United States Environmental Protection Agency
Office of Pollution Prevention and Toxics (MC7409) Washington, DC 20460
EPA742-R-96-003
December 1996

EPA

Valuing Potential Environmental Liabilities for Managerial Decision-Making:

A Review of Available Techniques

EPA 742-R-96-003
December 1996

Valuing Potential Environmental Liabilities for Managerial Decision-Making: A Review of Available Techniques

Prepared Under:

Contract No. 68-D2-0064
Susan McLaughlin, Work Assignment Manager

and

Contract No. 68-W2-0008
Holly Elwood and Martin A. Spitzer, Work Assignment Managers

Pollution Prevention Division (MC-7409)
Office of Pollution Prevention and Toxics
Office of Pollution Prevention and Toxic Substances
U.S. Environmental Protection Agency
401 M Street, SW
Washington, D.C. 20460

Prepared by:

ICF Incorporated
9300 Lee Highway
Fairfax, VA 22031

Paul E. Bailey, Project Manager

Disclaimer

Descriptions of environmental liability valuation techniques and mention of trade names, products, or services do not convey, and should not be interpreted as conveying, official approval, endorsement, or recommendation by the U.S. Environmental Protection Agency.

Acknowledgements

This document benefited immeasurably from the reviews, comments, and assistance of people from a wide variety of organizations. The United States Environmental Protection Agency (EPA) sincerely appreciates the efforts of the numerous individuals who helped to develop the report.

EPA would like to thank the following individuals for providing extensive comments to draft versions of this report:

Ali Alavi
Horsehead Resource Development Co, Inc., & Zinc Corporation of America

Rob Anex
University of Miami

Karl C. Ayers
Mead Corporation

David S. Baker
Powell, Goldstein, Frazer & Murphy

Beth Beloff
University of Houston

Bert Black
Weinberg & Green

Laura Bulatao
U.S. Environmental Protection Agency

Ellen Caya
Florida Power & Light Company

John Cross
U.S. Environmental Protection Agency

James D. Englehardt
University of Miami

Julian Freedman
Institute of Management Accountants

Suwanna B. Gauntlett
The Gauntlett Group, Inc.

Karen Harrison
U.S. Environmental Protection Agency

Miriam Heller
University of Houston

Jon Horin
Mitretek Systems

Richard B. Johns
Motorola

Alfred M. King
Valuation Research Corporation

John Mincy
Ciba-Geigy Corporation

George J. Muhlebach
Ciba-Geigy Corporation

Greg Norris
Decision Dynamics

Larry Onisto
Ontario Hydro

Amy A. Ripepi
Arthur Andersen

Nancy H. Roen
Florida Power & Light Company

Donald Salmond
Arthur D. Little

James H. Schaarsmith
Foster Wheeler

Monali Shah
Avery Dennison

Robert J. Sonnelitter, Jr.
Financial Accounting Standards Board

Edward W. Trott
KPMG Peat Marwick, LLP

David W. Vogel
The Gauntlett Group, Inc.

Edward Weiler
U.S. Environmental Protection Agency

Allen White
Tellus Institute for Resource and Environmental Strategies

Mark A. White
University of Virginia

Diana Zinkl
Tellus Institute for Resource and Environmental Strategies

Melissa Zoepfl
Mitretek Systems

Prior to the completion of this document, EPA asked individuals involved in the development of the profiled valuation tools to review their respective profiles for accuracy. EPA extends its thanks to the following individuals for providing information for, and feedback on, the profiles: James Aldrich, Air Force Institute of Technology; Amy Bouska, Tillinghast; Linda Burlington, National Oceanic and Atmospheric Administration; Joel S. Chansky, Milliman & Robertson, Inc.; James D. Englehardt, University of Miami; Sidney Feld, U.S. Nuclear Regulatory Commission; Steven E. James, Woodward-Clyde Group; Jonathan Libber, U.S. EPA; Paul Merges, New York Department of Environmental Conservation; Joseph A. Miakisz, Niagara Mohawk Power Corporation; Tuula Moilanen, Paras; Mary Morton, U.S. Department of the Interior; Paul and Joyce Schoemaker, Decision Strategies International; Betty S. West, U.S. Air Force; Lester Wittenberg, American Institute of Chemical Engineers; and John Zeh, New York Department of Environmental Conservation.

EPA is also grateful for the assistance and input provided by the following individuals: Louis Bisgay, Institute of Management Accountants; Corinne Boone, Ontario Hydro; Alan Ehrlich, US EPA; Marc J. Epstein, Stanford University; Frederick Gill, American Institute of Certified Public Accountants; Mike Harbordt, Temple-Inland Forest Products, Inc.; Cord Jones, Organization Resource Counselors; James Lawrence, Chevron; Louise Little, U.S. EPA; Andrew Mangan, Business Council for Sustainable Development; Michael Northridge, US EPA; L. Hal Rogero, Jr., Mead Corporation; Kathy Seikel, US EPA; and Jeannie Wood, Arthur Andersen.

This document was completed under Contract No. 68-D2-0064 with ICF Incorporated (Susan McLaughlin, EPA Work Assignment Manager, and Carol Rawie, EPA Project Officer). It was begun under Contract No. 68-W2-0008 with ICF Incorporated (Holly Elwood and Martin Spitzer, EPA Work Assignment Managers and Carlos Lago, EPA Project Officer). The ICF team members were Paul E. Bailey (Project Manager), Mary D. Clark, Matthew S. Borick, Paul J. Raskin, Annie M. Ho, and Margo D. Brown.

Table of Contents

Table of Exhibits

1. Introduction

1.1 Purpose of this Report

Companies are increasingly aware of the environmental aspects of their businesses. More and more managers want to consider the beneficial and adverse environmental implications of their business activities, products, and services. These "implications" include impacts on environmental conditions, associated financial effects, corporate image consequences, and significance for business strategy. However, some companies have found it difficult to measure these implications, both because of the inherent uncertainties in measuring them, and because existing information, planning, and decision-making practices do not highlight those implications sufficiently.

To address those obstacles, companies have begun to use environmental evaluation techniques such as life cycle analysis (LCA), environmental life cycle costing (ELCC), and total cost assessment (TCA). Environmental cost accounting techniques such as TCA and ELCC are used to demonstrate the potential for environmentally-beneficial investments to yield significant financial pay-offs. One such pay-off is the avoidance of *environmental liabilities*. If this benefit is overlooked, environmental investments may appear less attractive than they truly are. The same logic applies to operating, design, and other business decisions that are not viewed as primarily "environmental" in nature. Businesses can prevent or reduce environmental liabilities by, first, paying attention to the environmental aspects of their business decisions and operations, and, second, translating the liabilities into monetary terms so they can more easily be made a part of financial evaluations.

Unfortunately, the estimation of environmental liability costs is an area fraught with uncertainty. Managers may feel that they cannot estimate these costs with a sufficient degree of accuracy to merit inclusion in decision-making calculations.[1] They may be unaware of existing environmental liability valuation techniques. They may also be unsure of the relevance of the various techniques to different types of liabilities. As of yet, accounting for environmental liability costs receives relatively little attention, with the exception of accounting and disclosure requirements under Securities and Exchange Commission (SEC) rules, Financial Accounting Standards Board (FASB) statements, and a recently issued Statement of Position from the American Institute of Certified Public Accountants (AICPA) (See Appendix D.) Regardless of

---

[1]In a survey of U.S. manufacturing firms conducted by the Tellus Institute and commissioned by EPA's Environmental Accounting Project, an average of approximately one third of the respondents indicated that, for the purposes of investment financial evaluations, they regularly calculate cost values for such items as environmental fines and penalties, personal injury, future regulatory compliance costs, and natural resource damages. With respect to Superfund remediation liabilities, it was found that only about 10 percent of all respondents regularly determine the liability costs for inclusion in project financial analyses. The most commonly cited barriers to calculating Superfund liability costs were the difficulties associated with estimating the likelihood, magnitude, and timing of the liability costs. (Tellus Institute, *Environmental Cost Accounting for Capital Budgeting: A Benchmark Study of Management Accountants*, September 1995, EPA 742-R-95-005.)

financial accounting requirements, however, managers naturally are concerned about minimizing the costs associated with environmental liabilities, just as they are concerned about minimizing other business expenses. Thus, as the costs of environmental liabilities mount, due both to expansion in the nature and types of environmental liabilities and to increased costs for each type of liability, business managers have greater incentives to carefully consider the extent to which existing and proposed activities give rise to environmental liability costs.

The Environmental Protection Agency (EPA) is issuing this report as a step toward helping companies assess and manage their environmental liability costs. **The report describes valuation approaches and tools that have been specifically developed or adapted for estimating environmental liability costs for consideration in business management decisions such as capital investments, process/input substitutions, product retention and mix, facility siting, and waste management. The emphasis in this report is on techniques for placing a monetary value on potential, preventable environmental liabilities.** Sources of information on estimating environmental liability costs are somewhat obscure; EPA thus offers this summary of documented valuation techniques to managers who are interested in estimating potential environmental liability costs, but are unaware of techniques to do so. While estimation techniques are still under development, and possibly controversial, this report is intended to assist organizations to estimate future and/or potential environmental liability costs within reasonable limits of accuracy such that a manager is comfortable using the estimations when making decisions.

This report was developed under the auspices of EPA's Environmental Accounting Project, which has been working with stakeholders for the past three years to encourage and motivate businesses to understand the full spectrum of environmental costs and incorporate these costs into decision-making. In December 1993, a national workshop of experts drawn from businesses, professional groups, government, consulting firms, nonprofits, and academia produced an *Action Agenda* which identifies four overarching issue areas that require attention to advance environmental accounting: (1) better definition of terms and concepts, (2) creation of management incentives to upgrade managerial accounting practices, (3) education, guidance, and outreach, and (4) development and dissemination of analytical tools, methods, and systems.[2] The purpose of this document is to help address the fourth recommendation. At the workshop, opinion was split over whether or not techniques for valuing environmental liabilities were available. This report is intended to follow up on that discussion.

The activities and products of the Environmental Accounting Project are part of EPA's commitment to fostering pollution prevention solutions to environmental problems. For EPA, pollution prevention means eliminating or minimizing the pollution at the source, including practices that minimize the creation of pollution through increased efficiency in the use of raw materials, energy, water, or other resources. EPA supports pollution prevention approaches

---

[2] The U.S. Chamber of Commerce, the Business Roundtable, the American Institute of Certified Public Accountants, the Institute of Management Accountants, AACE International (the Society of Total Cost Management), and the U.S. EPA co-sponsored the Workshop. For more information on the workshop, see *Stakeholders' Action Agenda: A Report of the Workshop on Accounting and Capital Budgeting for Environmental Costs, December 5-7, 1993*; EPA 742-R-94-003 (May 1994).

because they are potentially the most environmentally effective and economically efficient methods of environmental protection.

The identification of environmental costs, including potential environmental liabilities, is an important step towards reducing those costs. Many types of management decisions may benefit from environmental cost information, including product pricing and mix decisions, choices on approaches for compliance with regulations, and decisions on design modifications to eliminate process waste or releases. More information on the consideration of these costs in management decision-making can be found in EPA's *An Introduction to Environmental Accounting as a Business Management Tool: Key Concepts and Terms* (EPA 742-R-95-001, June 1995).

1.2 Intended Audience

The discussion and terminology used in this report focus on environmental management issues faced and addressed by managers in industry. It is hoped that the report will be used by managers representing a variety of professions: e.g., environmental, health and safety personnel; managerial accountants; engineering staff; legal staff; and so on. EPA has therefore attempted to choose vocabulary that is as clear as possible to a broad audience.[3] The techniques described in this report may be very useful to other audiences, such as the insurance, banking, and financial accounting communities.

1.3 Organization of Report

This report consists of five major sections and four appendices, organized as follows:

- Section 1 is this Introduction.
- Section 2 describes the research methodology used to develop this report.
- Section 3 provides a definition of "environmental liability" and discusses the different types of environmental liabilities that firms may face.
- Section 4 describes the results of the research to identify techniques for estimation of environmental liability costs.
- Section 5 profiles twenty-four specific tools.
- Appendices:

[3]EPA recognizes that many terms in this report have specific meanings to the accounting community, and, in that community's eyes, some of the terms may be used overly loosely. "Liability" and "costs" constitute two examples. In the case of "costs", nuances of the term are expressed -- where clearly appropriate -- with such words as "expenditures", "expenses", and "payments". However, "costs" is often applied as the default term, and is used to mean "future cash flows".

- Appendix A describes timing, likelihood, and uncertainty issues associated with the different types of liabilities.

- Appendix B presents an annotated bibliography of sources of further information.

- Appendix C presents a list of other documents that provide guidance on valuing natural resource damages.

- Appendix D provides a list of authoritative literature on accounting for environmental liabilities in financial statements.

1.4 Limits to the Scope of this Report

- This report is not intended to address the recognition or reporting of environmental liabilities in financial statements or disclosures subject to the jurisdiction of the Securities and Exchange Commission (SEC) or in accordance with Generally Accepted Accounting Principles (GAAP). However, EPA acknowledges that the valuation techniques described in this report may have implications for such reporting.

- This report focuses on the valuation of environmental impacts that constitute business liabilities, i.e. "private" or "internal" costs. It is not intended to address those impacts termed "societal costs" or "externalities" for which a company is not financially liable or legally accountable.[4] However, in a changing legal environment, the line between private and societal costs is not static, and it may be worthwhile to consider the possible enactment or modification of environmental laws when deciding what constitutes a potential business environmental liability.

- This report does not present a legal analysis of environmental liability issues.

- This report does not describe how to identify the types of potential environmental liabilities faced by a given company nor does it provide specific guidance on applying valuation techniques to those liabilities.

- This report does not address the potential jail terms that individuals can incur as a result of violating environmental laws.

1.5 A Living Document

EPA views this document only as a step towards assisting organizations in valuing the costs of potential and avoidable environmental liabilities. Because the valuing of environmental

[4] For a description of the difference between private costs and societal costs, see *An Introduction to Environmental Accounting as a Business Management Tool: Key Concepts and Terms* (EPA 742-R-95-001, June 1995).

liabilities is an emerging and rapidly developing issue, the Environmental Accounting Project intends that this report be a “living document”. Accordingly, if readers are aware of other, as-of-yet unmentioned, techniques in use or that are described in literature, they are encouraged to submit information on those techniques to the Project for possible inclusion in future editions of this document. The Project also welcomes suggestions on the report’s format and content. Please send valuation techniques, comments, and suggestions to:

The Environmental Accounting Project
Pollution Prevention Division (MC-7409)
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
401 M Street, SW
Washington, D.C. 20460
Fax: (202) 260-0178
Phone: (202) 260-4164

2. Research Methodology

This report is based on extensive research and review of literature to identify techniques for valuing environmental liabilities. Techniques were also obtained by contacting individuals in industry, government, academia, and consulting organizations.

EPA's Environmental Accounting Project continually seeks, receives, and reviews environmental accounting materials for inclusion in its literature file and its regularly updated *Resource Listing*. The literature file contained a limited number of documents addressing the valuation of environmental liabilities. To locate additional materials, EPA secured the assistance of ICF Incorporated (ICF), a government contractor that has been active in developing environmental liability valuation models, maintains a file of related materials, and previously had performed similar literature searches for government agencies. ICF, assisted by the EPA library, conducted stack and on-line searches for relevant documents. In addition, hard copy searches were conducted at the American Chemical Society library.

ICF and professional librarians searched journals and reports contained in computerized databases and services, including DIALOG and NEXIS. On-line and hard-copy catalogs of trade and professional associations' publications, including conference papers, also were searched. In addition, references and footnotes were reviewed in all materials retrieved in order to identify other potential sources. Ph.D. dissertations were not systematically searched.

The search strategy focused on key words of "environmental liability(ies)," "pollution liability(ies)" and combinations with "measurement," "quantification," "evaluation," "valuation," "monetization," or "assessment." Due to the limited number of pertinent references located, the literature on environmental cost accounting, activity-based accounting, life cycle costing, and risk management identifiable through on-line databases also was reviewed. The document screening process and selection criteria included the following:

- Focus on documents prepared in the United States to reflect environmental liabilities under U.S. law.

- Identify documents that address the topic of environmental liability valuation with some specificity and provide illustrations of valuing environmental liabilities.

- Identify documents that are not exclusively focused on financial accounting/reporting in the context of GAAP and SEC requirements.

- Exclude cost-benefit and risk assessment methodologies developed for and applied to governmental regulatory decisions. These were not viewed as central to this research and, with few exceptions, are not included in this report.

To supplement the literature search, individuals were contacted who were listed in the Business/Industry and Consulting categories of *EPA's Environmental Accounting Network*

Directory[5] and who had noted experience potentially relevant to this project. These people were asked to identify any tools or approaches used to express potential liabilities in financial terms for inclusion in this report. Additionally, in the draft review process, EPA sought input from a cross-section of interested and knowledgeable parties and queried them to identify further relevant documents and/or software tools.

[5] EPA 742-B-96-006 (April 1996).

3. Environmental Liabilities: Definitions and Categories

The term "environmental liabilities" crops up in many discussions of environmental issues. Yet there is much confusion about the term. Often, "environmental liabilities" is used to refer to the potential for fines, penalties, and jail terms for violations of environmental laws. "Environmental liabilities" also frequently serves as short-hand to refer to the clean-up obligations under the federal Superfund and state counterpart laws for contaminated sites. Another common usage is to label the costs involved in complying with regulations as "environmental liabilities." In contrast, when companies perform or commission "environmental liability" assessments, they want to know their exposure to potential environmental liabilities even when they are in complete compliance with regulatory standards.

