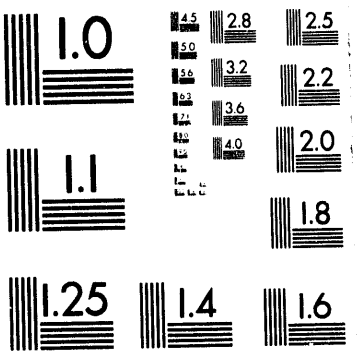
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ESTIMATION OF COSTS FOR APPLICATIONS OF REMEDIATION TECHNOLOGIES FOR THE DEPARTMENT OF ENERGY'S PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

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ESTIMATION OF COSTS FOR APPLICATIONS OF REMEDIATION TECHNOLOGIES FOR THE DEPARTMENT OF ENERGY'S PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

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ABSTRACT

The Programmatic Environmental Impact Statement (PEIS) being developed by the U.S. Department of Energy (DOE) for environmental restoration (ER) and waste management (WM) activities expected to be carried out across the DOE's nationwide complex of facilities is assessing the impacts of removing, transporting, treating, storing, and disposing of waste from these ER and WM activities. Factors being considered include health and safety impacts to the public and to workers, impacts on the environment, costs and socio-economic impacts, and near-term and residual risk during those ER and WM operations.

The purpose of this paper is to discuss the methodology developed specifically for the PEIS to estimate costs associated with the deployment and application of individual remediation technologies. These individual costs are used in developing order-of-magnitude cost estimates for the total remediation activities. Costs are developed on a per-unit-of-material-to-be-treated basis (i.e., $\$/m^3$) to accommodate remediation projects of varying sizes.

The primary focus of this cost-estimating effort was the development of capital and operating unit cost factors based on the amount of primary media to be removed, handled, and treated. The unit costs for individual treatment technologies were developed using information from a variety of sources, mainly from periodicals, EPA documentation, handbooks, vendor contacts, and cost models. The unit cost factors for individual technologies were adjusted to 1991 dollars.

INTRODUCTION

The primary focus of this cost-estimating effort was the development of capital and operating unit cost factors based on the amount of primary media to be treated. The unit costs for individual treatment technologies were developed using information from a variety of sources, mainly from periodicals, government documents, handbooks, vendor contacts, and cost models. The unit cost factors used in the PEIS for individual technologies were adjusted to 1991 dollars.

COST-ESTIMATION METHODOLOGY

The methodology used to obtain point-estimate unit cost factors associated with deployment and application of individual remediation technologies is discussed in this section. The technologies considered facilitate remediation of buried waste,soils, groundwater, and surface water. The primary focus of the cost-estimation effort for buried waste, soils, groundwater, and surface water was to develop capital and operating unit cost factors for individual treatment technologies.

Cost estimates reflect only those personnel and materials directly associated with onsite remediation activities. They do not include costs such as site characterization and permitting, project contingencies, recycling/recovery, transportation of hazardous materials to another location, or the offsite treatment of those materials. Whenever possible, cost estimates reflect only those personnel and materials directly associated with onsite remediation activities.

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The estimated unit cost factors are applied to the amount of media at a site to be treated. The results are order-of-magnitude estimates (plus 50%, minus 30%) of the cost of remediation activities at that site.

All costs are provided per unit of material to be treated. Although some technologies (e.g., constructed barriers, caps) are reported as cost per square meter ($/m^2), the most common unit is cost per cubic meter ($/m^3). The purpose of this approach is to accommodate remediation projects of various sizes.

Costs for individual treatment technologies were developed using information obtained from a variety of sources. A majority of the cost data was obtained from periodicals, U.S. Environmental Protection Agency (EPA) documents pertaining to specific remediation technologies, U.S. Nuclear Regulatory Commission (NUREG) documents, and handbooks citing remediation technology information and construction data manuals.

When insufficient data were available from published sources, cost estimates were obtained using the ENVEST[1] cost model, the VISITT[2] database, or by direct communication with vendors. ENVEST is the cost-estimating model associated with the Remedial Action Cost Engineering and Requirements (RACER) system. RACER was developed for use by the U.S. Air Force to estimate all phases of site restoration that includes the Remedial Action Assessment System (RAAS) (which identifies applicable remediation technologies) and ENVEST (which estimates associated costs). The Vendor Information System for Innovative Treatment Technologies (VISITT) is a database that includes current information on innovative treatment technologies. It includes data obtained from developers, manufacturers, and suppliers of treatment equipment and services.

