THE COST OF REMEDIAL ACTIONS (CORA) MODEL--APPLICATION TO THE U.S. DEPARTMENT OF ENERGY'S (DOE'S) ENVIRONMENTAL RESTORATION PROGRAM

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ABSTRACT

This paper will provide an overview of the Cost of Remedial Actions (CORA) model and review current and potential applications to the U.S. Department of Energy's (DOE's) environmental restoration program. The CORA model estimates site-specific remedial action costs for Superfund sites. The model is microcomputer-based and has two components: an expert system and a cost system. The expert system interacts with the user to develop a range of reasonable response actions. The cost system contains algorithms capable of developing order-of-magnitude cost estimates for 40 technologies. The CORA model has been used successfully in a number of different applications. The model was used to develop cost estimates for 97 Superfund sites considered to be possible FY 1989 remedial action candidates. The EPA used these cost estimates in the development of the FY 1989 Superfund remedial action budget. The model was also recently applied to 661 Navy Installation Restoration Program sites for use in developing FY 1989, 1990, and 1991 remedial action budgets. In addition, the model has been used for economic analysis of the Resource Conservation and Recovery Act (RCRA) Location Standards Rule and for preliminary scoping and budgeting for several National Priorities List sites. The model has applications in both site-specific scoping and budgeting and outyear budget estimating. In addition, the potential exists for use in predicting programmatic remediation costs for federal and state agencies, and other parties, and for estimating specific remediation components, such as removals, and interim actions.

The CORA model is currently designed to address only sites contaminated with hazardous waste. However, recent data indicate that approximately 30 percent of existing DOE sites are contaminated soley with hazardous wastes. Additional evisions to the model are required to make it applicable to mixed waste and radioactive waste sites.

INTRODUCTION

The CORA model includes two distinct microcomputer-based subsystems. One subsystem is an expert system for selecting a range of reasonable remedial action technologies from technologies in the system. The other is a cost system with cost modules for all remedial action technologies in the expert system. The cost system is used to develop order-of-magnitude cost estimates for site remedial scenarios. The cost and expert subsystems operate independently of each other.

The system was not intended to incorporate all of the many technologies that would be necessary to address every type of site; the goal instead was to address the majority of EPA sites. "Outliers" included sites with radioactive waste and mining sites. Fig. 1 lists the technologies now in the expert system and cost modules, as well as the proposed additions in the new version of CORA due in early 1990. Four auxiliary cost modules (site preparation, site administration, health and safety, and contingencies and allowances) interface with these primary technology cost modules to generate scenario-specific site costs for remediation. Each technology was selected based on its frequency of use for EPA hazardous waste remediation and the ability to define a scope range and develop cost estimates for it. Some emerging technologies (such as in situ vitrification or UV-ozonation) were not included in the model because of scope and cost uncertainties. However, the CORA framework allows for expansions, and other technologies will be considered for addition during annual updates of the model.

EXPERT SYSTEM

The expert system portion of CORA was developed using the Level 5 Expert System shell version 1.0. This functions by processing the compiled knowledge bases, making queries to the user, executing external programs, and evaluating the rules of the knowledge bases to establish conclusions and recommendations.

The CORA knowledge bases consist of approximately 670 decision rules for applying 40 fairly well-developed