Clearly, "environmental liability" is an umbrella term. The following pages present a brief definition of the term and describe the major types of environmental liabilities in order to establish a framework for reviewing approaches and tools identified for expressing these liabilities in monetary terms. For readers who would like more information about the timing, likelihood, and uncertainty characteristics of the various forms of environmental liabilities, more information on these subjects is provided in Appendix A.

3.1 Defining "Environmental Liability"

The term liability has important accounting and legal dimensions. Accounting institutions define liability as a "probable future sacrifice of economic benefits arising from present obligations to transfer assets or provide services in the future as a result of past transactions or events."[6] More simply, a liability is a *present* obligation to make an expenditure or to provide a product or service in the *future*.

Liability has an important legal dimension as well. A liability is a legally enforceable obligation, whether it is voluntarily entered into as a contractual obligation, or is imposed unilaterally, such as the liability to pay taxes. The law both establishes liabilities and determines who is responsible for discharging them.

For the purposes of this document, an **environmental liability** is a legal obligation to make a future expenditure due to the *past* or *ongoing* manufacture, use, release, or threatened release of a particular substance, or other activities that adversely affect the environment. A ***potential* environmental liability** is a *potential* legal obligation to make a future expenditure due to the *ongoing* or *future* manufacture, use, release, or threatened release of a particular substance, or other activities that adversely affect the environment. An obligation is *potential* when it depends on future events or when a law or regulation creating the liability is not yet in effect. A "potential environmental liability" differs from an "environmental liability" because an organization has an opportunity to prevent the liability from occurring by altering its own practices or adopting new practices in order to avoid or reduce adverse environmental impact.

---

[6] Financial Accounting Standards Board Concept Statement No. 6, Paragraph 35 (1985); Institute of Management Accountants Statement No. 2A Management Accounting Glossary (1990).

3.2 Types of Environmental Liabilities

Environmental liabilities arise from a variety of sources. Federal, state, and local environmental statutes, regulations, and ordinances, whether enforced by public agencies or through private citizens' suits, give rise to many types of environmental liabilities. Another legal source of these liabilities is "common law" (i.e., judge-made law) that can vary from state to state. A detailed list of environmental liabilities would be very lengthy. Thus, this report distinguishes the following broad categories of environmental liabilities:

- **compliance** obligations related to laws and regulations that apply to the manufacture, use, disposal, and release of chemical substances and to other activities that adversely affect the environment

- **remediation** obligations (existing and future) related to contaminated real property

- obligations to pay civil and criminal **fines and penalties** for statutory or regulatory non-compliance

- obligations to **compensate** private parties for personal injury, property damage, and economic loss

- obligations to pay "**punitive damages**" for grossly negligent conduct

- obligations to pay for **natural resource damages**

The following paragraphs elaborate on each of these types of environmental liabilities. (Readers who are well-versed in the types of environmental liabilities may want to skip the following few pages and move on to Section 4.)

<u>Compliance obligations</u>. As laws and regulations are enacted that apply to the manufacture, use, or release of regulated substances, companies find themselves facing future compliance costs. In evaluating business plans, some companies may also consider the possibility that new laws and regulations will be enacted. Additionally, a company may discover that it is not in compliance with existing laws and regulations. The costs of coming into compliance can range from modest outlays required to conform to administrative requirements (e.g., recordkeeping, reporting, labeling, training) to more substantial outlays, including capital costs (e.g., to pretreat wastes prior to land disposal or release to surface waters, to contain spills, to "scrub" air emissions). Laws and regulations also impose "exit costs" (e.g., to properly close waste disposal sites and provide for post-closure care, and to decommission nuclear power reactors at the end of their useful lives).

<u>Remediation obligations</u> are sometimes subsumed under "compliance" because some property clean-up requirements have been enacted as part of regulatory programs applicable to operating facilities under, for example, the Resource Conservation and Recovery Act (RCRA) and the Safe Drinking Water Act's Underground Injection Control program. Also, it is easy to

blur the distinction between the compliance obligation of routine closure of facilities at the end of their useful lives and the remediation obligation for cleaning up pollution posing a risk to human health and the environment. And meeting current compliance obligations may help minimize future remediation obligations. Nevertheless, remediation obligations are considered a separate category in this document because of some distinguishing characteristics of the liability and the attention that has been paid to this category of environmental liability. Remediation tends to be expensive, ranging up to many millions of dollars, and can include excavation, drilling, construction, pumping, soil and water treatment, and monitoring, and can include the response costs incurred by regulatory agencies. Remediation costs also can include the provision of alternate drinking water supplies for affected community residents, and, in some circumstances, purchase of properties and relocation expenses. Technical studies and the expenditure of management, professional, and legal resources add to the cost of remediation.

The remediation obligation is distinctive because a company may face remediation obligations due to contamination at inactive sites that are otherwise unregulated; at property formerly but not currently owned or used; at property it never owned or used, but to which its wastes were sent; and, at property it acquired but did not contaminate (e.g., in "Superfund liability" scenarios). Because many dollars will be needed in the near-term to remediate existing environmental contamination, particularly at inactive and abandoned sites, these liabilities often dominate (and can distort) a firm's assessment of its environmental liabilities. Therefore, it is helpful to distinguish between remediation obligations for existing contamination and potential remediation obligations for future contamination because managers can have more impact on ongoing and future activities and releases -- whether accidental or not -- that may trigger future remediation obligations.

<u>Fines and penalties</u>. Companies that are not in compliance with applicable requirements may be subject to civil or criminal fines or penalties for noncompliance and/or expenses for projects agreed to as part of a settlement for noncompliance. Such payments fulfill punitive and deterrent functions and are in addition to the costs of coming into compliance. Fines and penalties (and related outlays for supplemental environmental projects) can range from modest amounts to a few million dollars per violation. Generally, a civil penalty is assessed that is at least equal to the costs a company saved through noncompliance, thus removing any financial incentive to ignore a law. Other factors may add to or reduce the penalty amount assessed for a violation.

Compensation obligations. Under common law and some state and federal statutes, companies may be obligated to pay for compensation of "damages" suffered by individuals, their property, and businesses due to use or release of toxic substances or other pollutants.[7] These liabilities may occur even if a company is in compliance with all applicable environmental standards.

Distinct subcategories of compensation liability include personal injury (e.g., "wrongful death," bodily injury, medical monitoring, pain and suffering), property damage (e.g., diminished value of real estate, buildings, or automobiles; loss of crops), and economic loss (e.g., lost profits, cost of renting substitute premises or equipment). Compensation costs can be fairly minor or quite substantial, depending on the number of claimants and the nature of their claims. Oftentimes, legal defense costs (potentially including technical, scientific, economic, and medical studies) can be substantial in handling such claims, even when the claims are ultimately determined to be without merit. Moreover, responding to compensation claims can consume management time and require expenditures in order to control damage to corporate image. Compensation liabilities may involve costs for remediation of contaminated property as well as provision of alternate water supplies, thus somewhat overlapping the remediation category.

Because of workers' compensation and employer liability laws, payments to compensate employees for occupational exposure and injury from hazardous or toxic substances are not generally determined through litigation against the employer or considered environmental liabilities. However, occupational claims sometimes may be brought against another party who is not the employer; for example, workers responding to a train wreck have sued the shipper of hazardous wastes released at the scene of the wreck; for the shipper, these claims can be viewed as environmental liabilities. Managers will want to understand the potential costs of occupational exposure and injuries, because actions taken to prevent or reduce environmental liabilities may also eliminate or reduce occupational liabilities.

Punitive Damages. To supplement compensatory payments to those harmed by the actions of others, the law allows the imposition of what are called "punitive damages" to punish and deter conduct viewed as showing a callous disregard for others. Unlike compensatory liability, the measure of punitive damages is not directly tied to the actual injuries sustained. Punitive damages are often many times larger than the costs of compensation; although rarely assessed, punitive damages in environmental litigation usually exceed $1 million. Punitive damages tend to be more common in product liability than environmental liability cases; the most notable recent imposition of punitive damages in the environmental context arose from the Exxon *Valdez* spill.

---

[7] This is also known as "toxic tort" liability where the word "tort" is a legal term meaning "a wrong" under common law. Most "toxic tort" cases do not relate to environmental liabilities but fall under the realm of "product liability" where the issues are the danger posed by a "product," such as a pharmaceutical, pesticide, household chemical, or industrial product (e.g., asbestos insulation), and whether there was adequate warning or disclosure of the risk. In contrast, "environmental torts" are most often associated with emissions from a facility, waste disposal sites, and accidental releases.

Natural resource damages. A relatively new category of environmental liability is best termed "natural resource damages." Established by state and federal statutes, notably Section 311 of the Clean Water Act, Section 107 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or "Superfund"), and Section 1006 of the Oil Pollution Act (OPA), this liability generally relates to injury, destruction, loss, or loss of use of natural resources that do not constitute private property. Rather, the resources must belong to or be controlled by federal, state, local, foreign, or tribal governments. Such resources include flora, fauna, land, air, and water resources. The liability can arise from accidental releases (e.g., during transport) as well as lawful releases to air, water, and soil. To date, most natural resource damage payments have been relatively small.[8]

[8] See General Accounting Office, *Superfund: Outlook for and Experience with Natural Resource Damage Settlements* (RCED-96-71) (4/16/96). In June, 1995, the General Accounting Office (GAO) testified before Congress that natural resource damage claims had been settled for relatively small amounts: of 98 cases settled by federal trustees, 48 cases were settled for zero dollars; 36 cases for less than $500,000 each; 9 cases for between $500,000 and $5 million; and 5 cases for greater than or equal to $12 million. GAO also identified 4 states where 17 claims had been settled by non-federal trustees for an aggregate of $23.4 million.

4. Research Findings

4.1 Overview of Findings

4.1.1 General Overview

Discussions of environmental accounting and accounting for environmental liabilities can be found in a variety of accounting, managerial, environmental, and legal publications. Much of the available literature focuses on SEC requirements and generally accepted accounting principles (GAAP) in connection with the reporting of environmental remediation liabilities in external financial statements.[9] It is clear from this literature that rules and practices for measuring (as well as recognizing and reporting) environmental liabilities for a company's *financial statements* are still evolving (See Appendix D). Some of the tools and approaches developed to measure environmental liabilities for these purposes may also be useful for addressing potential environmental liabilities outside of the external reporting context. However, in general, the requirements and limitations (e.g., focus on expenditures and materiality at the level of the firm as a whole) of this branch of environmental accounting result in data that do not meet the needs of most managers for disaggregated, forward-looking information for planning, decision-making, and operations.

Environmental accounting literature oriented towards *managerial decision-making* focuses on (1) methods for evaluating pollution prevention investments, (2) examples of financially and environmentally attractive actions taken by companies, and (3) internal recognition and proper allocation of environmentally-driven expenditures. This literature often refers to the value or importance of considering the dollar magnitude of environmental liabilities, but tends to stop there. Or, the literature describes elements to be considered in valuing environmental liabilities without providing numerical illustrations, detailed methodologies, databases, or default values. Some of the literature claims that environmental liabilities cannot be estimated, and some provides qualitative scoring approaches only. But more of the authors make the point that even an uncertain monetary estimate may be better than ignoring a potential environmental liability, which implicitly equates to a monetary value of zero. In failing to place a value on environmental liabilities, managers may reject pollution prevention actions that would be seen as financially attractive if the potential reduction in liability costs were valued. EPA's *Pollution Prevention Benefits Manual*[10] recognizes that accounting for conventional costs (e.g., labor, materials, and utilities) and potentially hidden environmental costs in project financial analyses alone will often suffice to identify financially attractive pollution prevention actions, and suggests a middle course: value environmental liabilities only when they might make a difference in the cost-benefit calculus or assess what the value of avoided liability costs would have to be for the pollution prevention action to make financial sense.

---

[9] A parallel body of literature addresses tax treatment of environmental remediation expenditures.

[10] See reference *28 in Appendix B and the associated profile in Section 5.

4.1.2 Valuation Approaches

There are a variety of general *approaches* to valuing environmental liabilities, such as actuarial techniques, professional judgment, engineering cost estimation, decision analysis/ statistical techniques, modeling, scenario techniques, and valuation methods. These approaches have been developed and applied, usually in combination, in specific *tools* for valuing particular types of environmental liabilities that can arise from certain situations, as discussed starting on page 19. Although full explanations of these general approaches go beyond the scope of this document, they can be described as follows:

<u>Actuarial techniques</u> involve the statistical analysis of historical data on the costs and/or occurrence of environmental liabilities or events (such as accidents) or consequences (such as adverse health outcomes) that can lead to environmental liabilities.

<u>Professional judgment</u> includes the expert judgment of engineers, scientists, lawyers, environmental specialists, and other professionals.[11] Specifically, engineering judgment can be used to identify appropriate compliance and remediation activities and estimate the likelihood of accidental releases; scientific judgment can be used to assess hazards, the transport and fate of substances released to the environment, and the potential responses of exposed plants, animals, human beings, their property, and ecosystems; and legal judgment can be used to assess legal bases for liability and potentially recoverable damages.

<u>Engineering cost estimation</u> develops costs (e.g., for remediation, restoration, compliance, provision of replacement water supplies) by systematically identifying required implementation activities (termed activity-based estimating) and corresponding units, unit costs (e.g., labor, materials, utilities), and contingency factors or through parametric cost estimation which uses cost equations, either individually or grouped into more complex models, developed by analyzing the correlation between cost drivers and costs.[12] A *life cycle cost* estimate encompasses all costs, including design, development, operation, maintenance, and final disposition over the anticipated lifespan of a process, product, facility, or system.

<u>Decision analysis techniques</u> (e.g., event trees, probability distributions, level of confidence calculations) are used in structuring expert judgment, reflecting (and quantifying) uncertainties in liability valuation, and in characterizing and presenting the results of environmental liability valuation.[13] Uncertainties regarding the magnitude, likelihood, and timing of potential environmental liabilities can be explicitly addressed, producing a set of liability values and their associated likelihoods.

---

[11] See, for example, Cooke, R.M. *Experts in Uncertainty: Opinion and Subjective Probability in Science* (Oxford University Press, New York, 1991).

[12] See, for example, Humphreys, K. (ed.), *Project and Cost Engineers Handbook*, American Association of Cost Engineers (Marcel Dekker, Inc., New York, 1984).

[13] See, for example, Ross, S.M. *Introduction to Probability Models, 3rd Ed.* (Harcourt Brace Jovanovich Publishers, 1985) and Schaeffer, Richard and James McClave, *Probability and Statistics for Engineers, 3rd Ed.* (PWG-Kent Publishing Co., Boston, 1990).

Modeling is used as an alternative or supplement to professional judgment when historic data are limited or not available, and cost or occurrence values must be simulated due to many uncertain variables or complex interactions. (A *model* is a set of equations and associated rules for their applicability and interaction.) Modeling typically draws upon available data; professional judgment; quantitative expressions of pollutant release, transport, fate, exposure, and consequences; and statistical analysis techniques.

Scenario techniques are used to describe and address future situations that can affect environmental liabilities, such as changes in regulatory requirements, remediation policy, legal standards for compensation and natural resource damages, and enforcement policy. A few scenarios can bracket a wide range of possibilities, represent diverse views, and challenge managerial thinking. The scenario development process involves the formal elicitation of expert judgments about future environmental scenarios.[14]

Valuation methods include a variety of legal rules and economic techniques for putting monetary values on environmental consequences for compensation and natural resource damage liabilities, respectively. Legal approaches to valuation of injuries to people, their property, and their businesses comprise the accepted practices that have been developed and used to put monetary values on compensation claims in litigation. Different types of claims (e.g., fear of cancer, increased risk, clinical impairment, morbidity, pain and suffering, mortality, diminished market value, lost profits) will each have their own valuation approaches, which can vary across legal jurisdictions. Economic approaches to valuing the services provided by natural resources that are not privately-owned constitute a set of techniques intended to value, directly or indirectly, the various use and non-use services injured or lost due to releases of pollutants.

[14] See, for example, Schoemaker, P.J.H. "When and How to Use Scenario Planning: A Heuristic Approach with Illustration," *Journal of Forecasting*, v. 10, 1991, pp. 549-564, and "Scenario Planning: A Tool for Strategic Thinking," *Sloan Management Review*, v. 36, Winter 1995, pp. 25-40.

4.1.3 Overview of Valuation Tools

This research has documented a diverse set of specific tools that employ one or more approaches to value environmental liabilities. **Some of the tools can help the user calculate potential liability costs and/or provide monetary values, while other tools describe either a more general process for developing, or a framework for using, such monetary estimates; this latter group may or may not provide clear illustrations or examples.** The level and clarity of documentation vary considerably, both within and across tools. For some of the tools, the source(s) of key information (e.g., liability costs per unit, probability of accident) are not provided; other tools may require the user to estimate such variables, but provide little in the way of guidance or benchmarks to help that process. The diversity of features, approaches, and orientations in the tools makes them very difficult to classify.

For the most part, the tools have been developed to address specific situations or answer specific questions. Often, the results or methods may be applied to other situations or questions. Linking the results or approaches of different tools may be feasible for some situations but not for others. The tools uncovered in this research do not address all potentially relevant situations; and the research uncovered no comprehensive, up-to-date compilations of data that could be used in assessing magnitude, likelihood, and timing of all potential liabilities.

