is assumed to be unconsolidated.

7. Well spacing is assumed to be 100 feet for gravel/gravel-sand, 50 feet for sand/gravelly sand, 35 feet for sand-silt/sand-clay, and 22 feet for silt/silty-clay.

8. Vapor flow rates per well are assumed to be 150 cubic feet per minute (cfm) for

gravel/gravel-sand, 35 cfm for sand/gravelly sand, 15 cfm for sand-silt/sand-clay, and 6 cfm for silt/silty-clay.

9. Regression equations were developed for capital and O&M costs as a function of area and depth. However, the resulting cost equations were not accurate. Therefore, only specific costs for various areas and depths are presented.

10. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 7 to 14% of the capital costs.

Costs - 2004$

Area (ft^2)	Depth (ft)	SVE Costs in Gravel/ Gravel-Sand	SVE Costs in Sand/ Gravelly-Sand	SVE Costs in Sand-Silt/ Sand-Clay	SVE Costs in Silt/Silty-Clay
Capital Costs Year 2004$					
5,000	10	$23,000	$26,900	$29,900	$45,400
6,000	20	$24,100	$36,000	$43,600	$68,200
7,000	30	$25,000	$39,700	$55,100	$98,300
50,000	10	$150,700	$152,200	$203,000	$356,500
60,000	20	$161,100	$235,500	$290,200	$559,600
70,000	30	$173,600	$284,500	$429,000	$847,800
500,000	10	$876,400	$1,193,100	$1,673,000	$3,153,800
600,000	20	$1,105,400	$1,777,000	$2,600,700	$5,323,700
700,000	30	$1,415,800	$2,368,200	$3,710,500	$7,883,500
O&M Costs Per Year 2004$					
5,000	10	$46,900	$44,200	$45,000	$45,400
6,000	20	$46,900	$45,200	$47,500	$47,800
7,000	30	$47,000	$48,600	$50,000	$51,300
50,000	10	$92,300	$92,200	$92,800	$97,200
60,000	20	$98,000	$95,700	$101,300	$106,300
70,000	30	$103,300	$102,700	$106,300	$114,500
500,000	10	$397,100	$370,400	$354,500	$412,300
600,000	20	$447,300	$448,700	$428,000	$509,900
700,000	30	$520,400	$520,500	$491,200	$609,100

Groundwater Monitoring Well Installation

Application

Applicable for total well depths from 15 to 210 feet. Screen length does not have a variable impact on cost; therefore, the equation does not consider screen length. Costs were developed for both steel and PVC well casings. Four cost scenarios were developed: PVC cased wells less than 100 feet, PVC cased wells greater than 100 feet, steel cased wells less than 100 feet, and steel cased wells greater than 100 feet.

Assumptions and Limitations

1. Well installation is assumed to be within a single unconfined aquifer.

2. Two types of drilling was assumed for well construction. For wells less than 100 feet in depth, an 8-inch diameter hollow stem auger is assumed. For wells greater than 100 feet in depth, an 8-inch diameter bore hole with an air rotary drill is assumed.

3. A two- or four-inch diameter well casing is assumed to be installed in an unconsolidated aquifer. Well casing diameter is dependent on depth of well. Wells constructed to a depth of 100 feet or less will used two inch diameter well casing; for depths greater than 100 feet, wells will be constructed using four inch diameter well casing.

4. A screen length of 10 feet is assumed for all wells. Longer or shorter screen lengths does not effect the well construction cost.

5. Cost include four guard posts per well and a two-foot by two-foot by four-inch thick concrete pad. Each guard posts is 5-foot tall, concrete-filled cast iron.

6. Soil cuttings from the drill bit (drill cuttings) are assumed to be drummed until analytical results and disposal options have been evaluated. Disposal costs are not included.

7. Costs include split-spoon sampling but do not include chemical analysis. Split-spoon samples are collected at five-foot intervals during borehole advancement. Samples are assumed to be screened with an organic vapor analyzer (OVA) for volatile organics.

8. Costs assume installation in an unpaved area. In areas of paving, additional coring or concrete cutting costs will be incurred.

9. Costs were created on the assumption that five wells would be installed. Costs presented below are a per well cost.

10. Capital costs include well components, drilling equipment, field screening equipment and labor, and well development.

11. No operation and maintenance costs are provided.

12. Sampling and analysis costs for groundwater are not included, see groundwater monitoring and analytical cost estimates.

13. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment (PPE), travel and per diem, permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup, profit, and design. RACER design factor are not included since this factor is dependent on the final corrective action (e.g., on-site or off-site treatment or disposal) and typically do not apply to investigation activities. Design factors typically range from 3.5 to 15%, depending on the management method and total remedial action cost.

<u>Costs</u> - 2004$

Depth to Groundwater (feet)	**Total Well Depth (feet)**	**Steel Cased Monitoring Well Cost per Well**	**PVC Cased Monitoring Well Cost per Well**
5	15	$3,739	$3,411
20	30	$5,575	$4,990
50	60	$8,802	$7,961
100	110	$24,056	$20,696
200	210	$42,861	$36,577

<u>Cost Equations</u> - 2004$

Steel Cased Wells

Well depth <100 feet — Total Cost = ($111.81 × D) + $2,125.70

Well depth >100 feet — Total Cost = ($188.05 × D) + $3,370.70

PVC Cased Wells

Well depth <100 feet — Total Cost = ($100.81 × D) + $1,925.90

Well depth >100 feet — Total Cost = ($158.81 × D) + $3,226.90

D = Total well depth in feet.