References provided varying levels of detail for the cost information. The most detailed information provided cost for each phase of remediation (e.g., labor, utilities, consumables, mobilization). These cost categories were directly assigned to appropriate capital or operating cost categories.

The least detailed information was a single cost estimate for the entire remediation project. This single cost was separated into capital and operating cost using knowledge of the technology and engineering experience. For any technology where reference material did not provide detailed cost information, engineering judgment was used to develop costs for those categories not identified in the source document.

Unit Cost Factors

Whenever available, cost data associated with technologies used in actual site remediations were used. In addition, costs associated with Superfund activities and/or mobile units were used rather than costs associated with industrial fixed facilities.

When sufficient information was available from references, capital costs were separated into the categories of plant and equipment, construction labor, start-up costs, and working capital. These categories represent the original expenses that accrue before the remediation process actually begins. Operating costs included mobilization and demobilization, operating and maintenance (O&M) labor, miscellaneous materials and rented equipment, consumables, and utilities. These categories capture the typical expenses that occur during a remediation process. Although estimates are developed for the various cost categories whenever possible, total capital and total operating costs are the variables of interest. These estimates are required as input into the Automated Remediation Assessment Method (ARAM) model that was developed for the PEIS.

Cost Categories

For the purposes of this paper, direct capital cost for onsite remediation includes four cost categories:

Plant and equipment includes the cost of such items as construction materials, process equipment, instruments, piping, buildings and fences required for the remediation technique.

Onsite labor includes the cost of labor associated with the construction of any required buildings or fences, the set-up and installation of equipment, and the initial start-up associated with the technology.

Start-up cost includes the funds required to cover such activities as operator training, test runs prior to full implementation of a

technology, extra maintenance, and plant modifications.

Working capital includes capital required to meet the everyday needs of operating the plant. This cost category covers such expenses as the purchase of chemicals and the meeting of payroll.

Cost estimates for plant and equipment are often available from the reference material. Construction labor, if not specifically identified, is assumed to account for a percentage of total capital cost. Start-up cost is either indicated in the reference documents or estimated to be equal to one month's total O&M costs plus two percent of plant and equipment cost.[3] Based on recommendations from the American Association of Cost Engineers (AACE) Recommended Practice No. 16R-90,[4] working capital is estimated as two months of total O&M cost.

Operating cost includes two general cost categories: site-specific mobilization and demobilization costs and general O&M costs:

Site-specific mobilization and demobilization includes costs associated with the mobilization of equipment and material, and cleanup and dismantling of any equipment associated with a remediation effort after the project is completed.

O&M labor includes costs associated with the daily operation and maintenance of the equipment or remediated area.

O&M rented equipment includes costs associated with equipment that is rented only for the duration of the remediation activities. Rented equipment is generally specified in the reference documents. If not specified, it is assumed all equipment costs are included in the capital cost category "Plant and Equipment."

Miscellaneous O&M materials costs include costs associated with items that may not be included in the other O&M cost categories but are still required during normal operations (e.g., personal protective equipment, spare parts, or lab analysis). Rented equipment and miscellaneous materials are estimated as a single cost category.

O&M consumables costs include those costs normally associated with items such as chemicals, lubricants, catalysts, or solvents that are consumed during normal remediation operations.

O&M utility costs include the costs of such items as steam, electricity, process and cooling water, compressed air, natural gas, and fuel oils.

Adjustments to Initial Costs

Cost estimates were developed for the technologies identified used in the PEIS methodology. Factors were applied to the different cost categories to standardize the estimates to 1991 constant dollars. These factors include a producer price and plant cost index, each specific to the chemical industry, and a labor cost index based on the construction industry. It is assumed that the activities and production processes in the chemical industry most closely match the activities and processes that will be required for remediation. It is further assumed that the construction industry most closely matches the activities required of remediation labor.

Plant and equipment, start-up, mobilization and demobilization, miscellaneous materials and rented equipment, and utilities were standardized to 1991 dollars by multiplying those costs by a factor developed from the plant cost index taken from Chemical Engineering.[5] The costs of consumables and utilities were standardized to 1991 dollars using the chemical producer plant index that was also taken from Chemical Engineering.[5] Construction and operating labor costs were standardized to 1991 dollars using the employment cost index for the construction industry taken from the Monthly Labor Review.[6]

Each capital cost category was multiplied by a fixed charge rate (FCR). Fixed charge rates account for the time value of money and the expected life of the capital investment. In addition, the FCR adjusts the estimates to account for taxes and inflation over the lifetime of the remediation project. The derivation of the FCR and supporting assumptions are covered in the next section.