Currently, the most common applications of environmental liability valuation tools relate to waste management and disposal, and releases from underground storage tanks of petroleum, with fewer tools applied to releases from fixed facilities. Exhibit 1 is an attempt to show how the reported tools identified in this study map across various situations and the types of liabilities described in the preceding section of this report. ***Important note: Throughout the exhibits and the text of this section, identified tools are referred to by their reference numbers from the annotated bibliography in Appendix B (starting on page 105). Tool reference numbers marked with an asterisk (*) are also profiled in Section 5 (starting on page 35).***

It is not always clear in the literature which liabilities or situations are being or can be addressed by a tool. Thus, assigning valuation tools to the pigeonholes in Exhibit 1 is sometimes problematic. Although liability valuation tools appear to have been developed and applied to most of the applicable cells of the Exhibit 1 matrix, there is not an abundance of tools available. In addition, with a few exceptions, the documented tools are generally not stand-alone commercially available software packages or workbooks.[15]

---

[15]This report does not present a side-by-side comparison of values, assumptions, or approaches used to address different environmental liabilities.

EXHIBIT 1

LIABILITIES AND SITUATIONS ADDRESSED BY VALUATION TOOLS

(Numbers refer to the tools' reference numbers in the Annotated Bibliography in Appendix B.)

(* Asterisked items are also profiled in Section 5.)

	TYPE OF LIABILITY					
TYPE OF SITUATION	**Compliance**	**Remediation**	**Compensation**	**Fines and Penalties**	**Punitive Damages**	**Natural Resource Damages**
Active Waste Disposal Site	*13, *24, *25	*1, 4, 5, *10, 11, *13, 19, *22, *24, *25, *28, *29, 37	4, 5, *10, *13, 19, *24, *25, *28, *29	5, *27, *28	none found	*10, *19, *24, *26, *28, *29
Inactive Waste Disposal Site	not applicable	4, 5, *14, 15, *21, 37	*21, *36	not applicable	none found	*26
Release from Underground Storage Tank	not applicable	*6, *7, *12, 15, *30, 31, 35	*6, *7, *12, *30	*27, *28	none found	none found
Facility Operations	3, *13, 32	not applicable	*8, *13, *22	5, *13, *22, *27, *28	none found	*13, *22, *26
Operating Facility: Accidental Release	not applicable	not applicable	*2, 4, 5, *17, 33	5, *27, *28	none found	9, *22, *23 *26, *28, 34
Operating Facility: Intentional Release	*16, 18	not applicable	4, 5, *21	5, *27, *28	none found	9, *23, *26
Accidental Release During Transport	not applicable	*8, *14, *20, *25, *28	4, 5, *20, *25	none found	none found	9, *20, *23, *26, *28, 34

4.1.4 Data Sources and Requirements

The tools draw upon different sources and types of data relating to the potential magnitude, likelihood, and timing of environmental liabilities. Some of the tools require more or less data as inputs, while others provide answers or default values. Some of the tools take the form of stand-alone models/databases, others represent the results of models, while some are primarily judgment driven. Many of the more complex or data-driven tools were developed with funding from state and federal government agencies; a smaller number are the products of industry or consultants/academics. Liability valuation techniques may be embedded in larger decision-support tools or may be independent.

Exhibit 2 distinguishes between (1) those tools that require input data and (2) those that provide environmental liability values through tables, graphs, and statistics. Tools that require user inputs differ greatly in the number and types of data inputs required. Many of those tools (e.g., 2, 3, 9, 10, *17, *21, *22, *23, *26, *27, *28, 34) require inputs to an existing model or framework to yield site-specific results. Others in this first group rely heavily on expert judgment and decision analysis techniques (e.g., *8, *13, *14, 15, *16, 37), though they can also incorporate hard data. Tools in the second group report results for *populations* of regulatory violations (5), active waste sites (11, *29), underground storage tanks (*6, *7, *12, *30, 31, 35), transportation vehicles (*20), and waste streams (*24, *25); *generic* values (*1, 19, 33); or *case examples* (5, *36). Some of the tools in the first group draw upon the results presented in tools of the second group.

EXHIBIT 2
DATA REQUIREMENTS OF TOOLS
(Numbers refer to the tools' reference numbers in the Annotated Bibliography in Appendix B.)
(*Asterisked items are profiled in Section 5.)

Requires Inputs	Requires No Inputs
2, 3, *8, 9, *10, *13, *14, 15, *16, *17, *21, *22, *23, *26, *27, *28, 34, 37	*1, 5 (case examples), *6, *7, 11, *12, 18, 19, *20, *24, *25, *29, *30, 31, *32, 33, 35, *36 (case example)

Several of the tools include computer models available to the public that were developed by government agencies for automating calculation of natural resource damages (e.g., DOI, NOAA) and other potential environmental liabilities (*22, *27). Other tools represent the results of computer models, most of which were developed for government agencies, though the models themselves are not currently available to the public (*7, 11, *12, *16, 19, *20, *24, *25,*29). Other tools represent simple models (e.g., *1, 33) or frameworks (e.g., *10, *21, *28) that users can easily use or adapt.

4.1.5 Scale of Application of Approaches and Tools

Environmental liability valuation approaches and, hence, tools that use those approaches, differ in the *scale* of their application -- a single process (e.g., waste disposal) or unit (e.g., underground storage tank), an entire facility, a population of units, or an entire company. Liabilities can be valued through **bottom-up** or **top-down** approaches. The former focuses on the liabilities of individual units of a firm or classes of liabilities and can serve as stepping stones to estimate firm-wide aggregate environmental liability. The latter approach starts with an aggregate liability estimate and apportions that liability to industries and firms (and, by extension, subdivisions and operations within firms).

Most of the identified tools appear to take a bottom-up approach, some characterize a population's environmental liabilities (see Section 4.1.4), and examples of the top-down approach are few. Some of the tools focus on waste management approaches (e.g., *1, *10, *24, *25), others focus on the industrial process level (e.g., *2, *13, *16, *28), while others deal with incidents (e.g., *8, 9, 19, *20, *23, *26, 34), and a small number of tools relate to specific chemical substances (e.g., 18, *22).

4.2 Valuation Tools by Type of Liability

This section reviews the tools identified by EPA that address the potential environmental liabilities defined in Section 3. The text discusses the tools in general terms, rather than individually, by each liability category.

Compliance Liabilities

Although some companies disclose material future compliance costs in conformance with SEC requirements, EPA found no references that describe the tools or approaches used to develop these overall, company-wide projections. With respect to future compliance costs for ongoing or future operations, most of the literature focuses on explaining coming regulatory requirements and describing technical compliance options. What little is published to help companies estimate the future costs of compliance focuses primarily on "end-of-pipe" abatement technologies and employs engineering cost estimation (see ref. 18). Historical data on compliance costs are rarely publicly available in any useful detail and may not be particularly helpful in developing cost estimates for new regulatory requirements, with some exceptions such as the costs of certain standard administrative requirements (e.g., recordkeeping), sampling and analysis, and common pollution treatment technologies. (A company's ability to project future compliance costs additionally may be hindered by the lack of accounting visibility for current compliance costs, which are frequently embedded with a variety of other costs.[16])

---

[16] This parenthetical note also applies to the other types of environmental liabilities addressed in this report. For more information on the hidden nature of environmental costs in managerial accounting systems, see *An Introduction to Environmental Accounting as a Business Management Tool: Key Concepts and Terms* (EPA 742-R-95-001, June 1995).

A tool has been developed to project potential compliance costs for regulated nuclear power reactors (see ref. 32). Some engineering cost estimation tools (e.g., guides, references, checklists) have been developed and used to estimate the future costs of the compliance obligations of closure/decommissioning/post-closure care for waste management facilities and nuclear power reactors (see ref. 3).[17]

In addition to future compliance obligations due to established statutes or regulations, companies also face potential future compliance costs from laws yet to be enacted, such as regulatory requirements for hazardous air pollutants emitted by powerplants or regulation of cement kiln dust as a hazardous waste. Industries with long planning horizons and that are responsible for substantial pollution may want to factor such potential environmental liabilities into their decision-making. The electrical power industry seems to have done the most in considering such potential liabilities. The scenario approach combined with engineering cost estimation is particularly well-suited for this application; Niagara Mohawk included prospective environmental requirements in its financial analysis in order "to provide a realistic reflection of the future environmental costs likely to be imposed" on its units (see ref. *16).

Exhibit 3A displays the tools that address future compliance costs.

EXHIBIT 3A
(*Asterisked items are profiled in Section 5.)

TOOLS THAT ADDRESS COMPLIANCE LIABILITIES		
Environmental Situation Covered	**Tool's Bibliography Reference # (Appendix B)**	**Approach(es) Used**
Active Waste Disposal Site	*13	Decision Analysis, Judgment
	*24, *25	Engineering Cost Estimation
Facility Operations	3	Engineering Cost Estimation
	*13	Decision Analysis, Judgment
	*32	Engineering Cost Estimation, Judgment
Operating Facility: Intentional Release	*16, 18	Scenario, Engineering Cost Estimation

[17] These future "exit costs" have received increased attention for financial reporting. See references listed in Appendix D, such as the Financial Accounting Standards Board (FASB) *Exposure Draft, Accounting for Certain Liabilities Related to Closure or Removal of Long-Lived Assets* and the Governmental Accounting Standards Board (GASB) Statement No. 18 *Accounting for Municipal Solid Waste Landfill Closure and Post Closure Care Costs* (August, 1993).

Remediation Costs

As discussed in Appendix A of this report, remediation liabilities may arise as future costs resulting from (1) past activities that have since ceased, (2) continuing activities, and (3) future activities that have not yet started. Due to both timing and contingency issues (also discussed in Appendix A), organizations may not yet know the full extent of remediation liabilities that will result from past activities that have ceased (e.g., unidentified releases or spills) and even past activities that are still ongoing.[18] Although managers may be able to mitigate these liabilities, they cannot prevent them. On the other hand, changes to ongoing activities and plans for the future can affect the remediation liabilities that companies will incur by reducing the number and size of required remediations.

Inactive Waste Sites. Much attention in developing tools for valuing environmental liabilities has focused on the remediation liabilities of existing, inactive waste sites (e.g., Superfund liability), as opposed to currently active or future waste sites. This attention to remediation liabilities relates both to financial reporting issues (e.g., disclosure, recognition, measurement) (see Appendix D) and to management needs to understand the costs of alternative remediation strategies for existing, inactive waste sites. This is an area characterized both by (1) a growing body of public data on the costs of remediation as well as (2) uncertainties about the cost and success of alternative remediation strategies. Use of decision analysis techniques and models (see refs. 5, *13, *14, 15, 37) has been illustrated as a means of addressing these liabilities.

Because companies may not be aware of all of their remediation liabilities for existing, inactive waste disposal sites (e.g., due to lack of records, prior sale of properties/businesses), some approaches drawing upon actuarial and scenario techniques have been developed to estimate those potential liabilities. Here the goal is to estimate the costs of remediating inactive sites that an organization has not identified but for which it may be responsible. Both "top-down" and "bottom-up" approaches (as described on page 19) have been addressed in the literature (see refs. 4, *21).

Active Waste Sites and Future Remediation. Because there is much less historical data on the costs of remediating *active* and future waste management facilities, non-actuarial approaches, such as use of scenarios, engineering judgment and cost estimation, and modeling have been employed. In response to past Congressional interest in the future liabilities of active waste sites regulated under RCRA, EPA conducted a major study of the magnitude, timing, and likelihood of future remediation costs (see ref. *29) and has performed related studies since. Some of this work has been converted into more user-friendly tools requiring a limited number of input parameters to develop ballpark cost estimates (see refs. 1, *10, 11, *13, 19, *22, *24, *25, 28).

Valuation of remediation liabilities resulting from accidental releases during transport has built on actuarial data concerning accident frequencies, consequence modeling, and engineering cost estimation for developing corresponding monetary values (see, especially, ref. *20; see also

[18] Risk managers, insurers, and reinsurers often refer to these unknown liabilities as Incurred But Not Reported (IBNR) Losses.

refs. *8, *25, *28). Valuation of remediation liabilities due to future spills at fixed facilities was handled in a similar fashion (see ref. *28).

Much work has been reported in estimating the costs, timing, and likelihood of remediation liabilities for existing and future leaks from underground (and, to some extent, aboveground) storage tanks (USTs) of petroleum (see refs. *6, *7, *12, *13, *30, 31, 35). Valuation tools for remediation liabilities for petroleum USTs have had the advantage of extensive remediation claims history data made available by insurance entities; although the documented applications have been prepared for state-level UST funds or agencies, the techniques are also applicable to companies responsible for large numbers of USTs.

Exhibit 3B lists the tools that address remediation liabilities.

EXHIBIT 3B
(*Asterisked items are profiled in Section 5.)

TOOLS THAT ADDRESS REMEDIATION LIABILITIES		
Environmental Situation Covered	**Tool's Bibliography Reference # (Appendix B)**	**Approach(es) Used**
Active Waste Disposal Site	*1, *22	Modeling
	4, *24, *25	Actuarial, Engineering Cost Estimation, Modeling
	5, 11	Engineering Cost Estimation, Modeling
	*10	Scenario
	*13, 37	Decision Analysis, Judgment
	19	Actuarial, Engineering Cost Estimation, Judgment, Modeling
	*28	Engineering Cost Estimation, Scenario
	*29	Engineering Cost Estimation, Judgment, Modeling
Inactive Waste Disposal Site	4	Actuarial, Engineering Cost Estimation, Judgment, Valuation
	5, *21	Actuarial
	*14, 15	Decision Analysis
	37	Decision Analysis, Judgment
Release from Underground Storage Tank	*6	Judgment, Modeling, Valuation
	*7, *12, *30	Actuarial, Judgment, Modeling
	15	Decision Analysis
	31, 35	Actuarial, Judgment
Accidental Release During Transport	*8	Actuarial, Judgment, Modeling
	*14	Decision Analysis
	*20	Actuarial, Engineering Cost Estimation, Judgment
	*25	Actuarial, Engineering Cost Estimation, Modeling
	*28	Engineering Cost Estimation, Scenario
Not Specified	*13	Decision Analysis, Judgment
	*22	Scenario

Compensation Liabilities

Just as for remediation liabilities, compensation liabilities also may arise as future costs resulting from (1) past activities that have since ceased, (2) ongoing activities, and (3) future activities that have not yet started. Due to timing and contingency issues discussed in Appendix A, organizations may not yet know the full extent of compensation liabilities that will result from the exposure of property and persons to pollutants from past activities that have ceased and activities that are still ongoing. There may be little that managers can do about these liabilities. On the other hand, changes to ongoing activities and plans for the future can affect the compensation liabilities that companies will incur. Valuing the likely costs and benefits of such changes is challenging, and only a limited amount of work to do so has been reported.

For compensation liabilities, an actuarial approach has proved feasible primarily for USTs -- to assess the magnitude, timing, and likelihood of compensation liabilities due to existing contamination as well as to releases yet to happen (see refs. *6, *7, *12, and *30). Petroleum USTs comprise a large population of relatively homogeneous facilities for which several years of compensation claims data had been pooled and made available by two insurance entities that provided the bulk of coverage for the industry. Moreover, most of the compensation liabilities from petroleum USTs have related to property damage, not personal injury; there is likely to be less uncertainty in measuring property damage liabilities than in valuing personal injury liabilities. Actuarial approaches have been used as a basis for other environmental compensation liabilities, although the available data (e.g., court awards and settlements) are sparse (see ref. *28); in other instances, the available data have been used as a "reality check" of insurance requirements,[19] modeling, and valuation approaches (see refs. *17, *25). Because of limited reported data on environmental compensation liabilities, surrogate data has been used drawn from other toxic tort litigation (e.g., asbestos) or more general sources (e.g., personal injury awards and settlements).

Other approaches have been applied to the compensation liabilities that arise from accidental releases from the transport of hazardous materials (specifically, low-level radioactive materials) and land disposal of hazardous waste. Environmental liabilities associated with hazardous material transportation and waste disposal can be readily factored into management decisions about routing or waste management practices, respectively, particularly when expressed in monetary terms (see refs. *10, 19, *20, *24, *25, *28, *29). Compensation liabilities due to transport of hazardous materials have been valued using actuarial data for transportation accidents, modeling consequence (e.g., exposure) scenarios, and applying "legal approaches" to valuation. (See ref. *20.) For the Report to Congress on the potential dollar liabilities of active RCRA land disposal facilities noted on page 20 above (see ref. *29), EPA's study modeled events and applicable legal regimes to assess the occurrence and timing of compensation claims, which were valued using legal valuation approaches.

Valuation techniques for compensation liabilities due to continuing, accidental, or catastrophic releases to air and water from operating facilities, have not been reported in literature. Work to develop "unit liability factors" for industrial facilities releasing pollutants to the air, land, and water was commissioned by the American Institute of Chemical Engineers

---

[19] In the 1980s, the EPA collected data on reported environmental compensation awards and settlements to assess the adequacy of liability coverage limits established for regulated waste management facilities and underground storage tanks of petroleum.

(AIChE) but not published.[20] A scenario-based scaling approach has been used to develop order of magnitude estimates of compensation liability for an entire corporation (see ref. *21). Compensation for injuries to property or employees has been valued using diverse techniques (see refs. *2, *8, *17, 33, and *36).

Exhibit 3C lists the tools that address compensation liabilities.

[20] The AIChE Center for Chemical Process Safety has published *Guidelines for Hazard Evaluation Procedures* (1992), which describes methodologies to identify hazards and qualitatively assess the associated risk; *Guidelines for Chemical Process Quantitative Risk Analysis* (1989), which describes techniques for quantifying risk in a chemical storage or processing facility and introduces a risk management framework; and *Tools for Making Acute Risk Decisions* (1995), which expands upon the previous books but does not address valuation of environmental liabilities.

EXHIBIT 3C
(*Asterisked items are profiled in Section 5.)