Groundwater Monitoring and Analytical

Application

Applicable for total well depths from 15 to 500 feet. Costs are dependent on the number of wells that can be sampled per day and on the well depth.

Assumptions and Limitations

1. A sampling crew of 2 field technicians is assumed.

2. The distance to the site is assumed to be 30 miles each way.

3. The defaults used in RACER for samples collected on a per day basis were assumed. The assumptions are presented in the following table.

Depth to Groundwater Range (ft)	Samples per Day	Assumed Groundwater Depth Representing Range
0-24	8	5 ft and 20 ft
25-50	6	50 ft
51-100	4	100 ft
101-500	3	200 ft

4. Analytical costs are presented on a per sample basis for water analysis. Multiple samples collected from a well does not increase the sampling costs for the well. That is, each well sampling cost is sufficient for any number of samples collected for laboratory analysis. For every 10 laboratory analysis sample collected or fraction thereof, a duplicate sample laboratory analysis is recommended for quality assurance purposes. RACER provides templates for typical analyses for types of contamination. These are provided in the following list.

Fuel Contamination

Total dissolved solids by EPA method 160.1
Total suspended soils by EPA method 160.2
Total petroleum hydrocarbons by method SW8015B
Polynuclear aromatic hydrocarbons (PAH) by method SW3510C/SW8310
Ethylene dibromide (EDB) by method EPA 504.1
Benzene, toluene, ethyl-benzene, xylene (BTEX), methyl tertiary butyl ether (MTBE), and total volatile petroleum hydrocarbons (TVPH) by method EPA 8021B/8015B

VOCs Contamination

Purgeable halocarbons by method SW5030B/SW8021B halocarbons

Purgeable aromatics by method SW5030B/SW8021B aromatics

SVOCs Contamination

Base neutral & acid extractable organics by method SW3510C/SW8270C

Pesticides Contamination

Pesticides and polychlorinated biphenyls (PCBs) by method SW3510C/SW8081/8082

Chlorinated phenoxy herbicides by method SW3510C/SW8151A

Metals Contamination

Total dissolved solids by EPA method 160.1

Total suspended soils by EPA method 160.2

Target analyte list metals (priority pollutant metals plus Al, Ba, Ca, Co, Fe, Mg, K, Na, V) by EPA method 6010/7000s

5. No monitoring report or reporting is assumed.

6. Sampling includes the following materials/equipment on a per well basis: disposable sampling personal protection equipment (PPE) (e.g., gloves), decontamination materials (e.g., alcohol and soap sprays), and a disposal polyethylene bailer.

7. Equipment used for well development and water quality parameter testing is rented on a weekly basis. For sampling groups of wells that require less than a week, the per well cost will increase as presented in the cost table. In general, equipment rental costs can be assumed to be prorated for the length of use (i.e, renting on a weekly basis is actually billed on a daily basis). Costs were developed on a weekly basis, but the per well sampling cost can be assumed to be accurate for shorter sampling time frames (i.e., sampling of 5 wells in one day has the same per well sampling cost as sampling 25 wells in a week [5 wells × 5 days]). For periods greater than one week, costs for each full week would be added to the partial week costs. That is, for a groundwater sampling event requiring seven days (one week and two days) sampling five wells a day, the costs incurred will include one full week of rental and two days of a prorated weekly rate.

8. Field water quality testing parameters are pH, dissolved oxygen, conductivity, and temperature.

9. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], travel and per diem, permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup, profit, and design. RACER design factor are not included since this factor is dependent on the final corrective action (e.g., on-site or off-site treatment or disposal) and typically do not apply to investigation activities. Design factors typically range from 3.5 to 15%, depending on the management method and total remedial action cost.

Costs - 2004$

Sampling Costs

Number of Wells Sampled Weekly	Number of Wells Sampled Daily	Weekly Sampling Cost	Cost per Well Sampled
15	3	$6,500	$433
20	4	$6,673	$334
25	5	$6,845	$274
30	6	$7,018	$234
35	7	$7,191	$205
40	8	$7,364	$184

Example: Sampling of 42 wells at rate of six wells per day (50 foot depth to groundwater).

One week at $7,018 + two days × six wells × $234 per well = $9,826

Analytical Costs

Analytical Constituent and Method	Analytical Cost Per Sample
Total dissolved solids by EPA method 160.1	$16.59
Total suspended soils by EPA method 160.2	$18.91
Total petroleum hydrocarbons by method SW8015B	$104.53
Polynuclear aromatic hydrocarbons (PAH) by method SW3510C/SW8310	$288.08
Ethylene dibromide (EDB) by EPA method 504.1	$119.82
Benzene, toluene, ethyl-benzene, xylene (BTEX), methyl tertiary butyl ether (MTBE), total volatile petroleum hydrocarbons (TVPH) by EPA method 8021B/8015B	$164.63
Purgeable halocarbons by method SW5030B/SW8021B halocarbons	$186.11
Purgeable aromatics by method SW5030B/SW8021B aromatics	$147.87
Base Neutral & Acid Extractable Organics by method SW3510C/SW8270C	$664.89

Analytical Constituent and Method	Analytical Cost Per Sample
Pesticides and polychlorinated biphenyls (PCBs) by method SW3510C/SW8081/8082	$316.13
Chlorinated phenoxy herbicides by method SW3510C/SW8151A	$356.91
TAL metals by EPA method 6010/7000s	$443.09
Nitrogen/nitrite/nitrate by EPA method 300.0/SM4110B	$45.22
Total petroleum hydrocarbons (TPH) by method EPA 418.1	$90.43
Pesticides/PCBs by EPA method 608	$235.18
Base neutral & acid extractable organics by method EPA 625	$533.46
Polynuclear aromatic hydrocarbons (PAHs) by method EPA 610	$164.63
Total petroleum hydrocarbons by method SW8015B	$104.53
Metal analysis, priority 17 metals	$94.33
Metals screen, 25 listed in method SW3005A/SW6010B	$433.39
Lead by method SW3005A/SW7421	$63.74

Cost Equations - 2004$

Per well sampling cost $= \$4{,}578.7 \times (W \times 5)^{-0.8731}$

Total monitoring well sampling cost $= (\$4{,}578.7 \times (W \times 5)^{-0.8731}) \times (T)$

W = number of groundwater wells sampled per day
T = total number of wells sampled
Assume a 5-day, 40-hour work week.