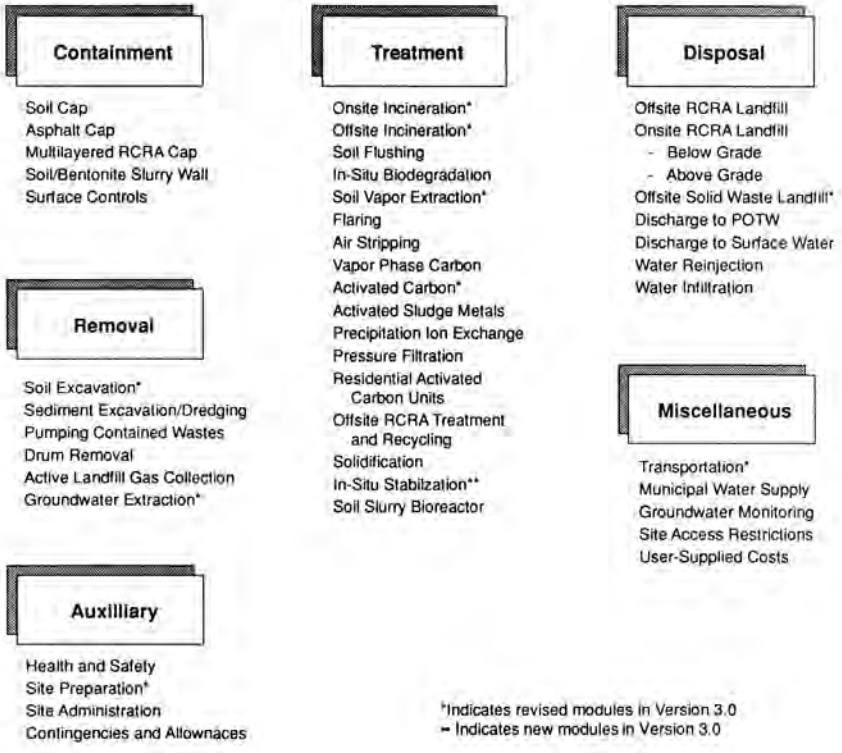

Fig. 1. CORA Cost Modules.

technologies at Superfund sites. The decision rules reflect both engineering expertise and approaches drawn from hazardous waste projects and policy issues. Also included in the decision rules are questions which include the concepts behind the Superfund Amendments and Reauthorization Act (SARA) and Hazardous and Solid Waste Amendments. The expert system analyzes a site by focusing on separate user-defined contaminated areas. The user responds to system-selected questions for each waste type within a contaminated area. For a particular set of user answers corresponding to a certain contaminated area, the expert system recommends a range of potentially implementable and applicable remedial action technologies. These technologies can be combined by the user to form one or more remedial action alternatives. The user can change his or her answer to particular questions to explore a range of outcomes.

COST SYSTEM

The CORA cost system was developed using dBASE III Plus software. Nine separate programs were developed, split into three different files, compiled with the Nantucket Clipper Compiler, and linked together to form the cost system.

After site remedial-action scenarios are determined, the cost system is used to develop order-of-magnitude cost estimates, which typically have an accuracy range of +50 to -30 percent. The cost system currently comprises 40 primary cost modules and a system designed to organize the cost estimates by site, operable unit, and alternative scenario. The following approach was used for developing each cost module:

- Key parameter range limits were assumed (e.g., treatment systems for groundwater extraction were limited to 2,000 gpm per unit)
- Conceptual designs were developed for each technology
- Detailed cost-line items were defined within specified range limits for each technology
- Microcomputer cost spreadsheets were created for each technology, with relationships allowing individual cost-line items to vary over defined design ranges
- Sensitivity analyses were performed to identify key cost variables
- Cost algorithms were developed based on the key variables
- Cost modules were developed with the key variables

as user inputs and with some default values where users may not initially have a site-specific value

The cost system is organized by site, operable unit, scenario, and technology. The system first asks the user to either select an existing site that is in the site cost data base, or designate a new site. The user then designates operable units and scenarios to be considered. Technologies for the scenarios may be based on recommendations from the CORA expert system or other technology screening and alternative development methods. The user then runs the cost modules and inputs the required costing parameters. The cost system calculates capital and first-year operation and maintenance cost estimates for each technology selected. Individual technology cost runs are stored under scenarios named by the user. The user can select combinations of remedial technologies which were previously costed and stored in the model and generate ranges of overall site costs for different alternatives.

Most cost modules provide the user with base-case default values for some parameters. The user may use the default values, or input known or estimated site-specific information. Example default parameters include:

- For a multilayered RCRA cap--thicknesses for seven different cap layers
- For a soil bentonite slurry wall--percent bentonite required for slurry, percent slurry loss due to waste and seepage
- For onsite incineration--percentage ash and moisture content, depending on user-selected waste form; kiln and afterburner temperature, depending on user information on waste constituents
- For air stripping--volatile organic compound (VOC) specific effluent concentrations for discharge to surface water
- For soil vapor extraction (SVE)--default radius of influence for SVE extraction wells, depending on user-selected type of soil

If the user selects default values, he or she can easily edit the input value and update the cost estimate when site-specific information is available.