TOOLS THAT ADDRESS COMPENSATION LIABILITIES		
A. Compensation for private property damages, personal injury, and economic loss		
Environmental Situation Covered	**Tool's Bibliography Reference # (Appendix B)**	**Approach(es) Used**
Active Waste Disposal Site	5, 19, *24, *29	Actuarial, Modeling, Valuation
	*10, *28	Scenario
	*13	Decision Analysis, Judgment
	*25	Actuarial, Modeling, Scenario
Release from Underground Storage Tank	*6	Judgment, Modeling
	*12, *30	Actuarial, Judgment, Modeling
Facility Operations	*13	Decision Analysis, Judgment
	*22	Actuarial, Modeling
Operating Facility: Accidental Release	*17	Judgment, Scenario
Accidental Release During Transport	*20	Actuarial, Modeling, Valuation
	*25	Actuarial, Modeling, Scenario
B. Compensation for Private Property Damages Only		
Inactive Waste Disposal Site	*36	Actuarial, Modeling
Release from Underground Storage Tank	*7	Actuarial, Judgment
Operating Facility: Accidental Release	*2	Actuarial, Modeling
C. Compensation for Personal Injury Only		
Active Waste Disposal Site	4	Actuarial, Modeling, Valuation
Facility Operations	*8	Actuarial, Judgment, Modeling
Operating Facility: Accidental Release	4, 5	Actuarial, Modeling, Valuation
	33	Modeling, Valuation
Operating Facility: Intentional Release	4, 5	Actuarial, Modeling, Valuation
	*21	Judgment, Scenario
Accidental Release During Transport	4, 5	Actuarial, Modeling, Valuation

Fines and Penalties

In published literature, this category of environmental liability is frequently mentioned as important, and EPA and others[21] have published extensive data on assessed fines and penalties. Although fines and penalties are amenable to actuarial treatment, there is little in the literature, with few exceptions, on how to use or apply this information in making forward-looking decisions (see refs. 5, *22, and *28). EPA has developed a framework for identifying and converting to net present values the financial savings from non-compliance (see ref. *27), which can be used as a baseline measure of potential fines and penalties.

Exhibit 3D shows the tools that address potential fines and penalties.

[21] For example, see Cohen, Mark A., Scott A. Fenn, and Jonathan S. Naimon. *Environmental and Financial Performance: Are They Related?*, Investor Responsibility Research Center (IRRC), Washington, D.C., 1995.

EXHIBIT 3D
(*Asterisked items are profiled in Section 5.)

TOOLS THAT ADDRESS FINES AND PENALTIES		
Environmental Situation Covered	**Tool's Bibliography Reference # (Appendix B)**	**Approach(es) Used**
Active Waste Disposal Site	5	Actuarial
	*27	Engineering Cost Estimation
	*28	Actuarial, Judgment
Release from Underground Storage Tank	*27	Engineering Cost Estimation
	*28	Actuarial, Judgment
Facility Operations	5	Actuarial
	*22	Actuarial, Scenario
	*27	Engineering Cost Estimation
	*28	Actuarial, Judgment
Operating Facility: Accidental Release	5	Actuarial
	*27	Engineering Cost Estimation
	*28	Actuarial, Judgment
Operating Facility: Intentional Release	5	Actuarial
	*27	Engineering Cost Estimation
	*28	Actuarial, Judgment
Not Specified	*13	Judgment, Decision Analysis

Punitive Damages

Punitive damages are so infrequent in environmental compensation litigation that they have not received attention in published literature on valuing environmental liabilities for forward-looking management decisions. Moreover, the lack of guidelines or common practices for determining the magnitude of punitive damages makes this category of environmental liability very difficult to value, except, perhaps, through use of scenario approaches.

Natural Resource Damages

Typically, natural resource damages are quantified in terms of lost services, due to the injury or death of fish and/or wildlife or closure of recreational areas, and the cost of restoration actions. This is the approach historically or currently recommended by the key agencies of the Federal government responsible for issuing guidance on the calculation of damages to natural resources (see refs. *23, *26). Some states have also developed schedules or models for valuing natural resource damages due to discharges into water (see refs. 9, 34).

Natural resource damage assessment regulations promulgated by the Department of the Interior (DOI) under CERCLA and by the National Oceanic and Atmospheric Administration (NOAA) under the Oil Pollution Act establish procedures to measure injury to natural resources. DOI has developed two types of procedures to correspond to the requirements under CERCLA, the Type A and Type B procedures. The Type A procedures consist of two computerized models, one for coastal and marine environments and one for Great Lakes environments, for calculating damages from minor releases of hazardous substances. The Type B procedures consist of site-specific procedures for conducting detailed damage assessments in other cases (see ref. *26).

The Type A models, the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME) and the Natural Resource Damage Assessment Model for the Great Lakes Environments (NRDAM/GLE) capture a limited range of injuries and values (e.g., restoration costs and lost use values). The Type B procedures may be used to estimate the lost economic value from damages not covered by the Type A models. (See also Appendix C.)

NOAA has developed regulations that apply to oil discharges into water habitats (see ref. *23). The regulations allow for the recovery of damages to natural resources for the restoration, rehabilitation, or replacement of the resource, or the acquisition of equivalent resources and services (generally referred to as restoration). The NOAA approach emphasizes restoration of injured resources, not valuation (e.g., compensation formulas for small incidents have been dropped).

Exhibit 3E presents the tools that address natural resource damages.

EXHIBIT 3E
(*Asterisked items are profiled in Section 5.)

TOOLS THAT ADDRESS NATURAL RESOURCE DAMAGES		
Environmental Situation Covered	**Tool's Bibliography Reference # (Appendix B)**	**Approach(es) Used**
Active Waste Disposal Site	*10	Scenario
	19	Valuation
	*24	Engineering Cost Estimation, Modeling, Valuation
	*26 (not federally permitted releases)	Engineering Cost Estimation, Modeling, Scenario, Valuation
	*28	Actuarial, Scenario
	*29	Actuarial, Engineering Cost Estimation, Judgment
Inactive Waste Disposal Site	*26	Engineering Cost Estimation, Modeling, Valuation, Scenario
Facility Operations	*13	Decision Analysis, Judgment
	*22	Modeling, Scenario
	*26	Engineering Cost Estimation, Modeling, Scenario, Valuation
Operating Facility: Accidental Release	9	Scenario, Valuation
	*22	Modeling, Scenario
	*23, *26	Engineering Cost Estimation, Modeling, Scenario, Valuation
	*28	Engineering Cost Estimation, Scenario
	34	Modeling, Valuation
Operating Facility: Intentional Release	9	Scenario, Valuation
	*23, *26 (not federally permitted releases)	Engineering Cost Estimation, Modeling, Scenario, Valuation
Accidental Release During Transport	9	Scenario, Valuation
	*20	Valuation
	*23, *26	Engineering Cost Estimation, Modeling, Scenario, Valuation
	*28	Actuarial, Engineering Cost Estimation, Scenario
	34	Modeling, Valuation

4.3 Summary

This section described the findings of EPA's research to identify techniques for valuing environmental liabilities. Using a fairly broad definition of potential environmental liabilities, EPA located over three dozen references with potential applicability to forward-looking management decisions. These tools have not previously been compiled in a single reference and may not have been widely known or available. The tools vary greatly in terms of the approaches that they employ, in their data sources and requirements, and in their scale of application. They also differ widely in their applicability to the variety of specific liability types and situations.

This collection of tools can help users in thinking about how to value potential environmental liabilities. The tools also may provide information and data to answer specific questions. Potential users of these tools may want to consider the value of updating information found in some of the tools. EPA hopes that this information will lead to more attention being paid to valuing potential environmental liabilities and greater documentation of techniques for doing so.

All of the tools for valuing environmental liabilities found in the course of EPA's research are displayed in Exhibit 4. *The references in the exhibit and the following text refer to the annotated bibliography provided in Appendix B (beginning on page 105). All asterisked items are profiled in Section 5 of this report (starting on page 35).*

EXHIBIT 4

Overview of Environmental Liability Valuation Tools

Key to Exhibit 4

Liabilities Addressed	**Approaches Used**	**Situations Addressed**
C Future Compliance (Excluding Remediation) R Remediation CD Compensation for Damages including private property damages, personal injury, and economic loss CDPP Compensation for Damages, Private Property only CDPI Compensation for Damages, Personal Injury only FP Fines and Penalties NR Natural Resource Damages	A Actuarial J Professional Judgment E Engineering Cost Estimation D Decision Analysis M Modeling S Scenario V Valuation	WD Waste Disposal, Active and Inactive Sites WDI Waste Disposal, Inactive Sites only WDA Waste Disposal, Active Sites only UST Releases from Underground Storage Tanks T Transportation Accident F Facility Operations FA Operating Facility: Accidental Release FI Operating Facility: Intentional Release

EXHIBIT 4: Overview of Environmental Liability Valuation Tools (*Asterisked items are profiled in Section 5.)				
TITLE	**Tool's Bibliography Reference # (Appendix B)**	**Liability(ies) Addressed**	**Approach(es) Used**	**Situation(s) Addressed**
Expected Value Estimates of the Long-Term Liability from Landfilling Hazardous Waste	*1	R	M	WDA
Dow's Fire & Explosion Index Hazard Classification Guide	*2	CDPP	A, M	FA
Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates	3	C	E	F
Quantifying Environmental Exposures for Business Decisions: Approaches to Monetizing Environmental Liabilities	4	CDPI, R	A, E, J, M, V	FA, FI, T, WD
Expressing Environmental Liabilities in Dollars and Cents: What Corporations Can Do Now	5	CD, FP, R	A, M, V, E	F, FA, FI, T, WD
An Actuarial Approach to Quantifying Environmental Exposure	*6	CD, R	J, M, V	UST
Missouri Underground Storage Tank Insurance Fund	*7	CP, R	A, J, M	UST
Information-Limited Bayesian Benefit-Risk Analysis for Sustainable Process Design	*8	CDPI, R	A, J, M	F, T
Florida's Pollutant Discharge Natural Resource Damage Assessment Compensation Schedule	9	NR	S, V	FA, FI, T
Financial Analysis of Waste Management Alternatives	*10	CD, NR, R	S	WDA
Estimating the Costs of Corrective Action at Land Disposal Facilities	11	R	E, M	WDA
State of Indiana - Analysis of Funding Requirements for the Petroleum Underground Storage Tank Excess Liability Fund	*12	CD, R	A, J, M	UST
Use of Decision Science Techniques in Management of Environmental Financial Risks	*13	CD, FP, NR, R	D, J	F, WDA

EXHIBIT 4: Overview of Environmental Liability Valuation Tools (*Asterisked items are profiled in Section 5.)

TITLE	Tool's Bibliography Reference # (Appendix B)	Liability(ies) Addressed	Approach(es) Used	Situation(s) Addressed
Using Decision Analysis to Manage Environmental Costs	*14	R	D	T, WDI
The Shape of Risk: A Protocol for Environmental Financial Risk Management	15	R	D	UST, WDI
How Niagara Mohawk Incorporates Environmental Factors into Policies, Plans, and Procedures	*16	C	E, S	FI
Financial Evaluation of Environmental Investments	*17	CD	J, S	FA
Current and Potential Future Industrial Practices for Reducing and Controlling Volatile Organic Compounds	18	C	E	FI
Financial Assurance Requirements for Low-Level Radioactive Waste Disposal Facilities	19	CD, NR, R	A, E, J, M, V	WDA
Risk Assessment and Financial Surety Requirements Analysis for Transportation of Low-Level Radioactive Waste in New York State	*20	CD, NR, R	A, E, J, M, V	T
Estimating Environmental Liability: Quantifying the Unknown	*21	CDPI, R	A, J, S	FI, WDI
Hazardous Materials Cost Trade-Off Analysis Tool	*22	CD, FP, NR, R	A, M, S	F, FA, WDA
Natural Resource Damage Assessments	*23	NR	E, M, S, V	FA, FI, T
A Comparison of the True Costs of Landfill Disposal and Incineration of DoD Hazardous Wastes	*24	C, CD, NR, R	A, E, M, V	WDA
Least-Cost DoD Hazardous Waste Management Strategies	*25	C, CD, R	A, E, M, S	T, WDA
Hazardous Substances Natural Resource Damages Assessment Regulations	*26	NR	E, M, S, V	F, FA, FI, T, WD
BEN: A Model to Calculate the Economic Benefits of Non-Compliance	*27	FP	E	F, FA, FI, UST, WDA

EXHIBIT 4: Overview of Environmental Liability Valuation Tools (*Asterisked items are profiled in Section 5.)				
TITLE	**Tool's Bibliography Reference # (Appendix B)**	**Liability(ies) Addressed**	**Approach(es) Used**	**Situation(s) Addressed**
Pollution Prevention Benefits Manual	*28	CD, FP, NR, R	A, E, J, S	F, FA, FI, T, UST, WDA
Post-Closure Liability Trust Fund Simulation Model	*29	CD, NR, R	A, E, J, M, V	WDA
Analysis of Kansas State Fund for Approval as Alternative Financial Assurance Mechanism	*30	CD, R	A, J, M	UST
Evaluation of Fund Amount for the Nebraska Petroleum Release Remedial Action Cash Fund	31	R	A, J	UST
FORECAST: Regulatory Effects Cost Analysis Software Manual	*32	C	E, J	F
Reassessment of NRC's Dollar Per Person-Rem Conversion Factor Policy	33	CDPI	M, V	FA
Preassessment Screening and Oil Spill Compensation Schedule Regulations	34	NR	M, V	FA, T
Joint Agency Report on the Petroleum Storage Remedial Action Fund (PECFA)	35	R	A, J	UST
Measuring Property Value Impacts of Hazardous Waste Sites	*36	CDPP	A, M	WDI
Evaluating Environmental Costs: Accounting for Uncertainties	37	R	D, J	WD

5. Profiles of Selected Tools

The following pages contain profiles of most of the liability valuation tools found in the course of preparing this report. In deciding which tools to profile, EPA attempted to select tools that covered a wide array of liabilities, situations, and approaches. The profiles are based on a direct review of the cited references, and summarize how the tools derive monetary values for environmental liabilities. The profiles were intended to be descriptive, rather than to evaluate rigorously the strengths or weaknesses of a tool or to assess how a tool might be used in different situations. The information in a profile may not always be sufficient to allow readers to apply the tool; for example, the profiles do not contain all the data used in a particular tool. For this reason, the profiles include availability information to assist readers in obtaining the tools.

The following tools are profiled:

Bibliography Reference #1: *Expected Value Estimates of Long-Term Liability from Landfilling Hazardous Waste*	
Originating Organization James R. Aldrich, Ph.D. Major, U.S. Air Force Air Force Institute of Technology/ENV 2950 P Street, Building 640 Wright-Patterson AFB, OH 45433-7765 Telephone: (513) 255-6565, ext. 4711 Fax: (513) 476-7302 e-mail: jaldrich@afit.af.mil	***Availability*** Published in the *Journal of Air and Waste Management* (1994)
Description of Environmental Liabilities Covered Future liability for remediation (through destruction) of wastes deposited in a landfill	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Can be widely used because key input parameters can be selected by the user Eliminates uncertainty inherent in transferring cost data from one waste site to another (i.e., is site-specific) Liability is computed on a per unit basis, so it eliminates potential application problems due to price variations caused by regional differences, technological advances, and individual capabilities in price negotiations Model is based on the premise that all waste will have to be destroyed eventually; however, the cost of any destruction method can be used in the model The simplified model shown in the example application requires the assumptions that tipping fees will not decrease and waste destruction costs will remain constant. However, these and all other input parameters/assumptions (e.g., interest rate, inflation rate) can be selected by the model user	

Description of the Expected Value Model

The Expected Value model estimates the expected value of the costs of destroying landfilled hazardous waste and represents that value in present value dollars. Accordingly, the model assumes that the liner of every landfill will eventually fail with the time to failure taken as 20 years - coinciding both with other EPA estimates and the landfill liner manufacture's warrantee period. Because the model expresses this failure as a probability function over the landfill ages from 20-26 years, the result is an expected value function which represents the cost of hazardous waste destruction during any year up to the time of landfill remediation. These individual, annual expected values are then summed and combined with the landfill tipping fee to represent the total cost of landfilling.

Bibliography Reference #1: ***Expected Value Estimates of the Long-Term Liability from Landfilling Hazardous Waste*** **(continued)**

The model is based on the following generic equation:

$P_{total} = P_{landfill} + \sum(PV)(P_D)(Prob)$ <u>where</u>

P_{total} = total present value cost of landfilling waste

$P_{landfill}$ = landfill tipping fee (in any units, e.g., \$/ton, \$/bbl)

$\sum$ ranges from t_0 to t_f

PV = present value factor = $1/(1+r)^n$
r = selected discount rate
n = number of years remaining to landfill failure

P_D = cost of waste destruction in year being analyzed, with costs expressed in the same units as $P_{landfill}$

Prob = risk factor = probability of failure in any given year, given the landfill age

Because the model expresses all costs in present value, as written, it is independent of changing landfill costs. As a result, the $P_{landfill}$ term does not need to be summed over all years.

The model assumes that waste destruction costs will remain constant for the foreseeable future (e.g., destructions cost increases in excess of inflation will be offset by additional competition in the destruction market due to the increase in sales caused by the shrinking number of landfills available for disposal). This assumption allows the model to be written in a more simplified form when dealing with RCRA wastes and RCRA remediation as:

$P_{total} = P_{landfill} + f_L P_D$ <u>where</u>

f_L = liability factor incorporating the summation in the generic equation shown above

<u>Notes</u>

(1) The tipping fee costs are assumed to be known and are expressed in present value terms; and current waste destruction costs are assumed to be known and the model requires that increases in excess of inflation be estimated by the user.

(2) Inflation can be incorporated into the model using an inflation factor of $(1+I)^m$ (where I = inflation rate, and m = number of years remaining to landfill failure).