PVC Groundwater Extraction Wells

Application

Costs for groundwater extraction well installation were obtained for four different extraction rates (10, 50, 100, and 200 gallons per minute) and four different depths to groundwater (20, 50, 100, and 150 feet). Costs for extraction wells of 10 gallons per minute (gpm) or less remain relatively constant, therefore, the 10 gpm costs can be used for lower extraction rates.

Assumptions and Limitations

1. Wells are installed in an unconsolidated formation into an unconfined aquifer.

2. The existing ground cover is soil or gravel and not pavement.

3. The thickness of the aquifer is 30 feet (i.e., 30 feet from the top of the static groundwater table to the base of the aquifer). The screen length for each well is 20 feet.

4. No free product is present in the aquifer.

5. Costs include well protection. Well protection consists of 4 concrete posts and an explosion proof receptacle.

6. Costs include 50 feet of PVC above ground piping from each well for connection to the next step in the treatment train.

7. Costs do not include a collection tank.

8. Costs do not include sampling or analytical costs.

9. Costs are not included for management of possible biofouling or inorganic fouling.

10. Costs were derived assuming that two wells are installed and maintained. Costs in the following table are per well.

11. Costs assume that drill cuttings are drummed but does not provide for disposal or sampling of drill cuttings.
12. The personal protection safety level for on-site staff is Level D.

13. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 3.5 to 4.5% of the capital costs.

Costs - 2004$

Extraction Well Flow Rate (gpm)	Depth to Groundwater (feet)	Total Depth of Well (ft)	Casing Diameter (inches)	Capital Per Extraction Well	Annual O&M Per Extraction Well
10	20	40	6	$16,400	$5,300
10	50	70	6	$20,000	$5,500
10	100	120	6	$30,300	$5,800
10	150	170	6	$38,200	$6,100
50	20	40	6	$17,300	$5,900
50	50	70	6	$20,200	$6,300
50	100	120	6	$31,100	$7,200
50	150	170	6	$40,400	$8,000
100	20	40	6	$6,300	$6,600
100	50	70	8	$7,200	$7,500
100	100	120	8	$8,800	$9,100
100	150	170	8	$9,900	$10,200
200	20	40	8	$7,700	$7,900
200	50	70	8	$9,300	$9,600
200	100	120	8	$11,600	$12,000
200	150	170	8	$14,300	$14,700

Costs Equations for PVC Extraction Wells - 2004$

Extraction Rate = 10 GPM

Capital Cost (per well) = ($172 × GW Depth) + $12,436
Annual O&M (per well) = ($6 × GW Depth) + $5,207

Extraction Rate = 50 GPM

Capital Cost (per well) = ($187 × GW Depth) + $12,584
Annual O&M (per well) = ($17 × GW Depth) + $5,513

Extraction Rate = 100 GPM

Capital Cost (per well) = ($289 × GW Depth) + $13,530
Annual O&M (per well) = ($29 × GW Depth) + $6,044

Extraction Rate = 200 GPM

Capital Cost (per well) = ($301 × GW Depth) + $17,346
Annual O&M (per well) = ($52 × GW Depth) + $6,914

GW Depth = Depth to groundwater table in feet

Stainless Steel Groundwater Extraction Wells

Application

Costs for groundwater extraction well installation were obtained for four different extraction rates (10, 50, 100, and 200 gallons per minute) and four different depths to groundwater (20, 50, 100, and 150 feet). Costs for extraction wells of 10 gallons per minute (gpm) or less remain relatively constant, therefore, the 10 gpm costs can be used for lower extraction rates.

Assumptions and Limitations

1. Wells are installed in an unconsolidated formation into an unconfined aquifer.

2. The existing ground cover is soil or gravel and not pavement.

3. The thickness of the aquifer is 30 feet (i.e., 30 feet from the top of the static groundwater table to the base of the aquifer). The screen length for each well is 20 feet.

4. No free product is present in the aquifer.

5. Costs include well protection. Well protection consists of 4 concrete posts and an explosion proof receptacle.

6. Costs assume 50 feet of Stainless Steel above ground piping from each well for connection to the next step in the treatment train.

7. Costs do not include a collection tank.

8. Costs do not include sampling or analytical costs.

9. Costs are not included for management of possible biofouling or inorganic fouling.

10. Costs were derived assuming that two wells are installed and maintained. Costs in the following table are per well.

11. Costs assume that drill cuttings are drummed but does not provide for disposal or sampling of drill cuttings.
12. A safety level D is assumed.

13. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 3.5 to 4% of the capital costs.

