

Cost Estimating of the Closure/ Post-Closure Phase

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The U.S. Department of Energy (DOE) is beginning major environmental restoration projects of both active and inactive sites throughout the United States. The problems at the sites include contaminated soils, groundwater and surface waters, structures, and old waste disposal areas.

IT Corporation, under the direction of the Office of Independent Cost Estimating (OICE) for DOE, developed a list of environmental problems at the sites and probable cleanup technologies and techniques that could be used. Estimated unit costs were then developed for these cleanup technologies, using available data and references.

Some procedures developed were common to many or all cleanup projects. These included site characterization, remedial investigation (RI), feasibility studies (FS), and the closure/post-closure phase. The article will focus on cost estimating of the closure/post-closure phase of a cleanup project. The cost data provided are for budget level or check estimates. Site-specific conditions as well as items peculiar to the environmental industry, such as governmental regulations and community relations, can influence both the cost and duration of a cleanup project.

CLOSURE

The closure phase of an environmental cleanup project covers the entire time period from the start to finish of decontamination and/or disposal. Since each project is site-specific with respect to the remediation and cleanup technologies applied, it is beyond the scope of this article to provide costs for all those approaches or technologies. Standard estimating data may be used for many of those approaches, especially in the earthwork areas. Other cost data are available for estimating treatment technologies, transportation/disposal, and building decontamination.

There are other work activities that are standard for all or nearly all cleanup projects. These should be considered and accounted for when estimating the closure phase requirements of a site. These activities include:

1. Removal of temporary roadways
2. Regrading of the site
3. Placement of topsoil
4. Seeding
5. Installation of monitoring wells
6. Erection of fencing
7. Erection of warning signs

Since these activities are fairly straightforward construction work items, standard data may be used to estimate costs for them. Unit costs for these activities are shown in **Table 1**, and include both labor and equipment costs.

One closure phase activity unique to the environmental industry is the certification of final closure. An estimate for this activity covers the labor for an *independent*, professional engineer (PE) to certify that the site has been closed in accordance with the approved closure plan developed by the owner/operator, or as agreed upon by the owner/operator and the applicable federal and state agencies. A complete estimate for this activity should include time for initial closure plan review, time for site inspection during the closure process, and time to prepare the final documentation.

The initial review of the closure plan should average approximately 8 labor hours. The major part of the estimate is comprised of the inspection time during the closure process. A reasonable estimate for these inspections is 8 labor hours per week for every week of the closure process. Preparation of the final documentation should average approximately 4 labor hours. Hence, the labor hours for the Certification of Final Closure for a site with a closure phase of 24 weeks would be:

$$8 + (8 \times 24) + 4 = 204 \text{ labor hours}$$

Table 1. Unit Costs for Closure Phase Activities^a

Activity	Unit	Typical unit cost ^b
Remove permanent roadway - 4" to 6" thick, bituminous	sy	\$ 5.43
Remove temporary roadway - fine grading	sy	1.26
Placement of topsoil - spreading and compaction, native soil for slope and fill	cy	3.50
Seeding, mechanical, 215 lb/acre	acre	1,306.00
Fine grading & seeding, including lime, fertilizer, & seed, with equipment	sy	1.67
Drilling and installation of monitoring wells	each	6,000.00
Erection of fencing with barbed wire	lf	11.23
Erection of fencing with no barbed wire	lf	10.76
Erect gate	ea	85.20
Erect warning sign	ea	22.36

^a Taken from "Guidance Manual: Cost Estimates for Closure and Post-Closure Plans," Subparts G & H, Volume 3, Unit Costs, Pope Reid Associates, Inc., U.S. EPA, EPA/530-5W-87-009, November, 1986 and the R. S. Means Company, Building Construction Cost Data, 1988.

^b Mid-1989 dollars.

Table 2. Unit Costs for Site Certification.

Activity	Manhours	Cost per Manhour*	Total Cost
Initial review-closure plan	8	\$ 50	\$ 400
Inspection during closure process	192	50	960
Preparation of Final Documentation	4	50	200
Total	204	\$ 50	\$ 10,200

* Average labor rate for professional consulting engineer, including overhead, G&A and profit.

Unit costs for these activities are shown in **Table 2**.