(3) The liability factor resulting from the simplified equation can be shown either graphically or in a look-up table. For example, the reference shows a table of liability factors for different landfill ages (0 to 25 years) and inflation rates (0% to 7%) at an interest rate of 6%. Although the combinations of interest and inflation could lead to a number of potential calculations, most firms use a set interest and inflation rate which leads to only one calculation which need not be repeated.

Bibliography Reference #2: _Dow's Fire & Explosion Index Hazard Classification Guide_	
Originating Organization American Institute of Chemical Engineers (AIChE)	**_Availability_** Available through AIChE, 345 East 47th Street New York, NY 10017 (212) 705-7657 ISBN 0-8169-0623-8
Description of Environmental Liabilities Covered Property damage loss (in dollars) that could result from an incident (e.g., release of fuel or reactive energy from a process unit) of reasonable magnitude with adequate (but not perfect) functioning of protective systems. (NOTE: The methodology can be applied to determine the potential business interruption resulting from a loss incident.)	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Calculations are based on quantifiable data Methodology is objective and straightforward Leading hazard index recognized by the chemical industry Applicability may be limited to certain types of chemical processes only Only one process unit may be evaluated at a time Designed for operations where at least 1,000 lb (454 kg) of a flammable, combustible, or reactive material is stored, handled, or processed	

Summary of the AIChE Methodology

Estimating the dollar value of property damage using the approach developed by AIChE proceeds in seven steps:

Step 1: Determine the Fire & Explosion Index (F&EI)

F&EI is used for estimating the damage that could possibly result from an incident in a process plant.

F&EI = MF x F_3

MF is the Material Factor, which is a measure of the intrinsic rate of potential energy release from a fire or explosion produced by combustion or chemical reaction. The Material Factor can be found using flammability and reactivity factors that are based on NFPA ratings, in conjunction with a "Material Factor Determination Guide" included in the methodology. In addition, a table of Material Factors for different compounds is provided in an appendix to the methodology.

F_3 is the Process Unit Hazards Factor, which is a measure of the magnitude and probability of a loss incident. The Process Unit Hazards Factor has a normal range of 1 to 8 and is the product of two other factors: the General Process Hazards Factor and the Special Process Hazards Factor. The General Process Hazards Factor measures the magnitude of a loss incident and is the sum of a "base factor" of 1.0 and six "penalty factors" that are based on historical experience. The Special Process Hazards Factor measures the probability of a loss incident and is the sum of a base factor of 1.0 and twelve penalty factors that are based on historical experience.

Step 2: Convert F&EI to a Radius of Exposure

Radius of Exposure = F&EI x 0.84

Step 3: Determine the Area of Exposure

Area of Exposure = π x (Radius of Exposure)^2

The Area of Exposure is the area containing equipment that could be exposed to a fire or to a fuel-air explosion generated in the process unit.

Step 4: Determine the Value of the Area of Exposure

Replacement Value = Original Cost x 0.82 x Escalation Factor

The 0.82 factor is an allowance for items of cost not subject to loss or replacement, such as site preparation, engineering expenses, etc. The basis for the 0.82 factor is not given, although the methodology notes that "this factor may be changed if a more accurate estimate exists."

The Escalation Factor is used to convert costs to present-day dollars.

Step 5: Determine the Damage Factor

The Damage Factor measures the overall effect of fire plus blast damage resulting from a release of fuel or reactive energy from a process unit. It is determined using a series of eight curves that correspond to Process Unit Hazards Factors of 1.0 to 8.0, with the Material Factor on the X-axis and the Damage Factor on the Y-axis. (The equations for each of these eight curves are listed in an appendix to the methodology, although few details are provided on their derivation.) The Damage Factor is found using the Material Factor from Step 1 (i.e., the X-value) to locate the Y-value on the curve associated with the Process Unit Hazards Factor from Step 1.

Step 6: Determine Base Maximum Probable Property Damage (Base MPPD)

Base MPPD = Damage Factor x Value of the Area of Exposure

The Base MPPD represents the dollar value of the property damaged by an incident.

Step 7: Determine Actual Maximum Probable Property Damage (Actual MPPD)

Actual MPPD = Base MPPD x LCCF

Actual MPPD is the property damage loss that could result from an incident of reasonable magnitude with adequate (but not perfect) functioning of protective systems.

LCCF is the Loss Control Credit Factor, which accounts for factors that have proven to be beneficial both in preventing serious incidents and in reducing the probability and magnitude of a particular incident. The LCCF is calculated as the product of three factors that are based on categories of loss control features: the Process Control Credit Factor, the Material Isolation Credit Factor, and the Fire Protection Credit Factor. Each of these three factors is also the product of several factors, which have fixed values or ranges of values that are generally based on historical experience.

Bibliography Reference #6:

An Actuarial Approach to Quantifying Environmental Exposure

Originating Organization	***Availability***
Milliman & Robertson, Inc. 289 Edgewater Drive Wakefield, Massachusetts 01880 **Contact:** Joel S. Chansky, tel: (617) 245-4847, fax: (617) 246-0508, e-mail: joel.chansky@milliman.com	Available through Air and Waste Management Association One Gateway Center Pittsburgh, PA 15222 tel: (412) 232-3444, fax: (412) 232-3450 Document number 94-TA31.05 (June 1994)

Description of Environmental Liabilities Covered

First party (e.g., clean up) and third party liabilities associated with hazardous waste sites, underground storage tanks (USTs), asbestos, and other environmental activities/problems.

Description of Derivation of the Monetary Values

SEE BELOW

Comments

Can be used to address many liabilities
Can provide cash flow estimates that are useful for budgeting purposes
May rely heavily on judgment and expert opinions instead of actual data

Description of the Risk Modeling Approach

Risk modeling is a probabilistic, actuarial approach to quantifying environmental exposure. The approach is divided into seven general steps, which are explained below in the context of an UST insurance fund application.

Step 1: Define the problem to be solved.

- The example UST application represents an attempt to determine the rates that should be charged for an UST insurance fund that issues claims made policies (with no prior acts coverage). Each policy is assumed to have a per occurrence deductible of $10,000 and a policy limit of $1 million.

- The insurance policy provides coverage for remediation costs and third party claims involving property damage caused by UST releases. Coverage is not provided for either bodily injury due to UST releases nor repair or damages to property beyond that required to contain or clean up a release.

Bibliography Reference #6: *An Actuarial Approach to Quantifying Environmental Exposure* **(continued)**

<u>Step 2</u>: Identify the universe of environmental exposures.

- In the example UST application, this step requires gathering data on the number of tanks in the area covered by the UST insurance policy, as well as tank age, tank construction, protective features, and monitoring systems.

- Based on the tank data and on discussions with technical experts, a tank risk classification system is developed using the numbers 1 through 4 (which pertain to tank age and construction) and the letters A through D (which pertain to protective features and monitoring systems). Tanks classified as 1A have the lowest risk of failure or spills, while tanks classified as 4D have the highest risk.

<u>Step 3</u>: Estimate the expected value of the cost of all events.

- In the example UST application, the first component of this step is to define a claim as any insured event resulting in at least $10,000 of clean up costs. Based on discussions with technical experts, the methodology then identifies the potential causes of loss (i.e., leak) as tank failure, piping failure, and spills/overfills, and assigns probabilities of occurrence to each.

- The next component is to determine the expected number of leaks in year 1 by multiplying the number of tanks in a particular risk class by the probability of a leak and summing these products over all risk classes.

- The third component is to estimate the percentage of tanks insured in year 1, based on discussions with state officials. This percentage is then multiplied by the expected number of leaks in year 1 to estimate the expected number of leaks that could potentially be covered by the UST insurance fund. Based on engineering assumptions, the expected number of claims (i.e., insured leaks that will be reported) in year 1 is then estimated.

- The fourth component is to estimate the average cost of a claim. The example application estimates an average claim cost of $61,360 (net of a $10,000 deductible), based on discussions with experts. The costs included here include clean up (remedial action), monitoring, screening, investigation, third party liability, and costs of technical experts.

- The final component in this step is to estimate the total expected value of losses and associated claim costs by multiplying the expected number of claims by the average claim cost. Dividing this product by the number of tanks covered by the insurance fund yields the average cost per tank.

<u>Step 4</u>: Estimate a range of possible cost results (i.e., distribution about the mean).

- This step requires conducting a "confidence level" analysis, which involves estimating the possible range of outcomes and the probability of each. The example UST application conducts a confidence level analysis using a computer model that simulates 1,000 years of first year claims made experience (i.e., losses). The model assumes a Poisson distribution for claim frequency and a lognormal distribution for clean up costs but allows the means of these distributions to vary. The cost results from the model are ranked from low to high in order to develop confidence levels.

Step 5: Select a value to achieve management objectives.

- In the example UST application, this step requires insurance fund managers to select a confidence level (i.e., total expected loss value) on which insurance rates will be based.

Step 6: Estimate the pattern of cash flow.

- In the example UST application, the duration of a clean up and the associated cash flow is estimated based on discussions with experts. The cash flow pattern for third party claims is derived by reviewing data from the insurance industry.

Step 7: If necessary, convert to an equitable unit cost basis.

- In the example UST application, the first component of this step is to estimate the average unit loss cost by dividing the selected confidence level for costs by the number of tanks covered by the insurance fund.

- The next component is to establish a rating plan based on the UST risk classes defined in Step 2. Administrative and overhead charges (which typically are fixed) can be added to these rates if desired.

Bibliography Reference #7:

Missouri Underground Storage Tank Insurance Fund

Originating Organization	***Availability***
Joel S. Chansky and William Gulledge Milliman & Robertson, Inc., Wakefield, MA and Environmental Insurance Management, Inc., McLean, VA	Contact: Joel S. Chansky Milliman & Robertson, Inc., 289 Edgewater Drive Wakefield, Massachusetts 01880 tel: (617) 245-4847, fax: (617) 246-0508, e-mail: joel.chansky@milliman.com

Description of Environmental Liabilities Covered

Cleanup costs. These include costs for monitoring, screening, investigation, and actual remediation.
Third-party liability costs. These include compensation costs for property damage and costs for technical experts and outside claim services.
Overhead and administrative costs. These include fixed costs for unallocated loss adjustments, state employee salaries (plus overhead), actuarial costs, audit costs, start-up costs, and other costs incurred by the Third Party Administrator.
Defense costs. These include costs of defending tank owners and operators from claims by third parties for property damage.

Description of Derivation of the Monetary Values

SEE BELOW

Comments

Includes many liabilities
Does not estimate liabilities for bodily injury
Methodology relies on judgement in several instances
Methodology is complex (use may require assistance from the developing organization)
Excludes incidents with cleanup costs of $10,000 or less

Description of the Milliman & Robertson Liability Estimation Model

The model estimates the total costs (TC) for an UST fund using the following equation:

TC = cleanup costs + third-party liability costs + overhead and administrative costs + defense costs - deductibles - amounts in excess of per occurrence limits - amounts in excess of aggregate limits

where:

Bibliography Reference #7: *Missouri Underground Storage Tank Insurance Fund* **(continued)**

(1) Cleanup costs = (number of claims) x (cleanup cost per claim)

- The number of claims is determined using data on the classifications and ages of tanks located in the state being examined, along with assumed release probabilities and reporting patterns.

- The cleanup cost per claim includes costs for remediation, monitoring, screening, and investigation.

- Three probability distributions of remediation costs ("Low," "Middle," and "High") are derived using historical data from various states (compiled by EPA), as well as judgement. The average cleanup costs derived from the "Low," "Middle," and "High" distributions are $47,867; $57,161; and $68,737, respectively.

- Monitoring ($4,500 per claim), screening ($5,600 per claim), and investigation ($2,100 per claim) cost estimates are based on engineering assumptions.

(2) Third-party liability costs = (number of claims) x (3%) x (cost per claim)

- The 3% factor reflects the assumption that third-party liability costs are incurred with 3% probability given a cleanup claim. No basis for this estimate is provided. (Third-party claims are assumed to occur only in the presence of a cleanup claim.)

- The cost per claim is derived from a distribution of third-party property/damage costs with a mean of $40,050 per claim. Additional third-party liability costs include costs for technical experts ($1,200 per claim) and outside claim services ($1,125 per claim). Due to a lack of historical data on third-party claims, all third-party costs (including the distribution) are based entirely on judgement.

(3) Overhead and administrative costs = $5,775 per claim x (number of claims) + yearly overhead

- The $5,775 per claim is for unallocated loss adjustment expenses (ULAE). This cost estimate is based on judgement.

- Yearly overhead costs are derived by taking the sum of state employee salaries, actuarial costs, audit costs, start-up costs, and other costs incurred by the Third Party Administrator. This information is to be provided by the administrative offices of the state being examined.

(4) Defense costs = $2,700 per claim

- This estimate is based on a $15,000 figure for defense costs associated with a cleanup claim, and a $30,000 figure for defense costs associated with both a cleanup and third-party claim. Both cost figures are based on judgement. The methodology assumes that for a cleanup there is a 15% chance of incurring the $15,000 defense cost. Furthermore, the analysis assumes that there is a .45% chance of incurring the $30,000 defense cost, since third-party claims are already assumed to occur with 3% probability given a cleanup claim (i.e., .15 x .03 = .0045).

Bibliography Reference #8:

Information-Limited Bayesian Benefit-Risk Analysis for Sustainable Process Design

Originating Organization	***Availability***
James D. Englehardt Assistant Professor Department of Civil and Architectural Engineering University of Miami P.O. Box 248294 Coral Gables, FL 33124-0630 tel: (305) 284-5557 fax: 305-284-3492 e-mail: jengleha@eng.miami.edu	*ASCE Journal of Environmental Engineering* (forthcoming; scheduled for publication in January 1997)

Description of Environmental Liabilities Covered

Environmental liabilities generally (an application of the model to paint stripping operations includes costs for cleanup of solvent sludge spills during transport and employee compensation claims for solvent-related health problems)

Description of Derivation of the Monetary Values

This approach uses a Bayesian compound Poisson model of accumulated discrete risk to estimate "intangibles" associated with industrial technologies, such as environmental, health, and safety liabilities; market and efficiency uncertainties; and production risks (e.g., product losses). The approach estimates these intangibles using Bayesian Pareto incident size distributions of the total number of incidents (e.g., spills) and the size of individual incidents, as well as the total costs of different types of incidents (as determined by local inquiry, court settlements, lifetime salary estimates, and past research).

Comments

Estimates uncertain parameters using probabilities and associated confidence intervals, as opposed to point estimates
General to industrial processes
Not data-intensive (inputs include professional judgment as well as available data)
Very mathematical and detailed (requires computer model)

Note: The Gauntlett Group, an environmental management consulting firm based in San Francisco, in involved in a joint development project with the University of Miami to explore potential uses of James Englehardt's model to quantify certain types of environmental liabilities.

Bibliography Reference #10:	
Financial Analysis of Waste Management Alternatives	
Originating Organization	***Availability***
General Electric Corporate Environmental Programs	Contact: Paul Bailey ICF Incorporated 9300 Lee Highway Fairfax, VA 22031 tel: 703-934-3225 fax: 703-934-9740 e-mail: pbailey@icfkaiser.com
Description of Environmental Liabilities Covered	
Corrective action costs, cleanup costs, monitoring costs, bodily injury damages, property damages, and natural resource damages (e.g., fish kills, lost recreation, resource restoration costs) resulting from hazardous constituents released to groundwater	
Description of Derivation of the Monetary Values	
SEE BELOW	
Comments	
Simple to use Includes many liabilities Widely applicable Highly standardized Numerical ratings contain a certain degree of arbitrariness	

Methodology to estimate the amount and timing of future environmental liabilities

(1) Estimating the total amount of future liabilities

- The methodology rates treatment, storage, or disposal facilities (TSDFs) on three factors: population, proximity to a water supply, and history of leaks.

- Population is divided into three rating categories: Low (for a rural location), Medium (for an industrial location), and High (for an urban location).

- Proximity to a water supply is divided into three rating categories: Low (for a well more than 10 miles away or a groundwater table more than 50 feet down), Medium (for a well between one and ten miles away or a groundwater table between 10 and 50 feet down), and High (for a well less than one mile away or a groundwater table less than 10 feet down).

Bibliography Reference #10: *Financial Analysis of Waste Management Alternatives* **(continued)**

- History of leaks is divided into three rating categories: Low (for no leak, spill, or discharge), Medium (for any leak, spill, or discharge that has not harmed human health and/or the environment and for any potential leak, spill, or discharge), and High (for any leak, spill, or discharge that has harmed human health and/or the environment).

- The methodology assigns a score to TSDFs based on their ratings for population, proximity to a water supply, and history of leaks. For all three factors, Low = 1, Medium = 2, and High = 3. Thus, the total score for a TSDF can range from 3 (all factors rated "Low") to 9 (all factors rated "High").

- The total score for a TSDF is then adjusted to account for what type of TSDF it is. The methodology provides 22 possible adjustment factors for different methods of treatment, storage, and disposal. To obtain the adjusted total score, the total score is simply multiplied by the applicable adjustment factor.

- To derive actual liability estimates for specific TSDFs, the methodology relies on a standard set of liability estimates associated with an "average" landfill with a total score of 6. An "average" landfill is defined here as a hazardous waste landfill meeting the Part 264 requirements of RCRA and receiving 143,000 tons of waste per year. The associated liability estimates are based on an ICF study for DOD and are as follows:

  - Surface Sealing = $2.5 million
  - Fluid Removal and Treatment = $5.8 million
  - Personal Injury = $36.8 million
  - Real Property Claims = $1.6 million
  - Economic Losses = $3.3 million
  - Natural Resource Damage Claims = $650,000
  - **TOTAL = $50.65 million**
  - **COST PER TON OF WASTE = $50.65 million/143,000 tons = $354**

- To calculate the liability cost per ton for a particular TSDF, the TSDF's adjusted total score is divided by 6 (i.e., the total score of the "average" landfill), and the resulting quotient is then multiplied by $354.