A productivity cost factor is applied, if necessary, to adjust the original operating cost estimates for the level of protection as defined by NIOSH.[7] Table I, and the Assumption section, describe the level of protection categories. For this project, all costs were standardized to protection level "C." For example, if the source documents provided costs for remediating a site using a protection level of "D," a factor is applied that adjusts for the decrease in worker productivity. Cost estimates for some technologies (e.g., Excavation - Protection Level A) were not calculated at safety level "C" but at higher protection levels, due to the requirements of the technologies involved.

After all adjustments were made to the separate cost categories, annualized capital and operating costs were obtained for each technology. These annual costs were divided by the annual throughput of the technology to obtain the final per unit cost, as follows:

$$\text{Capital (or Operating) Cost per } m^3 = \frac{\text{Annual Cost}}{\text{Annual Quantity Treated } (m^3)}$$

Fixed Charge Rate

The FCR discussed above was based on the procedures and assumptions of the AACE Recommended Practice No. 16R-90.[4] Equations 26, 27 and 28 of that Practice are generalized equations for calculating the "Real Levelized Cost of Services." This is what a restoration contractor would need to bill to cover the cost of performing one unit of remediation service (e.g., remediate one m^3 of soil, treat one gallon of groundwater). The real levelized cost of services includes all costs incurred by the contractor associated with the activities and individuals working at a remediation site.

To calculate the FCR, various financial assumptions were required. These assumptions relate to the appropriate discount rate to be used, the expected inflation rate, property tax rate, state and federal income tax rates, and equipment depreciation. These assumptions were programmed into a validated and verified model developed by PNL that automated the calculation of the FCR. Assumptions and calculations are discussed below.

Discount rates are used to account for the time value of money and the riskiness of cash flows. In order to evaluate projects with cash flows distributed over time, it is necessary to express all flows in terms of their value at a single point in time. A discount rate is required for these calculations. The appropriate discount rate for an organization or particular project depends on the degree of uncertainty associated with its future cash flows. The discount rate for projects of risk similar to a company's current business is equal to that company's weighted average cost of capital. For the PEIS, it was assumed companies that will be providing the remediation service are primarily in that business and, therefore, the appropriate discount rate is the various companies' weighted average cost of capital. Because company-specific information is not possible for this undertaking, a generic nominal discount rate has been used. A cost model developed at PNL was used to determine a generic after-tax weighted cost of capital that is the same as the generic industrial discount rate. The discount rate assumed for PEIS calculations was 9.3%.

The discount rate takes into account expectations regarding annual inflation rates. The historical arithmetic mean value of annual inflation (3.1%) was assumed.

Property tax rates vary widely between and within states. Because of this, the Electric Power Research Institute[8] (EPRI) recommends a levelized value for property taxes and insurance of 2% of the installed cost of an investment. This was the rate assumed for PEIS.

Assumed tax rates are based on the 1986 Tax Reform Act.[9] This Act affected, in part, marginal tax rates and depreciation schedules. In particular, the Act established a maximum marginal tax rate for corporations of 34%. This rate applies to taxable income in excess of $75,000. For the purposes of this undertaking, it is assumed that all corporations providing remediation services have taxable income in excess of $75,000, and are taxed at the marginal rate of 34%.

Because the majority of states have a state income tax, and do not allow the deduction of federal income taxes, this type of state income tax is assumed to be appropriate. It is assumed the average maximum marginal corporate state income tax for states with this type of income tax is 7.7%. It is further assumed that all corporations participating in the

remediation efforts have sufficient taxable income to put them in the top tax bracket. Additional assumptions are that allowable deductions from revenue (e.g., depreciation) are the same for state income taxes as they are for federal income taxes and that state income taxes are deductible for federal income tax purposes.

The combined state and federal income tax rate applied in the FCR formula was calculated from the following formula:

$$T_c = T_s + T_f (1-T_s)$$

where:

T_c = the combined tax rate (39.1%)
T_s = the average maximum state income tax rate (7.7%)
T_f = the maximum federal income tax rate (34%)

The Modified Accelerated Cost Recovery System[9] (MACRS) was used to determine the appropriate class life and depreciation schedule for remediation equipment. It is assumed for PEIS that all remediation equipment had an operating life of 15 years. For the 15-year MACRS class life, depreciation is calculated by the 150% declining-balance method with a switch to straight-line depreciation when deductions are maximized.