Costs - 2004$

Extraction Well Flow Rate (gpm)	Depth to Groundwater (feet)	Total Depth of Well (ft)	Casing Diameter (inches)	Capital Per Extraction Well	Annual O&M Per Extraction Well
10	20	40	6	$29,900	$5,600
10	50	70	6	$41,900	$6,000
10	100	120	6	$68,100	$6,600
10	150	170	6	$88,700	$7,300
50	20	40	6	$31,600	$6,200
50	50	70	6	$43,700	$6,800
50	100	120	6	$70,700	$8,000
50	150	170	6	$92,700	$9,200
100	20	40	6	$35,600	$6,900
100	50	70	8	$55,600	$8,100
100	100	120	8	$95,300	$9,900
100	150	170	8	$128,300	$11,800
200	20	40	8	$44,500	$8,400
200	50	70	8	$61,600	$9,900
200	100	120	8	$99,500	$13,100
200	150	170	8	$134,700	$16,300

Costs Equations for Stainless Steel Extraction Wells - 2004$

Extraction Rate = 10 GPM

Capital Cost (per well) = ($461 × GW Depth) + $20,281
Annual O&M (per well) = ($13 × GW Depth) + $5,363

Extraction Rate = 50 GPM

Capital Cost (per well) = ($480 × GW Depth) + $21,299
Annual O&M (per well) = ($23 × GW Depth) + $5,686

Extraction Rate = 100 GPM

Capital Cost (per well) = ($723 × GW Depth) + $20,868
Annual O&M (per well) = ($37 × GW Depth) + $6,178

Extraction Rate = 200 GPM

Capital Cost (per well) = ($704 × GW Depth) + $28,743
Annual O&M (per well) = ($61 × GW Depth) + $6,976

GW Depth = Depth to groundwater table in feet

Injection Wells

Application

Injection wells can be used for the re-introduction of treated groundwater to an aquifer or aqueous waste disposal. This cost estimate assumes the wells are used to re-introduce treated groundwater into the aquifer. Waste disposal wells are typically greater than 1,000-feet deep, which exceeds the cost estimating capabilities of RACER. Costs for injection well installation were obtained for four different injection rates (5, 10, 30, and 50 gallons per minute) and four different depths to groundwater (20, 50, 100, and 150 feet). Costs are provided for stainless steel wells at all depths and injection rates. In addition, costs were derived assuming the installation of PVC wells for depth to groundwater table of 50 feet and less. PVC wells are generally not considered resilient enough for total depths greater than 85 feet.

The capital costs provided include the costs to install the well (drill rig, well materials, labor, influent piping and concrete surface pad), provide and install a pump, a water level chart recorder, and a flow meter at each well. Annual operation and maintenance (O&M) costs include monthly visits to the site to check the operation of the wells, maintenance materials, labor, and electrical charges for the pump operation.

Assumptions and Limitations

1. The wells are installed in an unconsolidated formation.

2. The thickness of the aquifer is 20 feet (i.e., 20 feet from the top of the static groundwater table to the base of the aquifer) when the depth to the top of the aquifer is less than 100 feet. For groundwater tables located 100 feet or more below the ground surface, the aquifer thickness is assumed to be 40 feet.

3. The wells are installed using hollow stem auger as the drilling method.

4. The casing diameters are based on the injection rates.

5. Extensive site assessments are necessary to characterize the site and obtain regulatory authority prior to installing and operating an injection wells. Costs for a site assessment are not included in this estimate.

6. Costs for permits to install and/or operate the injection well are not included.

7. Costs include 100 feet of PVC or stainless steel above ground piping to each well. The type of piping assumed corresponds with the well construction material.

8. Costs do not include any mixing or feed tanks.

9. Costs do not include any soil or groundwater sampling or analytical costs.

10. Costs are not included for management of possible biofouling or inorganic fouling.

11. Costs were derived assuming that two wells are installed and maintained. Costs in the following table are per well. Costs per well decrease as more wells are installed due to the shared cost of mobilization of the drill rig.

12. Costs assume that drill cuttings are drummed but does not provide for disposal or sampling of drill cuttings.

13. Large concentrations of suspended solids (i.e., greater than 2 parts per million) can plug injection wells. Costs do not include any pretreatment of injected liquids for suspended solids or any other parameters.

14. The personal protection safety level for on-site staff is Level D.

15. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 4 to 4.5% of the capital costs.

Costs - 2004$

Well Material	Injection Rate (gpm)	Depth to Groundwater (feet)	Total Depth of Well (ft)	Casing Diameter (inches)	Capital Per Well	Annual O&M Per Well
PVC	5	20	40	2	$11,500	$5,200
PVC	5	50	70	2	$13,900	$5,200
PVC	10	20	40	2	$11,500	$5,200
PVC	10	50	70	2	$13,900	$5,300
PVC	30	20	40	2	$11,500	$5,500
PVC	30	50	70	2	$13,900	$5,500
PVC	50	20	40	4	$14,800	$5,800
PVC	50	50	70	4	$18,500	$5,900

Well Material	Injection Rate (gpm)	Depth to Groundwater (feet)	Total Depth of Well (ft)	Casing Diameter (inches)	Capital Per Well	Annual O&M Per Well
Steel	5	20	40	2	$15,800	$5,300
Steel	5	50	70	2	$19,000	$5,300
Steel	5	100	140	2	$27,700	$5,500
Steel	5	150	190	2	$33,100	$5,600
Steel	10	20	40	2	$15,800	$5,300
Steel	10	50	70	2	$19,000	$5,400
Steel	10	100	140	2	$27,700	$5,600
Steel	10	150	190	2	$33,100	$5,700
Steel	30	20	40	2	$15,900	$5,600
Steel	30	50	70	2	$19,000	$5,700
Steel	30	100	140	2	$27,700	$5,800
Steel	30	150	190	2	$33,100	$6,000
Steel	50	20	40	4	$24,800	$6,000
Steel	50	50	70	4	$29,300	$6,100
Steel	50	100	140	4	$41,000	$6,400
Steel	50	150	190	4	$48,100	$6,500