- To calculate total future liability costs, the cost per ton figure calculated in the previous step is multiplied by the total quantity of waste generated. (NOTE: If the organization using this methodology is sharing the use of a TSDF with "non blue chip" waste generators, it could be held responsible for the full liability costs of the TSDF and should increase its liability estimate by a factor of 50 or more.)

(2) Estimating the timing of future liability claims

- The methodology rates 83 hazardous waste constituents on two factors: mobility and toxicity.

- Mobility is divided into three rating categories -- Low, Medium, and High -- which are based on how fast constituents move to or through groundwater.

- Toxicity is divided into three rating categories -- Low, Medium, and High -- which are based on toxicity hazards (chronic vs. acute) and the stringency of EPA's requirements for corrective action.

- The methodology assigns a liability time factor to each of the 83 hazardous chemicals based on their mobility and toxicity. These time factors range from 4 years (high mobility and high toxicity) to 20 years (low mobility and low toxicity).

Bibliography Reference #12: *State of Indiana - Analysis of Funding Requirements for the Petroleum Underground Storage Tank Excess Liability Fund*	
Originating Organization State of Indiana	***Availability*** Contact: Amy Bouska Tillinghast 8300 Norman Center Drive, Suite 600 Minneapolis, MN 55437 Tel: (612) 897-3430 Fax: (612) 897-3307 e-mail: BOUSKAA@tillinghast.com
Description of Environmental Liabilities Covered Cleanup costs. These include costs of all actions to identify the extent, nature, and impacts of tank losses; costs of developing a plan for site restoration; notification costs; and actual cleanup costs. Third-party liability costs. These are costs for bodily injury and/or property damages. Administrative costs. These include costs of developing a claim department, issuing policies, collecting premiums and registration fees, overseeing the maintenance of financial responsibility within deductibles, financial reporting, and other activities. Third-party liability defense costs. These include costs of defending tank owners and operators from claims by third parties for bodily injury and/or property damage.	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Accounts for inflation Includes many liabilities Relies somewhat on "human estimation," rather than data Using the methodology may require the assistance of the developing organization	

Description of the Tillinghast Liability Estimation Methodology

The methodology estimates the total costs (TC) for an UST fund using the following equation:

TC = cleanup costs + third-party liability costs - deductible amounts - amounts in excess of per occurrence limits - amounts in excess of aggregate limits + defense costs + administrative costs

where:

Bibliography Reference #12: *State of Indiana - Analysis of Funding Requirements for the Petroleum Underground Storage Tank Excess Liability Fund* **(continued)**

(1) Cleanup costs = (cleanup cost per occurrence) x (number of occurrences)

- Cleanup costs per occurrence are based on a distribution of third-party cleanups reported to Tillinghast in 1987 by an industry source. Tillinghast updates these 1987 estimates with information on more recent first-party cleanups and increased cleanup severity to obtain a more recent distribution. Also, based on discussions with state officials, consultants, and other UST experts, Tillinghast tailors these costs to the individual state being examined.•The number of occurrences (i.e., "discovered" occurrences) is derived using leak frequency rates (by tank age and type) based on state data, extrapolations of data from other studies, state monitoring programs, and other estimates and adjusted for each state being examined. The number of occurrences also depends on leak discovery rates, which are based on historical rates, regulatory coverage and compliance, different types of monitoring, review of leak reports, and discussions with environmental engineering firms.

(2) Third-party liabilities = (cost per claim) x (state factor) x (number of occurrences) x (2%)

- A distribution of costs per claim is derived from a mean value of $350,000 per claim, which is based on Tillinghast experience and an ICF study on tort losses. The "state factor" adjusts the $350,000 mean estimate to reflect legal conditions in the particular state being examined, which in turn adjusts the distribution of costs per claim. Furthermore, based on other studies and experience, the methodology assumes that two percent of the discovered leak occurrences lead to third-party claims.

(3) Defense costs = (third-party liabilities) x (15%)

- This calculation is based on discussions with an attorney whose firm defends environmental claims.

(4) Administrative costs = (cleanup costs and third-party liabilities) x (10%)

- This calculation is based on discussions with a former executive of an insurer of underground tanks.

Notes

- Tillinghast bases all of its assumptions on the tank demographics for the individual states being considered. These demographics (which include number, condition, age, and construction material of tanks; substances contained, size of tank owner, tank usage, and tank accessibility) are based on actual data.

- Cost payout timing is based on discussions with various state environmental departments.

- Other factors such as compliance with EPA Leak Detection Requirements, temporarily out of use tanks, and tanks taken out of service are based on actual data or assumptions derived from data and discussions with state officials.

Bibliography Reference #12: *State of Indiana - Analysis of Funding Requirements for the Petroleum Underground Storage Tank Excess Liability Fund* **(continued)**

- Inflation is assumed to follow a 10-year pattern: 15%, 10%, 10%, 5%, 5%, 5%, 5%, 5%, 5%, and 5%.

- Deductible amounts, per occurrence limits, and aggregate limits are based on those specified by the individual state being examined.

Bibliography Reference #13: *Use of Decision Science Techniques in Management of Environmental Financial Risks*	
Originating Organization Steven E. James and James H. Schaarsmith, Woodward-Clyde Group, 500 12th Street, Suite 100, Oakland, California 94607-4014 Contact information: Steven James: Woodward-Clyde, tel: (510) 874-3259, fax: (510) 874-3268, e-mail: sejames0@wcc.com James Shaarsmith: Foster Wheeler Environmental Corporation, tel: (703) 358-8985, fax: (703) 522-1534	***Availability*** Published in the *Journal of Environmental Practice* (1994)
Description of Environmental Liabilities Covered Most environmental liabilities (e.g., remediation, human health damage, natural resource and wildlife damage, property damage, noncompliance penalties and fines, and legal defense).	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Widely applicable to many types of environmental liabilities Relies on available environmental data (instead of additional site assessments) by substituting expert opinions for environmental data where data are unavailable Solely structures an analysis and does not provide any quantitative data on costs of liabilities nor algorithms for estimating such costs Relies heavily on expert judgment	

Description of Environmental Risk Quantification (ERQ)

In general, ERQ seeks to establish baseline financial measurements of reasonably possible environmental liabilities, associated costs of remediation or prevention, and indications of where further physical site evaluation is necessary to refine probability and cost estimates. Also, by comparing the present costs of remediation to the future costs of unattended environmental problems, the ERQ can facilitate rational, prioritized risk reduction decisions.

Bibliography Reference #13: *Use of Decision Science Techniques in Management of Environmental Financial Risks* **(continued)**

In deriving dollar values, ERQ is a process that (1) relies on available environmental data (instead of additional site assessments); (2) makes use of decision analysis techniques including event trees, probability distributions, likelihood of occurrence estimates, and level of confidence calculations; and (3) substitutes subjective expert opinions for hard environmental data where data are unavailable.

Conducting an ERQ typically requires three types of experts to offer their professional judgment regarding costs. The three types of experts are a decision analyst (to structure the problem set), an environmental engineer (to estimate costs), and a lawyer (to estimate the costs and probabilities of compensatory damages, fines, and penalties). A sample ERQ proceeded using the following steps:

<u>Step 1</u>: Prepare an inventory of gradual and sudden environmental risks for each facility. This step requires the following information:

- Quantitative assessment of the likelihood of occurrence (drawing on either published historical failure rates or on "fault tree" analysis of the likelihood of individual problems) (observed or known problems have a probability of occurrence of 1.0)
- Seriousness of the risk (e.g., human health effects, animal and natural resource effects)
- Potential receptors of the problem such as humans, animals, aquatic life, crops
- Nature of potential financial loss
- Likely response in the event of problem occurrence
- Appropriate prevention and response measures

<u>Step 2</u>: Screen risks to exclude those that do not have significant potential for major loss.

<u>Step 3</u>: Review identified risks with company staff and make adjustments as appropriate.

<u>Step 4</u>: For all identified risks, estimate the costs of problem prevention, remediation, litigation, compensation, or further study, as appropriate, using available engineering and scientific information (e.g., site investigation report). These estimates are prepared by engineers, scientists and attorneys.

<u>Step 5</u>: Using distributions for the probability of occurrence of each problem and estimated costs of each problem should it occur (both probabilities and costs to be supplied by the experts), estimate the range of costs for each risk reduction alternative.

<u>Step 6</u>: Calculate mean costs for each risk and risk reduction alternative (mean cost = 50% level of confidence).

<u>Step 7</u>: Calculate standard deviation and varying levels of confidence. Assume a log-normal distribution.

Bibliography Reference #13: *Use of Decision Science Techniques in Management of Environmental Financial Risks* **(continued)**

NOTE: The following information is not described in the article cited in the bibliography.

Woodward Clyde uses its Environmental Risk Management Information System (ERMIS), a relational database incorporating risk calculating algorithms, to describe and rank individual and aggregate risks; summarize data by site, medium, and type of problem; and calculate present costs of correction and future liability using varying timeframes and levels of confidence.

ERMIS is an auditing database that contains records on problems and conditions at a site. For each problem observed, ERMIS contains cost estimates for present costs of prevention and/or correction, and for future costs of prevention, correction, legal liability, governmental sanctions, and compensatory costs. "Future costs" are defined to be costs that would be incurred if the problem or condition is not corrected now. All costs are stored in the form of probability distributions, developed by engineers, scientists and attorneys involved in the audit.

Bibliography Reference #14: *Using Decision Analysis to Manage Environmental Costs*	
Originating Organization Gayle S. Koch, Paul R. Ammann, and Kenneth T. Wise The Brattle Group, Cambridge, Massachusetts	***Availability*** Available through Air and Waste Management Association One Gateway Center Pittsburgh, PA 15222 tel: (412) 232-3444, fax: (412) 232-3450 Document number 94-TA33.02 (June 1994)
Description of Environmental Liabilities Covered Liabilities for remediation of hazardous waste sites under CERCLA and RCRA.	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Simple and straightforward method of estimating potential costs Can be applied to any type of environmental liability Can be used to develop an "expected cost" and a "cumulative likelihood curve" of the potential cost (These measures may be more useful to decision-makers than a "most likely" cost estimate or "best case/worst case" cost estimates.) Solely structures an analysis and does not provide any quantitative data on remediation costs nor algorithms for estimating such costs	

Description of the Decision Analytic Approach

The decision analytic approach allows for estimation of (1) the expected cost and (2) a cumulative likelihood curve of potential costs (which shows the percentage chance that costs will be at or below any selected cost level).

A decision analytic approach to estimating environmental liabilities for hazardous waste sites under CERCLA and RCRA must consider (1) costs for site evaluation, (2) remedial costs, and (3) legal costs. Costs for each of these factors vary widely by site. In addition, allocation of costs among various corporate entities (potentially responsible parties) may be relevant. For each of the three cost factors, the approach is to (1) identify the components of the environmental problem while capturing the range of potential events, (2) develop engineering estimates of the cost of each possible event, (3) estimate the probability of each possible event using all available information, and (4) derive an expected cost and distribution of potential costs.

Bibliography Reference #14: *Using Decision Analysis to Manage Environmental Costs* **(continued)**

The following example is given for remediation costs for a site requiring both soil and groundwater remediation:

> Suppose that soil remediation will require incineration of either 2,000, 4,000 or 20,000 cubic yards of soil at a cost of $1, $2, or $10 million, respectively, and at a likelihood of 30, 60, and 10 percent, respectively. Also suppose that groundwater remediation will require treatment for either 2 or 4 years at a cost of $2 or $4 million, respectively, and at a likelihood of 60 and 40 percent, respectively. Because there are three possible outcomes for soil remediation and two possible outcomes for groundwater remediation, there are six possible outcomes (i.e., three times two) overall. The six possible outcomes are shown in the following table, along with the cost of each outcome, the probability of each outcome, and the expected cost associated with each outcome (defined as the cost times the probability), with total expected costs shown in the bottom row:

Example of Decision Analytic Approach for Remediation

Soils	Groundwater	Cost	Probability	Expected Cost
Incinerate 2,000 cu. yd.; $1 million cost; 30% probability	Treat 2 years; $2 million cost; 60% probability	$3 million	18%	$0.54 million
Incinerate 2,000 cu. yd.; $1 million cost; 30% probability	Treat 4 years; $4 million cost; 40% probability	$5 million	12%	$0.60 million
Incinerate 4,000 cu. yd.; $2 million cost; 60% probability	Treat 2 years; $2 million cost; 60% probability	$4 million	36%	$1.44 million
Incinerate 4,000 cu. yd.; $2 million cost; 60% probability	Treat 4 years; $4 million cost; 40% probability	$6 million	24%	$1.44 million
Incinerate 20,000 cu. yd.; $10 million cost; 10% probability	Treat 2 years; $2 million cost; 60% probability	$12 million	6%	$0.72 million
Incinerate 20,000 cu. yd.; $10 million cost; 10% probability	Treat 4 years; $4 million cost; 40% probability	$14 million	4%	$0.56 million
TOTAL EXPECTED COST				$5.30 million

<u>Notes</u>

(1) The methodology recommends that cost estimates for remediation include design, treatability, pilot test, permitting, construction, operation and management, monitoring, agency reporting, project management and oversight costs, and appropriate contingencies.

(2) A complete decision analytic approach would also include this type of analysis for site evaluation costs and legal costs.

Bibliography Reference #16: *How Niagara Mohawk Incorporates Environmental Factors into Policies, Plans, and Procedures*	
Originating Organization Joseph A. Miakisz Niagara Mohawk Power Corporation 300 Erie Boulevard West Syracuse, NY 13202 tel: (315) 821-6614; fax: (315) 428-3549	***Availability*** Published in *Total Quality Environmental Management* (Summer 1995)
Description of Environmental Liabilities Covered Compliance costs associated with prospective air pollution control requirements affecting electric utility fossil fuel-fired generating units.	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Incorporates into current planning decisions the possibility of stricter environmental regulations in the future Useful for identifying and monetizing future compliance costs Solely structures an analysis and does not provide any quantitative data on future environmental compliance costs nor specify any algorithms for estimating future compliance costs Relies heavily on expert judgment predictions of future environmental regulations	

Summary of the Fossil Optimization & Capital Utilization Study (FOCUS)

FOCUS incorporates the costs of compliance with existing and potential future environmental regulations into decisions about continued operation of fossil generating units and construction of new units. The FOCUS process consists of four basic steps, as shown below.

Step 1: Assessment of future environmental scenarios.

- In this step, environmental regulatory experts on the utility company's staff and other utility staff use expert judgment to predict future additional emission control requirements -- for SO_2, NO_x, CO_2, particulates, and hazardous air pollutants -- that could be instituted during a planning period. Predictions include the level of control required, the year that new controls will be instituted, and the probability that controls will be instituted.

Bibliography Reference #16: *How Niagara Mohawk Incorporates Environmental Factors into Policies, Plans, and Procedures* **(continued)**

- The predictions of future requirements are based on several factors, including (1) a review of recent legislative/regulatory proposals, (2) communication with legislators and regulators, (3) participation in industry and regulatory advisory committees, and (4) monitoring of governmental trade journals. Using this information, a number of future regulatory scenarios are identified.

Step 2: Identification of least-cost options for compliance.

- This step involves a substantial amount of data collection, including financial data, system load and capacity data, capital and expense data for fossil generating units, and environmental control cost data. Compliance costs for the future regulatory scenarios are based on information on alternative control technologies from the Electric Power Research Institute, equipment vendors, and other sources, as well as on forecasts of fuel prices and emission allowances.

Step 3: Analysis of production costs and regulatory scenarios.

- This step involves using the costs associated with the selected control option, along with load/capacity data and capital and expense data, as inputs to a production cost model (PROMOD®). The model is used to determine the system production costs, marginal energy costs, and emissions associated with each future regulatory scenario.

- The PROMOD® results are downloaded to a spreadsheet that calculates the following information for each fossil generating unit: (1) production cost savings/energy value, (2) capacity value, (3) capital and expense savings associated with shutdown, (4) NO_x, air toxics, and SO_2 technology costs, (5) SO_2 emissions reductions with shutdown, (6) revenue requirements associated with capital expenditures, and (7) net benefits.

- The probabilities assigned to each of the future regulatory scenarios are then used to derive "expected values" for each fossil generating unit.

Step 4: Budget review.

- For a particular generating unit that does not add value (i.e., the unit's incremental O&M costs exceed the economic benefits received by customers), fossil plant managers can explore options for reducing costs (e.g., alternative emission control strategies) and can re-run the analysis until all potential cost reductions for the unit are exhausted. (Units projected to detract value even after cost reductions become candidates for retirement on an economic basis.)

Bibliography Reference #17:

Financial Evaluation of Environmental Investments

Originating Organization	***Availability***
Tuula Moilanen and Christopher Martin c/o Paras Limited 120A High Street Newport, Isle of Wight PO301TP United Kingdom tel: +44 1983 528700; fax: +44 1983 528800 e-mail: tmo@paras.demon.co.uk	Published in 1996 by Gulf Publishing Company P.O. Box 2608 Houston, TX 77252-2608 tel: 1-800-231-6275 fax: (713) 525-4647 ISBN 0 88415 293 6

Description of Environmental Liabilities Covered

Future liability costs associated with accidents.