Some of the CORA cost modules contain powerful built-in modeling capabilities, including those for:

- Groundwater extraction. If the number of extraction wells is not known, CORA will estimate a number based on the following factors: aquifer storativity, hydraulic conductivity, aquifer thickness, area of contamination, depth of wells, and desired time for cleanup.
- Soil excavation. CORA allows for sequencing of excavation activities at sites where multiple lifts may be taken and where there may be loss of productivity due to analytical turnaround times between lifts. The excavation productivity modeling algorithms include considerations for anticipated depth of contaminated zone, contaminated zone excavation layer thicknesses, area to excavate, and levels of worker health and safety protection.
- Onsite incineration. CORA runs through more than 70 material and energy balance equations to determine case-specific waste feed rates, auxiliary fuel, power requirements, and makeup water for a rotary kiln incinerator.
- Air stripping. CORA sizes air stripping systems (tower diameter, packing height, blower horsepower, air flow rate) based on user inputs for influent flow rate and specific VOC influent and desired effluent concentrations.

HISTORICAL APPLICATIONS

Version 1.0 of the CORA model was completed in April 1987, and Version 2.1 in June 1988. Version 3.0 of the model is due in early 1990. The U.S. EPA contracted with an outside consultant to conduct a validation study of the model. The study included a review of the decision rules and expert system operation and recommendations. The study also ran the CORA cost system for 12 Superfund sites to compare the results with existing design, bid, or construction costs. Of the 12 sites, 10 of the 12 Version 1.0 CORA estimates and all 12 Version 2.1 estimates were within the system design cost range based on comparison with the EPA design, bid, or construction costs. The study concluded that the expert system "is a useful tool for EPA budget estimates," uses sound logic, and develops reasonable recommendations.(1)

In May 1987, the CORA model was used to develop out-year cost estimates for 97 EPA Superfund sites likely to be FY 1989 remedial action candidates. For each site, CH2M HILL team members worked one-on-one with EPA regional project managers and completed CORA expert system and cost system runs.

Results for sites in the pre-Feasibility Study (FS) stage were combined with cost information from FSs and Records of Decision (RODs) to develop the FY 1989 budget. A number of analyses have been conducted on the FY 1989 site costs, and the results have helped the EPA shape the selection of remedy processes under SARA. The model was also used in April 1988 to develop out-year costs for the FY 1990 budget, and was used in April 1989 to develop out-year costs for the FY 1991 budget.

The CORA model was also applied during the summer of 1988 to 661 Navy Installation Restoration Program sites. As with the EPA costing exercise, each team member

worked one-on-one with the Naval Facilities Engineering Command engineer responsible for the site. The costs were used by Navy personnel to estimate Defense Environmental Restoration Act funding for FY 1989, 1990, and 1991. In addition, CORA has been used to develop remedial action strategies and estimate total Department of Defense-wide remediation costs.

The CORA model has also been used for RCRA regulatory support. For the RCRA Location Standards Rule, the model was used to analyze remediation costs for six site types in differing hydrogeologic, ecological, and geographic settings to support the regulatory impact analysis. A total of 30 corrective alternatives were identified and costed.

Another independent validation of CORA was performed for the DOE Costing Assessment Team in December 1989. A randomly selected sample of 25 EPA RODs signed between January 1, 1987, through July 1, 1989, were evaluated. Using data from the ROD, CORA was executed for both a containment strategy and a treatment strategy. CORA results were then compared with the actual ROD recommendations for the site. This validation study determined that CORA recommended the selected ROD alternative 97 percent of the time.(2)

The CORA model has also been used to screen technologies, develop alternatives, and estimate initial remediation costs for several other sites. To date, more than 150 copies of the model have been distributed to federal and state agencies, foreign governments, environmental consultants, and industries.