<u>Costs Equations for PVC Injection Wells</u>
Injection Rate = 5 GPM
Capital Cost (per well) = ($82 × GW Depth) + $9,804
Annual O&M (per well) = ($2 × GW Depth) + $5,150

Injection Rate = 10 GPM
Capital Cost (per well) = ($82 × GW Depth) + $9,804
Annual O&M (per well) = ($2 × GW Depth) + $5,214

Injection Rate = 30 GPM
Capital Cost (per well) = ($82 × GW Depth) + $9,818
Annual O&M (per well) = ($2 × GW Depth) + $5,467

Injection Rate = 50 GPM

Capital Cost (per well) = (\$125 × GW Depth) + \$12,276
Annual O&M (per well) = (\$2 × GW Depth) + \$5,768

GW Depth = Depth to groundwater table in feet

Costs Equations for Steel Injection Wells

Injection Rate = 5 GPM
Capital Cost (per well) = (\$138 × GW Depth) + \$12,875
Annual O&M (per well) = (\$3 × GW Depth) + \$5,207

Injection Rate = 10 GPM
Capital Cost (per well) = (\$138 × GW Depth) + \$12,875
Annual O&M (per well) = (\$3 × GW Depth) + \$5,271

Injection Rate = 30 GPM
Capital Cost (per well) = (\$138 × GW Depth) + \$12,889
Annual O&M (per well) = (\$3 × GW Depth) + \$5,524

Injection Rate = 50 GPM
Capital Cost (per well) = (\$186 × GW Depth) + \$20,944
Annual O&M (per well) = (\$4 ×GW Depth) + \$5,955

GW Depth = Depth to groundwater table in feet

French Drain

Application

French drains can be used to remove or contain non-aqueous phase liquid (NAPL) or free-phase product that has accumulated on or below the water table. French drains are most appropriate when relatively continuous large pools of NAPL (generally greater than one foot thick) are present. Using a french drain recovery system for LNAPL removal is much more common and effective than for DNAPL removal. RACER cost estimating software's french drain model assumes that the maximum applicable depth to groundwater is 22 feet.

Obtained costs for a french drain designed to remove a 2 foot and a 5 foot layer of LNAPL from the groundwater table. A depth to groundwater of 20 feet is assumed. Costs do not vary significantly depending on the depth to groundwater (i.e., the costs to install and operate a french drain when the groundwater table is 10 feet below the ground surface is not significantly less than when the groundwater table is 20 feet below the ground surface). Therefore, costs are provided for a 20 foot depth to groundwater only but are applicable to any depth up to 22 feet below the ground surface. Assumed trench lengths include 100, 200, 500, 700, and 1,000 feet.

Assumptions and Limitations

1. Costs include trenching, and furnishing and installing a geotextile liner, perforated PVC piping, sump(s), backfill, a dual phase product recovery skimmer/pump, product holding tank, groundwater holding tank, and carbon steel transfer piping.

2. The soil is silty sand with a permeability of approximately 0.0142 inches per hour.

3. Existing and replacement cover is soil or gravel.

4. The trench is three-feet wide.

5. Costs for product and groundwater treatment and disposal are not included. Costs for these items vary depending on contaminant type, volume, and available disposal options.

6. No sampling or analytical costs are included.

7. The personal protection safety level for on-site staff is Level D.
8. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 3.5 to 4% of the capital costs.

Costs - 2004$

Product Thickness (Feet)	Length of Trench (Feet)	Capital Cost	Annual O&M
2	100	$74,500	$5,400
2	200	$83,100	$6,300
2	500	$112,800	$8,500
2	700	$132,800	$9,700
2	1,000	$159,600	$11,500
5	100	$76,500	$5,400
5	200	$87,100	$6,400
5	500	$122,700	$8,700
5	700	$146,600	$10,000
5	1,000	$179,100	$12,000

Costs Equations - 2004$

Product Thickness = 2 Feet

Capital Cost = ($96 × L) + $64,742

Annual O&M Cost = ($7 × L) + $4,917

Product Thickness = 5 Feet

Capital Cost = ($115 × L) + $64,873

Annual O&M Cost = ($7 × L) + $4,917

L = Length of Drain in Feet

Slurry Wall

Application

A slurry wall is a vertical subsurface barrier used to contain, capture, and/or redirect groundwater flow in the vicinity of a contaminated site. The cost equations were developed based on slurry wall lengths of 100, 200, 500, 700, and 1,000 feet. Costs were developed for three depths: 20, 50, and 80 feet. Each depth has a different cost equation due to different excavation methods required.

Slurry walls are applicable to contain contaminated groundwater, divert contaminated groundwater from drinking water sources, divert uncontaminated groundwater, and/or provide a barrier for a groundwater treatment system. Slurry walls are typically placed at depths from 20 to 80 feet and are generally 2 to 4 feet thick.

Assumptions and Limitations

1. The slurry wall is a 3-foot thick soil-bentonite wall.

2. Costs are applicable when the soil being excavated is silt/silty-clay mixture, sand/gravelly sand mixture, or sand-silt/sand-clay mixture.

3. The depth of the slurry wall determines the type of equipment used to excavate the trench. For depths to 25 feet, a hydraulic excavator is used. For depths between 25 and 75 feet, a hydraulic excavator with an extension boom is used. For depths between 75 and 120 feet, a dragline is used.

4. The slurry wall is keyed 2.5 feet into bedrock.

5. A working area equivalent to the length of the wall with a 75-foot width is needed for slurry and backfill mixing and storage. The working area will need to be graded and compacted prior to use.