POST-CLOSURE

This phase covers the activities and costs associated with monitoring and maintenance of the site for some period of time after formal closure. This may entail monitoring or maintenance of the actual site if the contaminated material has been treated or buried on site, or monitoring and maintenance of an off-site disposal facility (such as a landfill). A post-closure phase of 30 years is standard; however, the time period may be extended if the potential health impacts of the contaminated material and the location of the site warrant it. For example, the post-closure phase for the Uranium Mill Tailings Remedial Action (UMTRA) project is 100 years, while the post-closure phase for the Formerly Utilized Sites Remedial Action Program (FUSRAP) is 200 years.

Activities for the post-closure phase cover primarily operation and maintenance activities, which occur both quarterly and annually. Quarterly activities may include groundwater monitoring, sampling, testing and analysis; air monitoring, sampling, testing and analysis; leachate removal; and time for the inspection of landfill systems and covers. Annual activities may include routine maintenance of wells, pumps, and other equipment as well as repairs required by landfill facilities, caps/covers, roads, and fencing.

Quarterly Activities

Groundwater Monitoring

Costs are estimated for quarterly monitoring, sampling, testing, and analysis of the groundwater. This activity occurs throughout the post-closure phase. The monitoring wells will have been installed for the site characterization and cleanup phases. However, it may be determined that

additional wells are necessary and these must be installed during the post-closure phase. Maintenance of the wells will also be necessary.

Cost components for the groundwater monitoring activity include labor and expenses for the sampling effort, laboratory analysis of the samples, report writing, and well maintenance. Estimated costs for these activities are shown in **Table 3**.

Air Monitoring

Costs are estimated for air monitoring, sampling, testing, and analysis. This activity will occur throughout the post-closure phase. Again, the air monitoring equipment will have been erected during the site characterization and cleanup phases. However, additional equipment may be required and maintenance of the equipment will be necessary. Cost components for the air monitoring include labor and expenses for the sampling effort, laboratory analysis of the samples, reporting writing, and maintenance. Estimated costs for these activities are also shown in Table 3.

Inspection Activities

Costs must be estimated for the inspection of landfill facilities and caps/covers. This activity will occur throughout the post-closure phase. Cost components include labor and expenses for the inspection of the facilities/site, and report writing. The unit costs for these activities will vary depending on the size of the site and the facilities. However, the labor required to inspect the facilities should be approximately equal to the labor required to conduct the groundwater/air sampling effort.

Leachate Removal

Removal of leachate from the site may also be required on a quarterly basis. Leachate is water that percolates through the waste material, solubilizing various components of the waste and becoming polluted. Removal of the leachate will occur throughout the post-closure phase. Cost components of this activity include sampling and analysis of leachate, removal and transport, and disposal offsite. These costs should be minimal since proper design of the cap or cover prevents the movement of the leachate through the waste deposit. However, if the cover fails and the leachate moves into the groundwater, then on-site treatment must be performed. The unit costs for this activity will vary depending on the system used for collection, removal, treatment and/or transportation and disposal.

Annual Activities

Annual activities include mowing, seeding, and fertilizing, landfill and/or cap/cover maintenance, road maintenance, and fence repair. Post-closure costs for the Uranium Mill Tailings Remedial Action (UMTRA) project are shown in **Table 4**. Costs are given on a per-acre and per-cubic-yard basis. The post-closure phase for UMTRA is 100 years.

Table 3. Estimated Costs for Groundwater and Air Monitoring Activities

A. SAMPLING

1. Subsurface Soil

Drilling —	\$105 per Vertical Linear Foot (VLF) (subcontractor cost - includes all Mob, Demob, Overhead, G&A and Profit)
Technical Labor — (includes Geologist, Technician, H&S watch, QA, and Project Management)	20 labor hours per sample, 2 labor hours per VLF 20 labor hours x \$50/labor hour (includes Overhead, G&A and Fee) = \$1,000 per sample or \$100 per VLF