DOE APPLICATIONS

DOE's Environmental Restoration and Waste Management Five-Year Plan has as one of its fundamental goals to ensure that risks to the environment and to human health and safety posed by inactive and surplus facilities and sites contaminated by radioactive, hazardous, or mixed wastes are either eliminated or reduced to safe levels.(3) The Department's technical approach to addressing these sites includes the following steps: (1) identify the site, (2) assess nature and extent of contamination, (3) minimize any further spread of contamination, (4) clean up, and (5) long-term monitoring.

This will not be a simple task. The DOE, Office of Energy Research has estimated that there are approximately 3,700 potentially contaminated sites that must be addressed. Assessment and clean up of these sites will be a monumental and costly effort. The DOE has estimated that it will cost from $3 billion to $5 billion to characterize these sites and another $35 billion to $65 billion to clean up these sites.(4)

To help in this characterization and cleanup effort, a variety of expert systems are being developed to assist in

WASTE	FUNCTION/USE			RESTORATION STAGE		TECHNOLOGY SELECTION
	Ballpark	Budget	Definitive	Investigation	Design Construct	
Chemical Waste	CORA, HAZRISK*	PRACES*	M-CACES*	SCEES*, HAZRISK*	CORA, PRACES* HAZRISK*	CORA
Mixed Waste	HAZRISK*, RAAS*	Generic	Generic	HAZRISK*	HAZRISK*, RAAS*	RAAS*
Radioactive Waste	HAZRISK*, RAAS*	Generic	Generic	HAZRISK*	HAZRISK*, RAAS*	RAAS*

*Under development

Fig. 2. Typology of Cost Estimating Tools for Environmnetal Restoration.

both technology selection and cost estimating. A study prepared for the DOE Costing Assessment Team has evaluated many of the existing expert systems.(5) As illustrated in Fig. 2, CORA is currently the only validated and available expert system that provides either remedy selection or cost estimating capabilities.

The CORA model is currently designed to only address sites contaminated with hazardous wastes. However, recent data indicate that approximately 30 percent of existing DOE sites are contaminated solely with hazardous wastes. Of the remaining sites, 48 percent are contaminated with mixed wastes while 22 percent are contaminated with radioactive wastes.(6)

Representatives of EPA and DOE are currently discussing a joint effort to modify CORA so that it would be more applicable to both Agencies' remediation problems. Development of new costing modules and revisions to the existing expert system are needed so the model can assist in addressing the technology selection and cost estimating portion of mixed-waste and radioactive-waste site remediation. These revisions to CORA should be made in close conjunction with the DOE R&D program. The role of R&D in DOE's approach to site remediation includes: (1) providing an improved technical and economic basis for dealing with hazards through the development of improved and new assessment and cleanup technologies; (2) reducing the potential for exposure of the public through development of automated, remote handling technologies; and (3) broadening the available technical base by adapting technologies not previously considered for application to this field.(7)

Close coordination between those responsible for the CORA revisions and the R&D staff will ensure that the most current information is transferred from the implementation stages to the CORA model.

ACKNOWLEDGEMENTS

The authors express their thanks to Mr. R.F. Shangraw, Jr., of Independent Project Analysis, Inc., and Mr. Tim Van Epp of CH2M HILL for their technical review and suggestions.

REFERENCES

1. ICF, INC., "Performance Evaluation of Cost of Remedial Action (CORA) Model" (Jan. 1989).
2. M. ZOCHER and R. SHANGRAW, "Validation of the Cost of Remedial Action (CORA) Model's Technology Selection Module," Prepared for the U.S. Department of Energy, Costing Assessment Team (Dec. 1989).
3. U.S. DEPARTMENT OF ENERGY, "Environmental Restoration and Waste Management Five-Year Plan," DOE/S-0070.
4. U.S. DEPARTMENT OF ENERGY, Office of Energy Research, "Evaluation of Mid- to Long-Term Basic Research for Environmental Restoration," DOE/ER-0419 (Sept. 1989).
5. B. SCHROEDER and R. SHANGRAW, "A Review of Computerized Cost Estimating Tools For Environmental Restoration Projects," Prepared for the U.S. Department of Energy, Costing Assessment Team (Jan. 1990).
6. U.S. DEPARTMENT OF ENERGY, Environmental Restoration Program, "Program and Implementation Plan," Preliminary Draft (May 31, 1988).
7. [3].