6. Approximately 35% of the excavated material will have insufficient fines content (i.e., < 30%) and will be replaced by borrow material.

7. The slurry wall construction will occur outside of the contaminated zone, if present. Therefore, excavated material is not contaminated.

8. Upon completion of the backfilling operation, the slurry wall is assumed to be covered with a vegetative cap using on-site top soil. The soil cap is assumed to be 6 inches thick and 13 feet wide (i.e., cover the 3 feet of the wall and 5 feet on either side). This soil cap will prevent the slurry wall from drying and cracking.
9. Annual O&M costs include labor to visually inspect along the top of the slurry wall and

remove any growth (i.e., trees or shrubs) that could damage the wall's integrity. Therefore, the annual O&M costs vary only with respect to the length of the wall and do not change with varying depths of the wall.

10. Costs for extraction wells and/or capping, which are often used in conjunction with slurry walls, are not included.

11. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 5.5 to 10% of the capital costs.

Costs - 2004$

Depth of Wall (Ft)	**Length of Wall (Ft)**	**Capital Cost**	**Annual O&M**
20	100	$29,800	$2,400
20	200	$57,000	$3,900
20	500	$114,300	$7,500
20	700	$153,300	$9,300
20	1,000	$206,600	$11,800
50	100	$57,400	$2,400
50	200	$110,800	$3,900
50	500	$260,900	$7,500
50	700	$326,800	$9,300
50	1,000	$423,100	$11,800
80	100	$101,300	$2,400
80	200	$195,000	$3,900
80	500	$476,000	$7,500
80	700	$660,100	$9,300
80	1,000	$843,500	$11,800

Costs Equations - 2004$

Capital Cost for 20 feet deep wall = $(\$676 \times L)^{0.83}$

Capital Cost for 50 feet deep wall = $(\$1{,}046 \times L)^{0.88}$

Capital Cost for 80 feet deep wall = $(\$1{,}362 \times L)^{0.94}$

Annual O&M Cost = $(\$104 \times L)^{0.69}$

L = Length of Wall in Feet

Groundwater Remediation: Air Stripping

Application

Costs are valid for packed tower air strippers with system flow rates of 10 to 2,250 gallons per minute (gpm). Air stripping is effective with volatile organics compounds (VOCs), such as chlorinated solvents (e.g., tetrachloroehtylene [TCE]) and petroleum constituents (e.g., benzene and toluene). RACER categorizes volatile constituents as described in the following table:

Volatility	**Henry's Law Constant ($atm \times m^3/mole$)**
Very High	>0.028
High	0.0145-0.027
Moderate	0.0012-0.144
Low	<0.0012

Assumptions and Limitations

1. The technology is typically used in conjunction with other equipment or systems. A typical treatment train utilizing air stripping includes groundwater recovery, influent water pretreatment, air stripping, off-gas treatment (depending on volatility and concentration), post treatment for effluent (i.e., a polishing step), influent and effluent sampling, and chemical analysis.

2. The influent flow was assumed to contain a moderately volatile organic compound, for which air stripping has an assumed 80% removal efficiency.

3. The air stripping system is configured in a single packed tower. Systems can be constructed with a one, two, or three towers in series.

4. Costs were not included for a housing building or building heat.

5. Influent and effluent sampling and chemical analysis costs are not included.

6. Capital costs include furnishing and installing the packed tower air stripper, electrical controls, pump, piping, concrete slab, blower, packing, and a sump. Annual operation and maintenance costs include electricity, labor, annual reconditioning of the packing, and annual maintenance materials. Labor costs include a monthly visit to the site for monitoring of the system by a technician.

7. Costs were developed for ten flow rates (10, 30, 45, 100, 150, 300, 500, 700, 1,400, and

2,250 gpm). The capital cost equations tend to overestimate costs by up to 20% for smaller system sizes (i.e., systems less than 30 gpm). The opposite is true for O&M cost equation; the O&M cost equation will underestimate costs by up to 30% for smaller system sizes (i.e., systems less than 30 gpm).

8. Air emission treatment costs are not included in these estimates. For some systems with high efficiencies or relatively high VOC contamination levels, air emissions may exceed local, state, or federal limits. An off gas emission treatment system will be necessary if this occurs.

9. Costs for permits associated with air emissions or water discharges are not included.

10. Energy costs for equipment operation represents the majority of the annual O&M costs. Fluctuations in energy costs due to outside circumstances or bulk purchases may increase or reduce the overall operation costs. RACER estimates a electrical charge cost of $0.07 per kilowatt hour (kwh).

11. RACER includes markup factors to include general conditions costs (e.g., supervision of labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment (PPE), permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 5 to 6.5% of the capital costs.

<u>Costs</u> - 2004$

System Flow Through (gpm)	**Capital Cost**	**Operation and Maintenance ($/year)**
10	$47,418	$17,443
30	$56,172	$30,082
45	$60,789	$39,718
100	$79,162	$70,714
150	$98,416	$97,187
300	$112,136	$175,440
500	$138,561	$280,338
700	$162,170	$380,124
1,400	$214,527	$737,482
2,250	$265,278	$1,169,584

Cost Equations - 2004$

Capital cost	$= \$18,850 \times (S)^{0.3288}$
Annual O&M cost	$= \$512.96 \times (S) + \$18,454$

S = system design flow rate in gpm

Groundwater Remediation: Granular Activated Carbon Absorption

Application

Costs are valid for granular activated carbon (GAC) system flow rates of 1 to 2,000 gallons per minute (gpm). GAC systems are typically effective with organics and can be used as primary or secondary removal technologies (i.e., as initial removal or polishing steps). As a primary removal technology, however, the carbon replacement costs for GAC systems are generally prohibitive for relatively contaminated waste streams. For example, if contamination removed from the waste stream by GAC system requires carbon replacement at intervals greater than once every two months, the use of a GAC system as a primary removal technology will likely be more expensive than comparable removal technologies (e.g., air stripping).