Description of Derivation of the Monetary Values

The Moilanen/Martin approach is briefly described in *Financial Evaluation of Environmental Investments*, by Tuula Moilanen and Christopher Martin, which presents a conceptual model and a practical methodology for evaluating the financial implications of companies' environmental investments. The approach to liability valuation first requires estimating the annual probability (labelled "P" below) of an accident resulting from a particular process. (In the example application to an ozone bleaching process, a Hazop analysis is used to derive this probability.) Next, the approach requires identifying the maximum amount a company would be required to pay for an accident (labelled "C" below). (In the example application, this amount is derived based on the self-insured retention in the insurance policy held by the company in question). Finally, the distribution of potential costs within C is assumed to be equally likely (termed a "binomial distribution"). Based on this information, the following equation is used to calculate future (undiscounted) liability costs in any given year:

Future Liability Costs = 0.5 * P * C

Comments

Simple (i.e., includes very little detail)

Bibliography Reference #20:

Risk Assessment and Financial Surety Requirements Analysis for Transportation of Low-Level Radioactive Waste in New York State

Originating Organization	***Availability***
New York State Department of Environmental Conservation	Contact: Paul Merges Chief, Bureau of Pesticides and Radiation New York Department of Environmental Conservation, Room 402 Albany, NY 12233-7250 telephone: (518) 457-2225 fax: (518) 485-8390 e-mail: paul.merges@dec.mailnet.state.ny.us

Description of Environmental Liabilities Covered

Corrective action costs for environmental impairment (e.g., cleanup), third-party compensation (e.g., bodily injury, property damage), and natural resource damages (e.g., lost wildlife, lost recreational values) associated with transport, treatment, and disposal of low-level radioactive materials and wastes.

Description of Derivation of the Monetary Values

This report employs BIPDAM, the Bodily Injury, Property Damage Assessment Model, which builds on valuation methodologies initially developed for EPA's Post-Closure Liability Trust Fund Model and further refined for use by DOD, state government agencies, and Fortune 100 companies. BIPDAM generates dollar values for environmental liabilities associated with transport and disposal of low-level radioactive wastes. BIPDAM calculates estimated frequencies of events along with associated liability costs in a form that can be presented graphically.
(FOR MORE DETAILS, SEE BELOW)

Comments

Covers low-level radioactive waste
Includes many liabilities
Widely applicable
Relies on data in many instances
Relies on assumptions or judgement in many instances

BIPDAM Bodily Injury Estimation Methodology

(1) BIPDAM addresses the following types of injuries:

- Fatal cancer (or other chronic disease)
- Non-fatal cancer
- Birth defects
- Acute effects (fatal and non-fatal)
- No effects

(2) For each type of bodily injury, BIPDAM estimates seven types of costs:

- Lost earnings due to premature death
- Loss of consortium
- Cost of medical treatment
- Lost earnings due to illness
- Physical pain and emotional suffering
- Emergency medical treatment
- Medical monitoring costs

(3) Estimating the unit (i.e., per person affected) costs for each type of injury

- Unit costs are incurred with some probability, which is a function of the dose level. This is equal to the probability that the exposed individual will suffer the bodily injury in question, given his or her level of exposure to low-level radioactive waste.

- Lost earnings due to premature death are based on income, which is modeled for ten age groups as a fraction of the average wages earned by an individual in each age group (from BLS data) and the number of years remaining in life for an individual in each age group.

- Costs for loss of consortium apply to fatal cancers and acute deaths, and are estimated as the costs incurred by the spouse of the victim for psychological counseling. Counseling is assumed to cost $100 per week. The number of years of counseling required depends on the age group of the victim.

- Medical treatment costs apply to cancer (fatal and non-fatal) and birth defects. Costs for fatal and non-fatal cancers are based on studies by Bloom, Knorr, and Evans (1985) and Lansky, Black, and Carns (1983). Costs for birth defects are based on the costs of special care or education ($300 per week) over the first 20 years of life.

- Lost earnings due to illness are calculated as the product of wages that could be earned per day (dependent on the victim's age; from BLS data), the number of lost workdays per year (based on a 260 yearly workdays), and the number of years of earnings lost due to illness. For cancers, the number of lost years of earnings is based on Bloom, Knorr, and Evans (1985) and Lansky, Black, and Carns (1983). For birth defects, the number of lost years is assumed to be the individual's entire life (although an average birth defect is assumed to cause an individual to earn 10% less than an average individual over his or her lifetime). Finally, for acute illnesses, victims are assumed to lose from 6 months to one year of earnings.

- Costs for physical pain and emotional suffering are based on the costs for psychotherapy or treatment (assumed to be $100 per week). For each injury, therapy and treatment is assumed to last the same amount of time as is assumed for lost earnings (see above).

Bibliography Reference #20: *Risk Assessment and Financial Surety Requirements Analysis for Transportation of Low-Level Radioactive Waste in New York State* **(continued)**

- Emergency medical treatment costs apply to individuals suffering from acute, non-fatal effects and are based on hospital treatment and rehabilitation costs for burn victims. These costs are taken from an ICF study and are supplemented with estimates of hospital charges (67% of treatment costs) from the National Cancer Institute.

- Medical monitoring costs are equal to the average annual cost of a medical examination ($175) times the number of years of examinations. The number of years of examinations depends on the particular type of injury: 10 to 20 years for cancer (based on Klaasen, Amdur, and Doull, 1986); entire lifetime (70 years) for birth defects; and 44 to 70 years for acute effects and no effects.

BIPDAM Property Damage Estimation Methodology

(1) BIPDAM assumes that property damage can occur in four environmental "settings":

- Urban
- Suburban
- Farmland
- Vehicles

(2) For each property setting, BIPDAM estimates three types of cost:

- Cleanup
- Property devaluation
- Economic loss

(3) Estimating the costs for each setting

- Cleanup costs include several components. Decontamination costs are based on an NRC report. Transport costs are based on a transportation distance of 250 miles, and disposal costs are based on the cost of soil disposal at the Hanford disposal site in Washington State (taken from reports by ICF and EPRI).

- Property devaluation is based on the lost resale value of exterior property and the lost rental of interior property. Property devaluation is not assumed to apply to vehicles. BIPDAM calculates that, for radioactive contamination, property devaluation is equal to the original value of the property (i.e., its resale value) times a devaluation factor (.05 in the average case and .5 in the worst case).

- Economic loss is measured as lost revenue capacity. For exterior properties (i.e., urban, suburban, and farmland settings), lost revenue capacity is equal to net revenue earned per square meter. For vehicles, it is equal to the cost of temporarily renting a replacement vehicle ($33,300 for a small truck, $66,600 for a large truck, and $333,000 for a rail car). BIPDAM calculates that economic loss is equal to revenue capacity per year times a loss factor (.083 in the average case and .5 in the worst case).

BIPDAM Environmental Impairment Cost Estimation Methodology

(1) BIPDAM assumes that environmental impairment occurs in three environmental settings:

- Woodland
- Parks
- Rivers and lakes

(2) For each setting, BIPDAM estimates two types of costs:

- Cleanup
- Lost recreational value

(3) Estimating the costs for each setting

- Cleanup costs for woodlands and parks are based on costs for cleaning/washing, covering, and removal and replacement. These costs are derived from the cleanup costs used for property damage (see above). Cleanup costs for rivers and lakes include the cost of decontamination/treatment (i.e., dredging and disposal at $300 per cubic meter) and the cost of restoring aquatic life (estimated using the costs of restocking fish, which are based on data indicating that hazardous waste kills approximately 3,000 fish per acre--at a cost of $.25 to $3 per fish according to the American Fisheries Society).

- Economic loss is measured as the potential lost revenue from logging of publicly-owned woodlands and the lost recreational value of land and water resources. The lost revenue from logging is computed using the formulas for lost revenue from property damage (see above). Recreational values of land and water are based on communication with the Army Corps of Engineers. The median value of general recreation is estimated to be $4 per day per person, while the median value of specialized recreation is estimated to be $15.90 per day per person. Recreational loss per acre is computed as the value of recreation per day per person times the number of persons using a recreation area per year per acre.

Bibliography Reference #21: *Estimating Environmental Liability: Quantifying the Unknown*	
Originating Organization Paul J.H. Schoemaker and Joyce A. Schoemaker Decision Strategies International Conshohocken, PA Tel: (610) 941-2936	**Availability** Published in *California Management Review* (Spring 1995)
Description of Environmental Liabilities Covered (1) Future clean-up costs for hazardous waste sites (2) Future tort liability	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Generally applies to most companies Less expensive than bottom-up estimation of liabilities Methodology is fairly simple to use Heavily reliant on assumptions instead of actual data Less accurate than bottom-up estimation of liabilities	

Summary of the Schoemaker Approach to Estimating Environmental Liabilities

This methodology uses a top down approach for estimating hazardous waste clean-up costs and the case method for tort liability.

<u>Future Hazardous Waste Clean-Up Costs</u>

The methodology for estimating clean-up costs proceeds as follows:

(1) Ranges of total clean-up costs for hazardous waste are taken primarily from major studies by the University of Tennessee and the Office of Technology Assessment, as well as from other smaller studies. (For purposes of illustration below, label these costs "A.")

(2) The company for which liabilities are being estimated is placed in a particular hazardous waste-generating category (e.g., manufacturing). The percentage of hazardous waste generated by this category relative to all generating categories is then determined using EPA estimates. (For purposes of illustration below, label this percentage "B.")

(3) Costs from (1) are apportioned to the company in question. This is done by first sizing up the company's particular industry "by the total dollar value of its activities in the U.S. manufacturing sector and percent contribution of its toxic chemicals released (into air or water) and transferred off-site for treatment and disposal." (For purposes of illustration below, label this percentage "C.") Next, the company's share of its particular industry is determined using historical trends. (For purposes of illustration below, label this percentage "D.")

(4) Total costs from (1) are multiplied by the weighting factors in (2) and (3) to produce a top-down estimate of the company's potential future hazardous waste clean-up liabilities:

Future clean-up costs = A x B x C x D

(5) Costs are discounted. A discount rate of 5% is used if the cost data obtained in (1) do not include inflation. A discount rate of 10% is used if the cost data obtained in (1) already include inflation factors.

Future Tort Liability

The methodology for estimating tort liability proceeds as follows:

(1) The company's potential hazards are identified, along with who is affected by these hazards (e.g., consumers, employees, or the community).

(2) Chemicals having the greatest potential for bringing on "mega-lawsuits" or "mass toxic tort" are identified, based on (a) company use of the chemical, (b) scientific knowledge of the chemical's effects on human health, and (c) community awareness of the chemical.

(3) Two different methodologies are presented for estimating tort liability:

Method 1

For chemicals identified in (2), past and present lawsuits are examined to obtain estimates of potential dollar amounts for tort liability. These estimates are then weighted by an "industry fraction" (which reflects the likelihood that the company's industry will incur a lawsuit) and a "company fraction" (which reflects the company's share of the chemicals within its industry). Finally, costs are discounted at 5%.

Company Liability (discounted) = Lawsuit Amount x Industry Fraction x Company Fraction

Method 2

Each chemical identified in (2) is compared to a "benchmark" chemical -- one that has produced large numbers of product liability and tort cases to date (such as asbestos) -- in order to estimate the percentage chance that each chemical identified in (2) will turn into a similar type of problem.

These comparisons are used to assess the risks of major tort liability concerning the identified chemicals, and to apportion a percentage of those risks to the company.

Several probabilities are estimated using various studies and tests,:

(a) The probability that, within the next 30 years, a cancer or other serious health outcome will be specifically linked to exposure to a given chemical (for purposes of illustration below, label this probability "E");

(b) The probability of a conclusive causal link being established within 30 years between a given chemical and human disease, assuming that (a) is met (for purposes of illustration below, label this probability "F");

(c) The probability that the condition of long latency will be met in the case of a given chemical, assuming that (a) and (b) are met (for purposes of illustration below, label this probability "G");

(d) The probability that large numbers of identifiable individuals, such as workers, have been exposed to the chemical (for purposes of illustration below, label this probability "H"); and

(e) The probability that there will be significant and systematic suppression of evidence by industry concerning the chemical's ill-effects, relative to the "benchmark" chemical (for purposes of illustration below, label this probability "I").

These five probabilities are then multiplied together to determine the chance that the chemical will turn into a "liability nightmare":

Probability of liability = E x F x G x H x I

Finally, tort liability for the company is determined by multiplying lawsuit amounts associated with the "benchmark" chemical by the probability of liability and by the company share described in Method 1:

Company Liability = Benchmark Lawsuit Amount x Probability of Liability x Company Share

<u>Total Liabilities</u>

Using the methodologies described above produces two ranges of costs, one for clean-up costs and one for tort liability. These ranges are then combined using statistical methods to yield a range for total liabilities.

Bibliography Reference #22: *Hazardous Materials Cost Trade-Off Analysis Tool (HMCTAT)*	
Originating Organization U.S. Air Force	***Availability*** Contact: Betty S. West, Program Manager Human Systems Center/EMP Brooks AFB, TX 78235-5246 tel: (210) 536-5121 fax: (210) 536-3228 e-mail: west@emgate.brooks.af.mil
Description of Environmental Liabilities Covered Legal/environmental liability associated with (1) disposal of hazardous waste and (2) air emissions. Liabilities covered include fines and penalties, legal claim costs, contaminated water treatment costs, damages to property and natural resources, and regulatory authority correspondence costs.	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Addresses specific hazardous materials used in weapons systems	

Summary of the Potential Legal/Environmental Liability Algorithm in the Hazardous Materials Cost Trade-Off Analysis Tool

The Hazardous Materials Cost Trade-Off Analysis Tool (HMCTAT) is a component of the Hazardous Materials Model (HAZMAT), which is a tool for (1) estimating the environmental life cycle costs of using hazardous materials in weapon systems acquisition processes and (2) evaluating risks to human health, safety, and the environment. The cost data used in HAZMAT are based on facility-wide cost estimates developed for processes using or producing hazardous substances at selected weapons manufacturing and maintenance facilities. Costs for an individual weapon system are derived by multiplying costs by the percentage of workload allocated to a system and then dividing by the number of systems manufactured or maintained at the facility in a typical year.

Bibliography Reference #22: *Hazardous Materials Cost Trade-Off Analysis Tool (HMCTAT)* **(continued)**

The HMCTAT component of HAZMAT considers the following cost elements relating to use or production of hazardous materials:

- Procurement
- Transportation
- Handling
- Management
- Training
- Personal Protection
- Potential Legal/Environmental Liability
- Medical
- Facilities
- Support Equipment
- Emergency Response
- Disposal

The Potential Legal/Environmental Liability algorithm in HMCTAT covers potential liability for violations of Federal environmental acts or laws (with a special provision for violations of the Clean Air Act). The algorithm consists of two sub-elements, one addressing liability associated with contractor disposal of hazardous waste and one addressing airborne contaminants regulated under the Clean Air Act. Potential legal/environmental liability is estimated using the following general equation:

Potential Legal Cost = Contractor + AirEnv <u>where</u>

Contractor = cost of potential legal/environmental liability due to contractor disposal
AirEnv = cost of potential legal/environmental liability due to air emissions

The "Contractor" variable in the general equation is a function of the following elements:

- Surface area of the subsystem of interest
- Surface area of the reference subsystem in HMCTAT
- Quantity of the hazardous substance used per year in the selected process
- Percentage of hazardous materials disposed through a contractor
- Factor reflecting dilution or concentration of the hazardous substance in the selected process
- Cost per pound for potential legal/environmental liability for hazardous waste disposed of through a contractor (see <u>Notes</u> below)
- Probability of groundwater contamination due to disposal of hazardous materials
- Water treatment cost (constant value of $108.4 per pound of hazardous materials; see <u>Notes</u> below)

The "AirEnv" variable in the general equation is a function of the following elements:

- Surface area of the subsystem of interest
- Surface area of the reference subsystem in HMCTAT
- Quantity of the hazardous substance used per year in the selected process
- Percentage of hazardous materials/waste released to the air
- Cost per pound for potential legal/environmental liability for hazardous material/waste released into the air (see <u>Notes</u> below)

Bibliography Reference #22: *Hazardous Materials Cost Trade-Off Analysis Tool (HMCTAT)* **(continued)**

Notes

(1) The liability cost per pound in the Potential Legal/Environmental Liability algorithm is derived using information obtained from Westlaw on court cases and settlements, information from the Air Force Center for Environmental Excellence, and a 1989 EPA study. The liability cost per pound for hazardous materials released into the air includes fines and penalties only. The liability cost per pound for hazardous waste disposed of through a contractor includes the following liabilities:

- Fines and penalties;
- Settlement of tort claims (including lawyer preparation time, witness time, and court costs);
- Real property damage;
- Natural resource damages;
- Contaminated water treatment costs; and
- Regulatory authority correspondence costs (including environmental assessment fees, permits, and licenses).