2. Groundwater Investigation

Drilling and Installation of Monitor Wells —	\$6,000 per well or \$150 per VLF (subcontractor cost - includes all Mob, Demob, Overhead, G&A and Profit)
Technical Labor — (includes Geologist, Technician, H&S watch, QA, and Project Management)	50 labor hours per well or 2 labor hours per VLF 50 labor hours x \$50/labor hour (includes Overhead, G&A and Fee) = \$2,500 per well or \$100 per VLF

3. Water Sampling

Technical Labor — (Technician)	0.70 labor hours per sample 0.70 labor hours x \$50/labor hour (includes Overhead, G&A and Fee) = \$35 per sample
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4. Aquifer Testing

Technical Labor — (includes Geologist and Technician)	10 labor hours per well 10 labor hours x \$50/labor hour (includes Overhead, G&A and Fee) = \$500 per well
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Table 3. Continued

5. Air Sampling

Hi-Vol/PM-10 ^a	\$ 90 per sample
Metals ^a	\$ 90 per sample
Pesticides/PCBs ^a	\$ 70 per sample
VOCs ^a	\$ 70 per sample
Semi-VOCs ^a	\$ 70 per sample
Meteorological ^a	\$180 per sample

One-time-cost Equipment	
Preparation ^a	\$ 45 per sampler
Transport ^a	\$ 80 per sampler
Setup ^a	\$ 30 per sampler
Teardown ^a	\$ 30 per sampler

^a Includes Labor and Equipment Rental Costs. Analysis Costs are shown in Part B. Costs above assume 1 hour per type of sample, including all sampling, flow checking, calibration, chain-of-custody and documentation. Costs may be lower if several types of samples are being collected concurrently.

B. ANALYSIS - COST PER SAMPLE

Parameter	Clear Water	Other Waters/ Soils	Sludge/Other Solids
CLP Volatile Organics	\$ 305	\$ 350	\$ 400
CLP VOC with 10 Compound Library Search	\$ 355	\$ 400	\$ 450
CLP Acids + Base Neutral Combined	\$ 550	\$ 650	\$ 750
CLP Acids + Base Neutral Combined with 20 Compound Library Search	\$ 600	\$ 700	\$ 800
CLP Organochlorine Pesticides and PCBs	\$ 215	\$ 240	\$ 290
CLP Metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn)	\$ 365	\$ 450	\$ 540
CLP Inorganics (Cyanides)	\$ 150	\$ 165	\$ 185
Dioxin (2, 3, 7, 8-TCDD)	\$365	\$ 440	\$ 540
Total Dioxins	\$ 700	\$ 750	\$ 850
Sulfate	\$ 15	\$ 25	\$ 25
Gross Alpha/Beta	\$ 40	\$ 40	\$ 40
Tritium	\$ 55	N/A	N/A
Radiological Prep. Charge	\$ 25	\$ 25	\$ 25

Pu-239	\$ 130	\$ 150	\$ 150
Am-241	\$ 130	\$ 150	\$ 150
Uranium Isotopes	\$ 130	\$ 150	\$ 150
Sr-90	\$ 100	\$ 100	\$ 100

Laboratory Analysis Air Samples

Hi-Vol/PM10	\$ 20 per sample
HSL Metals	\$ 400 per sample
VOC	\$ 360 per sample
PUF-Pesticides/PCBs	\$ 450 per sample
PUF-Semi-VOC	\$ 450 per sample

- 1) Costs are in mid-1989 dollars.
- 2) Costs for Contract Laboratory Program (CLP) Analyses include dollars for CLP data report; costs for analyses with Certificate of Analysis report are approximately 10% lower.
- 3) Costs are for routine turnaround times of 10-15 working days, with the exception of dioxin and mixed waste, which are 20 working days. For rush or emergency service, add the following percentages:

Less than 48 hours	Cost + 200%
48-96 hours	Cost + 100%
5-10 days	Cost + 50%

Sample Shipping (Overnight)

Each cooler will hold 4-5 surface water, groundwater, soil and sediment samples.

The no-action alternative for the Weldon Spring site in Missouri consists of maintenance, surveillance, and monitoring of the site for 200 years. The estimated cost for this alternative is \$10,679,000 in mid-1989 dollars and the area of the site is 229 acres. The unit cost per acre for the post-closure phase is, therefore, $\$10,679,000 \div 229 \text{ acres} = \$46,600$.