The FCR is calculated in two steps, with the first step being the calculation of a Capital Recovery Factor (CRF). The formula for the CRF is:

$$CRF = \frac{k}{1 - (1 + k)^{-L}}$$

where:

k = the real discount rate
L = the project life

The second step determines an appropriate FCR, using the formula:

$$FCR = CRF \left(\frac{1 - \pi (DPF)}{1 - \pi} \right) + \beta$$

where:

CRF = capital recovery factor calculated above
π = combined state/federal income tax rate
DPF = real depreciation factor
β = property tax rate and insurance

General Assumptions

In those instances in which source material did not present sufficient data, assumptions were made regarding individual technology costs. These assumptions were necessary to provide unit costs that are consistent across technologies. The general rationale for the assumptions is given below.

- Single Unit Operation

  Unit cost estimates are developed based on the assumption that a single unit of technology (e.g., one extraction well or one incinerator) would be employed with the associated equipment and manpower.

- Standard Wage Rate

  Unless specifically identified in the reference materials, a standard wage rate was applied to both construction and operating labor.

- Level of Protection

  The National Institute for Occupational Safety and Health (NIOSH) has identified levels of protection appropriate for persons working with hazardous materials. Table I identifies the protection levels and productivity cost factors developed by PEIS, for each. These productivity cost factors are designed to reflect reductions in productivity associated with the wear and use of protective equipment. Unless otherwise indicated, costs provided by source documents are assumed to be at protection level "D." Productivity cost factors are used to bring these costs up to protection level "C."

- Equipment Life

  AACE Recommended Practice No. 16R-90[4] indicates the estimated economic life of equipment used for the manufacture of chemicals and allied products to be 17 years. As noted earlier, it is assumed remediation activities are similar to those of the chemical manufacturing industry. Unless otherwise specified in reference material, remediation equipment lifetimes are based on the AACE Practice but conservatively assumed to be 15 years.

- Length of Treatment

  For most buried waste, soils, groundwater and surface water remediation technologies, it is assumed the application of that technology results in the complete

remediation treatment required. For some technologies, (e.g., capping, constructed barriers) however, where the hazardous material is not treated but rather control technologies are used, it is assumed the technology has a lifetime of 30 years. Additional costs would be associated with each successive reapplication of the technology.

Verification

The purpose of the verification process was to compare the unit cost factors with references that cited costs for similar technologies. The information provided by other references was used to ensure that the unit cost factors were representative of the remediation industry.

Verification of the representative point-estimate costs was performed for each technology. Verification started with accumulating references and cost sources for the technology. The unit cost factors developed for the PEIS were compared with literature that presented Superfund and/or mobile technology costs, if available. Cost data references were considered more credible when detailed explanation of the derivation of the cost was provided.

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8. Electric Power Research Institute, "Technical Assessment Guide-Vol. 1 Dev 6," EPRI P-6587-L (1989).
9. United States Commerce Clearing House, "1987 U.S. Master Tax Guide-1986 Tax Reform Act" (1987).

TABLE I. Levels of Protection for Workers and Associated Productivity Cost Factors

Assumed Level of Protection	Applicable Conditions	Descriptions as defined by OSHA and NIOSH[7]	Productivity Cost Factor
Level D	Activities where hazardous and/or radioactive material are not directly exposed	No identified hazard present but conditions are monitored and minimal safety equipment is available	1.0
Level C	Activities where hazardous and/or low level waste materials are directly exposed	Hazardous constituents known; protection required for low-level concentrations in air: exposure of unprotected body areas (i.e., head, face and neck) is not harmful.	1.5
Level B	Activities where radioactive waste materials are exposed or handled (within an atmospheric enclosure structure).	Requires SCBA and cutaneous or percutaneous exposure to unprotected areas of the body (i.e., neck and back of head) be within acceptable exposure standards (i.e., below harmful concentrations).	2.0
Level A	Activities where radioactive waste materials are exposed or handled (within an atmospheric enclosure structure).	Requires full encapsulation and protection from any body contact, or exposure to materials (i.e., toxic inhalation and skin absorption).	4.8
Use of Shielding	Activities where substantial risks of large/violent radioactive emissions exist	Requires an atmospheric enclosure structure and use of robotics. No human presence in work area.	12

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