Assumptions and Limitations

1. The technology is typically used in conjunction with other equipment or systems. A typical treatment train utilizing GAC includes groundwater recovery, sedimentation, filtration, metals removal, oil removal, air stripping, pH adjustment, GAC, influent and effluent sampling, and chemical analysis.

2. Costs were developed for 13 flow rates (1, 5, 15, 25, 50, 75, 100, 200, 300, 500, 1,000, 1,500, and 2,000 gpm). No cost equations for the costs were developed for GAC systems since the estimated costs did not present a recognizable regression trend.

3. For flow rates less than or equal to 200 gpm, a single permanent adsorber system was used. For flow rates greater than 200 gpm, a dual bed carbon absorption system was used. Both systems used two adsorption units in series in each adsorber system (i.e., all systems have redundancy).

4. Carbon replacement is assumed to occur every three months.

5. Capital costs include furnishing and installing carbon adsorbers, transfer pump with piping, and a concrete slab. Annual operation and maintenance costs include electricity, labor, carbon removal and regeneration fee, replacement carbon, and annual maintenance materials. Labor costs include a monthly visit to the site for monitoring of the system by a technician.

6. Influent and effluent sampling and chemical analysis costs are not included.

7. Costs were not included for a housing building or building heat.

8. Costs for permits associated with air emissions or water discharges are not included.

9. RACER includes markup factors to include general conditions costs (e.g., supervision of

labor, temporary facilities including job and storage trailers and portable toilets, temporary plants, personal protective equipment [PPE], permits, sales and labor taxes, insurance, and bonds), overhead, prime and sub contractor markup and profit. RACER design factors are also included, ranging from 4 to 7% of the capital costs.

Costs - 2004$

System Flow Through (gpm)	Capital Cost	Operation and Maintenance ($/year)
1	$11,248	$5,545
5	$11,248	$5,545
15	$11,309	$23,101
25	$12,980	$33,868
50	$25,374	$58,754
75	$35,526	$81,817
100	$43,193	$105,355
200	$61,834	$194,952
300	$302,085	$234,952
500	$448,056	$373,131
1,000	$871,513	$722,851
1,500	$1,303,433	$1,070,146
2,000	$1,309,796	$1,407,600

Cost Equations - 2004$

No cost equations developed

Compendium of EPA Cleanup Program Remediation Documents with Information on Cost Estimating

EPA has developed a series of guidance and policy documents on cost estimating at sites regulated by EPA cleanup programs. This compendium provides a listing of EPA documents containing information on estimating costs at Superfund sites, Resource Conservation and Recovery Act (RCRA) Corrective Action sites, and Underground Storage Tank (UST) remediation sites. Please note that, except where specifically noted, all documents listed may be obtained from OSWER's Superfund web site and are publicly available. All links were active and accurate as of April 15, 2004.

Superfund Remedy Selection

Rules of Thumb for Superfund Remedy Selection" (August 1997). Describes key principles, expectations, and best practices (based on program experience) that should be considered during the Superfund remedy selection process. Three major policy areas are covered: human health risk; remedial alternatives; and ground water. [27 p.]. EPA 540/R/97-013, OSWER 9355.0-69, NTIS: PB97-963301INX

http://www.epa.gov/superfund/resources/rules/rulesthm.pdf

"A Guide to Principal Threat and Low Level Threat Wastes" (November 1991). Explains considerations of categorizing waste for which treatment or containment will generally be suitable. Provides definitions, examples, and ROD documentation requirements for waste that constitutes a principal or low level threat. [4 p.] OSWER 9380.3-06FS, NTIS: PB92-963345INZ

http://www.epa.gov/superfund/resources/gwdocs/threat.pdf

"The Role of Cost in the Superfund Remedy Selection Process" (September 1996). Summarizes the current role of cost in the Superfund program as established by CERCLA, the NCP, and current guidance. [8 p.] EPA 540-F-96-018, OSWER 9200.3-23FS, NTIS: PB96-963245

http://www.epa.gov/superfund/resources/cost_dir/cost_dir.pdf

"Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (April 1991). Provides guidance on how to use the baseline risk assessment to make risk management decisions such as determining whether remedial action under CERCLA Sections 104 or 106 is necessary. Clarifies the use of the baseline risk assessment in selecting appropriate remedies under CERCLA Section 121, promotes consistency in preparing site-specific risk assessments, and helps ensure that appropriate documentation from the baseline risk assessment is included in Superfund remedy selection documents. [10 p.] OSWER 9355.0-30.

http://www.epa.gov/superfund/programs/risk/baseline.pdf

"Selecting a Combined Response Action Approach for Noncontiguous CERCLA Facilities to Expedite Cleanups" (April 1992). Section 104(d)(4) of CERCLA allows EPA to treat noncontiguous facilities as one site for the purpose of taking actions when the facilities are related geographically, or on the basis of the threat to human health or the environment. This fact sheet provides a series of questions and answers designed to explain the factors, benefits, and limitations associated with taking a "combined" response action approach. [6 p.] OSWER 9355.3-14FS

http://www.epa.gov/superfund/resources/remedy/pdf/93-55314fs.pdf

"Coordination between RCRA Corrective Action and Closure and CERCLA Site Activities" (September 1996). Describes approaches for overcoming the three areas that often pose coordination difficulties at contaminated sites: acceptance of decisions made by other remedial programs, deferral of activities and coordination among RCRA, and CERCLA and state/tribal cleanup programs.