The unit costs for annual activities are shown in **Table 5**. The frequency for mowing the site would depend on the climate and precipitation of the region in which the site is located. The cost shown in Table 5 includes both

Table 4. Estimated Post-Closure Costs, Uranium Mill Tailings Remedial Action (UMTRA) Project

Site	Post-closure costs, \$1000 ^a	Acres	Cost per acre ^a	Volume, 1,000 cubic yards	Cost per cubic yard ^a
Ambrosia Lake	\$126	105	\$1,200	2,060	\$0.06
Belfield	303	NA ^b	—	133	2.28
Canonsburg	572	NA	—	363	1.58
Durango	157	14	11,214	2,500	0.06
Falls City	124	150	827	2,832	0.04
Grand Junction	133	60	2,217	3,083	0.04
Green River	194	9	21,556	185	1.05
Gunnison	98	35	2,800	812	0.12
Lakeview	255	30	8,500	910	0.28
Lowman	177	10	17,700	169	1.05
Maybell	104	73	1,425	415	0.25
Mexican Hat	134	68	1,971	1,510	0.09
Monument Valley	184	30	6,133	947	0.19
Naturita	129	23	5,609	433	0.30
Rifle	141	43	3,279	3,520	0.04
Riverton	264	72	3,667	1,613	0.16
Salt Lake City	164	100	1,640	2,450	0.07
Shiprock	386	72	5,361	1,336	0.29
Slick Rock	100	25	4,000	510	0.29
Spook	200	5	40,000	115	1.74
Tuba City	259	25	10,360	616	0.42
Total	4,204	949	\$3,508 ^c	26,512	\$0.16 ^c

^a Mid-1989 dollars^b NA - Not available^c Average cost based on the total post-closure cost by the total acres or total cubic yards.

labor and equipment (tractor mower) for the work to be done by an outside contractor.

The unit cost for seeding for erosion damage repair includes both labor and equipment (push spreader) and assumes a slope mix with an application rate of 261 pounds per acre. The application rate for re-seeding the final cover is approximately one-half the initial seed application or 131 pounds per acre.

Fertilizer is applied at the rate of 968 pounds per acre, while peat moss is spread to a depth of 1 inch for mulching. Labor and equipment costs are included in the unit costs for both activities.

Crushed stone may be used in arid areas to control erosion. The crushed stone layer will need to be repaired periodically. The costs shown in Table 5 include both labor and equipment and assume hand placement with compaction using a hand roller due to the small area.

Table 5. Unit Costs for Annual Activities Post-Closure Phase^a

Activity	Unit	Range of Costs	Typical Unit Cost ^b
Mowing	acre	\$20 - \$50	\$ 30
Seeding - routine erosion damage repair	acre	\$1,149 - \$2,875	\$1,306
Re-seeding of final cover	acre	\$1,094 - \$1,957	\$1,230
Fertilizing	acre	\$310 - \$9,728	\$ 310
Mulching	acre	\$2,835 - \$3,350	\$3,090
Cover Repair - using crushed stone:			
Purchase	cy	NA	\$ 12.30
Delivery	cy	\$1.66 - \$10.82	\$ 2.78
Spreading	cy	NA	\$ 16.35
Compaction	cy	\$1.47 - \$5.54	\$ 4.41

^a Taken from "Guidance Manual: Cost Estimates for Closure and Post-Closure Plans", Subparts G&H, Volume 3, Unit Costs, Pope Reid Associates, Inc., U.S. EPA, EPA/530-5W-87-009, November, 1986 and the R. S. Means Company, Building Construction Cost Data, 1988.

^b Mid-1989 dollars.

The unit costs shown in Table 1 for the initial installation of roadways and fencing may be used to estimate road maintenance and fence repair costs.

CONCLUSIONS

Accurately estimating the costs of the closure and post-closure phase can help in the budgeting process and in avoiding cost overruns. The costs of the closure phase are site-specific and depend entirely on the treatment technology being used on the specific contamination problems at the site. The post-closure phase involves monitoring and maintenance of the site for a specified period of time after the remediation is completed. Because the post-closure period may extend from 30 to as long as 200 years, the costs are very high, and are an important element which must be considered in the development of the remediation plan. ■