http://www.epa.gov/swerffrr/documents/924memo.htm

Superfund Remedy Cost Estimating

"A Guide to Developing and Documenting Cost Estimates During the Feasibility Study"[1] (July 2000). Addresses cost estimates of remedial alternatives developed during the remedial investigation/feasibility study process. The goals of this guidance are to improve the consistency, completeness, and accuracy of cost estimates developed to support the Superfund remedy selection process. The document presents clear procedures and expectations, a checklist of cost elements, and example formats. This guide is designed to help those with varying levels of cost estimating expertise, including: cost estimators, design engineers, technical support contractors, remedial project managers, and program managers. [108 p.]. OSWER 9355.0-75

Main Guidance	http://www.epa.gov/superfund/resources/remedy/pdf/finaldoc.pdf
App. A - Web Resources	http://www.epa.gov/superfund/resources/remedy/pdf/app-a.pdf
App. B-Cost Adjustment Factors	http://www.epa.gov/superfund/resources/remedy/pdf/app-b.pdf
App. C-Cost Templates	http://www.epa.gov/superfund/resources/remedy/pdf/app-c.pdf
D-Glossary	http://www.epa.gov/superfund/resources/remedy/pdf/app-d.pdf

"Scoper's Notes - An RI/FS Costing Guide. Bringing in a Quality RI/FS on Time and Within Budget"[2] (February 1990). Outlines the tasks and sub-tasks typically conducted as part of a Remedial Investigation/Feasibility Study (RI/FS), and presents a strategy based on site complexity and task difficulty for estimating a project's cost. Provides cost guidelines which can be used to estimate funding needs in advance of issuing work assignments and evaluating contractor proposals. [29 p.]. EPA 540/G-90/002, NTIS: PB90-258369INX

http://www.epa.gov/superfund/resources/remedy/pdf/540g-90002.pdf

"Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis" (June 25, 1993). Revises EPA policy regarding the discount rate that should be used in estimating the present worth value for potential remediation alternatives in the remedial investigation/feasibility study. Explains that EPA policy has been changed to 7% in order to be consistent with the 1992 revisions to Circular A-94, issued by the Office of Management and Budget. [2 p.] OSWER 9355.3-20.

http://www.epa.gov/superfund/resources/remedy/pdf/93-55320.pdf

RCRA/UST Remediation Cost Documents

"Making Solid (Waste) Decisions with Full Cost Accounting" (June 1996). This document provides decision makers with basic information on how to use full cost accounting to identify and calculate the costs for managing municipal solid waste (MSW). The primer will help local officials understand the direct and indirect costs of MSW management as well as past and expected future costs. EPA 530-K-96-001.

http://www.epa.gov/epaoswer/non-hw/muncpl/fullcost/docs/primer.pdf

“Transmittal of Interim Guidance on Financial Responsibility for Facilities Subject to RCRA Corrective Action” (September 2003). This document provides EPA and state environmental agency staff with guidance on implementing financial assurance at RCRA Corrective Action sites to ensure that site owner/operators have secured financial assurance sufficient to demonstrate that they can assume full financial responsibility to cover remediation/closure costs.

http://www.epa.gov/compliance/resources/policies/cleanup/rcra/interim-fin-assur-cor-act.pdf

“Revised Draft Report on Analysis of Cost Estimates for Closure and Post-Closure” (October 1996). This document provides an analysis of the accuracy of cost estimates prepared for closure and post-closure care of RCRA-permitted hazardous waste treatment, storage and disposal units to determine how frequently/to what extent cost estimates prepared by owner/operators differed from cost estimates developed using an EPA model. The report also focused on the issue of whether correlations could be made between the timing and severity of enforcement actions undertaken at a facility and the closure of that facility.

http://www.epa.gov/epaoswer/hazwaste/permit/perm-docket/cost_est.pdf

“Estimating Costs for the Economic Benefits of RCRA Noncompliance” (December 1997). This document is intended to help EPA Regional offices develop consistent cost estimates for RCRA CA civil actions. Specifically, Chapter 10 of the document provides information on developing general and site-specific costs for closure and post-closure care at RCRA-permitted treatment, storage and disposal facilities.

http://www.epa.gov/epaoswer/hazwaste/gener/f006/s0004.pdf

“Cost Estimating Tools and Resources for Addressing Sites Under the Brownfields Initiative” April 1999. This guide is intended to provide decision makers with information on the cost-estimating process, including summaries of different types of cost estimates. The guide shows how cost estimates are developed and provides examples and descriptions of cost estimating sources, databases and models. USEPA – ORD –EPA/625/R-99/001

http://www.p2-pays.org/ref/11/10324.pdf

Not Available On-Line

"Cost Guide for Remediation Equipment at UST Sites". This guidance document provides information on the costs for certain equipment that is used during the cleanup of petroleum hydrocarbons that are released from USTs to soil and groundwater. It is intended to help state regulators and private firms estimate the cost of equipment used during the course of a cleanup. The document includes a glossary of technical terms.

AVAILABILITY: Hotline
EPA ORDER NO.: 510-R-93-004

"Resources for Preparing Independent Government Estimates for Remedial Contracting Work Assignments" This memorandum provides information regarding the availability of tools, databases, and assistance for developing independent government estimates of the cost of work for remedial work assignments performed by contractors.

AVAILABILITY: NTIS
NTIS ORDER NO.: PB93-963 267