(2) The $108.4 value used for water treatment (i.e., water contaminated by a leaking landfill) costs is derived using the following equation:

Water Treatment Cost = Factor * (Cost + (Maint * Length)) where

Factor = 1/500,000 = ratio of 1 pound of hazardous material mixed with 500,000 pounds of water
Cost = $10,200,000 = cost of water treatment equipment
Maint = $2,200,000 = annual maintenance cost to operate waste treatment equipment
Length = 20 years = length of contaminated water treatment operations

Bibliography Reference #23: *Natural Resource Damage Assessments (1/7/94 Proposed Rule)*	
Originating Organization National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce	***Availability*** Contacts: Linda Burlington or Eli Reinharz Office of General Counsel for Natural Resources National Oceanic and Atmospheric Administration 1315 East West Highway, Room 15132 Silver Spring, MD 20910 tel, Linda Burlington: (301) 713-1217 fax, Linda Burlington: (301) 713-1229 tel, Eli Reinharz: (301) 713-3038
Description of Environmental Liabilities Covered Natural resource damages. These include damages from oil discharges to (1) estuarine and marine habitats, and (2) inland waters habitats. Damages to these habitats include fishery species consumptive use values (fishing), wildlife species consumptive use values (hunting) and nonconsumptive (viewing) use values, restocking costs, and direct restoration costs of affected habitats.	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Simple and cost-effective Applicable to a wide range of the most commonly discharged oil products Allows both national consistency and regional specificity Limited to oil discharges Does not include indirect costs for restoration Does not include non-use values	

Compensation formulas for natural resource damages from oil discharges

(1) The formulas cover a range of discharge volumes:

- 10 gallons to <1,000 gallons
- 1,000 gallons to <5,000 gallons
- 5,000 gallons to <10,000 gallons
- 10,000 gallons to 50,000 gallons

- The 10-gallon lower bound was statistically determined by NOAA based on evaluations of thousands of scenarios involving very small spills. For discharges above 50,000 gallons, experience indicates that the resulting injuries would be more appropriately addressed by a different methodology (e.g., Type A computer model, Expedited Damage Assessment, or Comprehensive Damage Assessment).

(2) The generic damage formula used in this approach is:

Damages (in $) = (m x VOL) + b, where

- m is a multiplier
- VOL is the amount of oil discharged (see Notes below)
- b is an additional dollar figure

- The generic damage formula represents a linear interpolation of the damage curve shown by the results of simulated discharge scenarios. These scenario results were derived from models developed by the Department of the Interior (DOI). The linear interpolation was developed by breaking down the scenarios into the four discharge volume categories listed above.

- The specific damage formula for estuarine and marine habitats was developed using a DOI model for coastal and marine environments. The formula is based upon various coastal provinces, each with a representative habitat type, providing a total of 55 province/habitat combinations. Each of these combinations has an associated set of damage estimates based on the four seasons (Winter = January 1 to March 31, Spring = April 1 to June 30, Summer = July 1 to September 30, Fall = October 1 to December 31), five representative oils (heavy crude oil, light crude oil, No. 2 fuel oil, diesel, gasoline), and five possible discharge sizes, for a total of 5,500 damage estimate ranges (i.e., 55 province/habitat combinations x 100 combinations of season, type of oil, and discharge size). Each of the 5,500 damage scenarios includes certain predetermined environmental and other conditions. The results of these scenarios form the basis for a set of "compensation tables," which specify the values of "m" and "b" to be used in a given application of the formula. The parameters "m" and "b" are used to compute the dollar figure for damages based on linear interpolation from the range of discharge volumes listed in the compensation tables.

- The specific damage formula for inland waters habitats was developed using a DOI model for the Great Lakes Environment. The formula addresses Great Lakes habitats, fast and slow flowing rivers, streams, brooks, lakes, ponds, and wetlands. In this case, there are a total of 100 province/habitat combinations. Each of these combinations has an associated set of damage estimates based on the four seasons (see above), five representative oils (see above), and five possible discharge sizes, for a total of 10,000 damage estimate ranges (i.e., 100 province/habitat combinations x 100 combinations of season, type of oil, and discharge size). Each of the 10,000 damage scenarios includes certain predetermined environmental and other conditions. The results of these scenarios form the basis for a set of "compensation tables," which specify the values of "m" and "b" to be used in a given application of the formula. The parameters "m" and "b" are used to compute the dollar figure for damages based on linear interpolation from the range of discharge volumes listed in the compensation tables.

Notes

- In calculating damages to estuarine and marine habitats, the volume of oil discharged (VOL) is equal to the actual amount discharged minus the volume of oil cleaned up from the water within 24 hours of the onset of the discharge. Oil cleaned up from shorelines is not subtracted since the majority of shore impacts are immediate.

- In calculating damages to inland waters habitats, the volume of oil discharged (VOL) is equal to the actual amount discharged minus the volume of oil cleaned up from the water (in specified large rivers and lakes) within 24 hours of the onset of the discharge. Oil cleaned up from shorelines and other inland waters is not subtracted since the majority of impacts in these areas are immediate.

- While not calculated in the formulas, damages from beach and/or shoreline closure, as well as boating closure and lost recreational boating opportunities, can be determined using external NOAA guidance materials.

Bibliography Reference #24: *A Comparison of the True Costs of Landfill Disposal and Incineration of DoD Hazardous Wastes*	
Originating Organization U.S. Department of Defense (DoD)	***Availability*** Contact: Paul Bailey ICF Incorporated 9300 Lee Highway Fairfax, VA 22031 tel: 703-934-3225 fax: 703-934-9740 e-mail: pbailey@icfkaiser.com
Description of Environmental Liabilities Covered Cap repair (surface sealing); fluid removal and treatment; personal injury (out-of-pocket medical expenses, lost wages, costs of monitoring individuals' health conditions); real property damage (reductions in property value); economic losses (costs of alternative supplies of potable water); and natural resource damages (cost of restoring areas of contaminated surface water, value of lost recreation, and cost of fish kills)	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Includes many liabilities Relies on data in many instances Measures of personal injury, real property damage, and economic losses are limited	

Liability estimation methodology for releases from hazardous waste landfills

(1) Costs for cap repair (surface sealing)

- Because surface sealing is assumed to take one year to complete, these costs include capital costs only. Based on cost estimates from several sources, the methodology assumes that surface sealing has an average cost of $1.51 million for a landfill with a yearly capacity of 60,000 metric tons, and $3.43 million for a landfill with a yearly capacity of 200,000 metric tons.

(2) Costs for fluid removal and treatment

- The methodology assumes a one-year capital investment period and a 100-year completion period (to reflect the ongoing need for fluid removal and treatment in the event that the contaminant source is not removed completely). Average cost estimates for fluid removal and treatment are based on the output from a stochastic simulation model. For a landfill with a yearly capacity of 60,000 metric tons, capital and O&M costs are estimated to range from $4.93 million to $7.51 million, depending on the hydrogeologic characteristics of different regions. For a landfill with a yearly capacity of 200,000 metric tons, capital and O&M costs are estimated to be $8.16 million.

(3) Costs for personal injury claims

- These claims are simulated by estimating the number of people who consider themselves to have been harmed by a hazardous waste release into groundwater, and by estimating the amount of compensation these people seek.

- The potentially affected population is estimated using data from EPA, which are adjusted using population distribution data from the Department of Health and Human Services. The adjusted population data are categorized by age group.

- The average claim per person in each age group is divided into three components: wages lost due to illness, medical costs related to illness, and medical monitoring costs.

- Estimates of wages lost due to illness and medical costs related to illness are based on "background" cases of diseases that could be caused by a release. (Background cases refer to people with diseases that would have occurred anyway.) Relevant diseases are identified using the Eighth Revision of the International Classification of Diseases. Medical cost estimates for different diseases are taken from Cooper and Price (1976) and are adjusted using age incidence patterns from epidemiological and medical literature to produce an average medical cost per person per year. These costs range from $17.60 per person per year to $82.30 per person per year, depending on age category. Estimates of wages lost per year are derived using data from the Department of Labor and the Department of Health and Human Services, and range from $0 per person per year to $171.50 per person per year, depending on age category.

- The methodology uses medical monitoring costs of $160 per person per year, based on costs for routine exams in a clinic and for tests and examinations by a private physician in an urban area.

- Overall, personal injury costs are estimated as the average claim per person times the number of people in each age group, summed over all age groups. The methodology assumes that a personal injury claim is requested as a lump sum payment, which is computed as the net present value of the costs anticipated over the remainder of an individual's life. The methodology also assumes that only 75% of those eligible for medical monitoring actually make claims.

(4) Costs for real property damage claims

- Real property damage is measured in terms of reduction in property value, which is a function of (1) distance from the affected site, (2) pre-release property value, and (3) percentage by which property values fall due to the discovery of a release.

Bibliography Reference #24: *A Comparison of the True Costs of Landfill Disposal and Incineration of DoD Hazardous Wastes* **(continued)**

- The methodology assumes the affected area from a release to be within 1.5 times the distance to the point of detection. The pre-release property value of a given area is derived using data from the Department of Commerce. The methodology assumes that initial housing values near a hazardous waste site are one-half of median county values. For farmlands near a site, initial values are assumed to be one-half of average county values. Finally, the methodology assumes that a detected toxic release off-site results in a 30% loss in property value. Based on these data and assumptions, the methodology estimates that real property claims range from $740,000 to $2.42 million for a landfill with a yearly capacity of 60,000 metric tons, and from $860,000 to $2.76 million for a landfill with a yearly capacity of 200,000 metric tons.

(5) Economic losses

- Economic losses are measured as the capital costs of replacing a contaminated water supply. The methodology uses EPA estimates of these costs, which range from $300,000 to $292 million depending on the population served by the water source.

(6) Costs for natural resource damages

- Natural resource damage costs are measured as the costs for restoring areas of contaminated surface water, the value of lost recreation, and the cost of fish kills.

- The methodology assumes that the costs of restoring areas of contaminated surface water include costs for dredging and disposal of contaminated material in the river bed or lake bottom. These costs are estimated to be $588,000, based on communications with the Army Corps of Engineers and assuming that the size of the contaminated area is one acre.

- Estimates of the value of lost recreation are taken from communications with the Army Corps of Engineers. The methodology uses these estimates, along with assumptions that (1) the affected area will be unusable for a year, (2) the area would have been used by 50 people per weekend, and (3) weekend use accounts for half of the total use, to derive an average recreational loss of $16,640.

- The cost of fish kills is based on EPA data on fish kills from past cases of surface water contamination. Using these data, the methodology assumes that 3,000 fish are killed per release into surface water, at a cost of $0.50 per fish (based on data from the American Fisheries Society). These assumptions lead to an estimate of $1,500 for fish kills.

- The total estimate of natural resource damages is roughly $606,000 (i.e., $588,000 + $16,640 + $1,500).

Bibliography Reference #25:

Least-Cost DoD Hazardous Waste Management Strategies

Originating Organization	***Availability***
U.S. Department of Defense (DoD)	Contact: Paul Bailey ICF Incorporated 9300 Lee Highway Fairfax, VA 22031 tel: 703-934-3225 fax: 703-934-9740 e-mail: pbailey@icfkaiser.com

Description of Environmental Liabilities Covered

Cleanup costs (direct and indirect) and legal claim costs (direct and indirect) for injury or damages
NOTE: Indirect costs are those passed through in the price of hazardous waste management, including increases in prices charged for commercial services.

Description of Derivation of the Monetary Values

SEE BELOW

Comments

Simple to use
Widely applicable
Relies on data in many instances
Highly standardized
Costs are highly aggregated (e.g., legal claim costs are not broken down into individual components)

Liability estimation methodology for hazardous waste releases

Liabilities in this methodology are estimated as a function of (1) the probability and timing of a release, (2) the cost per cleanup, (3) the probability of a legal claim, and (4) the legal cost per claim. Generally, the total expected liability for a given waste management technique is given as the cost of cleanup plus the cost of a (successful or unsuccessful) legal claim (if made). When the annualized present value of this result is divided by the annual quantity of hazardous waste generated, the result is the expected unit cost per ton of waste.

(1) Probability and timing of a release

- The probability of a release from a storage drum is assumed to be .001, based on the general failure rate resulting from human error of .01 and ICF's estimate that 10% of handling errors result in releases. Because a release incident may happen any time, a drum release is assumed to happen in the same year the waste is generated (i.e., year 0).

- The probability of a release from a storage tank is assumed to be .0116, based on data from a report prepared for EPA on tank failure. Releases and cleanup are assumed to occur in the 10th year after the tank has begun operating.•The probability of a landfill leaking is assumed to be 1, based on ICF's analysis for EPA. Also based on this analysis, the methodology assumes that a release occurs 17 years after a landfill opens.

- A release from an injection well is assumed to occur with probability .075, based on a survey conducted for the Underground Injection Practices Council. This survey also indicates that a release may occur 17 years after the well has begun operating. ICF estimated that the cleanup of this release would begin 3 years later.

- Based on an ICF report for EPA, the probability of a release per trip is assumed to be .000042 for transportation of wastes to a regional facility. For transportation of wastes to a commercial facility, this probability is assumed to be .00028. Because a release incident may happen any time, a release during transportation is assumed to happen in the same year the waste is generated (i.e., year 0).

(2) Cleanup costs

- Cleanup costs can be direct or indirect. All costs for on-site and regional practices (e.g., drum storage and tank storage) are assumed to be direct. Costs for releases during transportation are assumed to be indirect. Off-site practices (e.g., landfilling and deep-well injection) are assumed to lead to both direct and indirect costs. The probabilities that costs are direct or indirect are based on EPA model results and an ICF report of firms in the commercial hazardous waste management industry.

- The methodology uses an ICF estimate of $500 for the cleanup of a drum release. This results in an expected unit cost of $3.26 per ton of hazardous waste stored in drums.

- Based on ICF calculations, the methodology assumes that a release from an on-site storage tank costs an average of $10,100 to clean up. Expected unit costs are $6.68 per ton or $32.57 per ton, depending on how long the waste is stored (less than or greater than 90 days).

- Based on ICF calculations, the methodology assumes that a release from a regional storage tank costs an average of $52,800 to clean up. Expected unit costs are $6.02 per ton or $20.31 per ton, depending on how long the waste is stored (less than or greater than 90 days).

- Based on an EPA study, the methodology assumes that the average cleanup cost for a landfill release is $11,782,000, which leads to an expected direct unit cost of $22.06 per ton and an expected indirect unit cost of $4.12 per ton.

Bibliography Reference #25: *Least-Cost DoD Hazardous Waste Management Strategies* **(continued)**

- In the absence of data of deep-well injection, the methodology assumes that the average cleanup cost for an injection well release is equivalent to that for a landfill release -- $11,782,000. Based on this figure, expected direct unit costs are $6.27 per ton, and expected indirect unit costs are $0.29 per ton.

- Based on a report by the Office of Technology Assessment, the methodology assumes that the average cleanup cost for a release during transportation is $20,000. Expected indirect unit costs range from $0.03 per ton or $0.28 per ton, depending on the type of truck (flat bed or tanker) and the waste's destination (regional or commercial facility).

(3) Probability of a legal claim

- Based on an ICF analysis of releases from solid waste management units, the methodology assumes that, for all practices except drum storage, the probability of a claim given a release is .10. Drum releases are not assumed to result in legal claims because they are likely to be cleaned up quickly before contaminants can migrate off-site.

(4) Legal claim costs

- Legal claim costs include payments to third parties for damages, as well as defense costs.

- Legal claim costs can be direct or indirect. All legal claim costs for on-site and regional practices (e.g., tank storage) are assumed to be direct, and are assumed to be incurred in 20% of claims. Off-site practices (e.g., landfilling, deep-well injection, and transportation) are assumed to lead to both direct and indirect costs. Several legal scenarios are possible in the case of off-site practices; thus, several probabilities are attached to incurring these costs. These probabilities are based on discussions with a lawyer, as well as assumption.

- The methodology assumes that a release from an on-site storage tank has an average legal claim cost of $1,000,000, which is consistent with liability coverage limits under RCRA and is supported by an EPA investigation of the liability costs of USTs. Expected unit costs are $0.25 per ton or $0.85 per ton, depending on how long the waste is stored (less than or greater than 90 days).

- The methodology assumes that a release from a regional storage tank has an average legal claim cost of $1,000,000, which is consistent with liability coverage limits under RCRA and is supported by an EPA investigation of the liability costs of USTs. Expected unit costs are $0.04 per ton or $0.13 per ton, depending on how long the waste is stored (less than or greater than 90 days).

- The methodology assumes that the average legal claim cost for a landfill release is $3,000,000, which is consistent with liability coverage limits under RCRA. Based on this figure, expected direct unit costs are $0.09 per ton and expected indirect unit costs are $0.04 per ton.

- The methodology assumes that the average legal claim cost for an injection well release is $3,000,000, which is consistent with liability coverage limits under RCRA. Based on this figure, expected direct unit costs are $0.02 per ton and expected indirect unit costs are zero.

- The methodology assumes that the average legal claim cost for a release during transportation is $1,000,000, based on the assumptions for storage tanks. Expected direct unit costs range from $0.06 per ton to $0.55 per ton, depending on the type of truck (flat bed or tanker) and the waste's destination (regional or commercial facility). Expected indirect unit costs range from $0.46 per ton to $4.02 per ton, depending on the type of truck and the waste's destination.

- Average legal defense costs are assumed to $60,000 per claim, based on ICF's review of legal costs associated with hazardous waste litigation.

Bibliography Reference #26:

Hazardous Substances Natural Resource Damages Assessment Regulations (3/25/94 final rule)

Originating Organization	***Availability***
U.S. Department of the Interior (DOI)	Contacts: Mary Morton or David Rosenberger Office of Environmental Policy and Compliance U.S. Department of the Interior Main Interior Building (MS 2340) 1849 C Street NW Washington, D.C. 20240 fax: (202) 501-6944 tel: Mary Morton: (202) 208-3302 tel: David Rosenberger: (202) 208-3811

Description of Environmental Liabilities Covered

<u>Natural resource damages</u>. These regulations define what constitutes an "injury" to a natural resource. The regulations then base the valuation of damages on the direct and indirect (e.g., overhead) costs for restoring, rehabilitating, replacing, and/or acquiring the equivalent of injured natural resources. Damages may also include the value of the services lost to the public between the time of release and the time the resources and services those resources provide are returned to baseline conditions (i.e., those conditions which would have existed had the release not occurred). The natural resources covered by the rule include land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other government- or privately-owned resources covered by CERCLA.

Description of Derivation of the Monetary Values

SEE BELOW

Comments

Covers releases of hazardous substances
Covers a broad scope of resources
Includes a choice of assessment approaches
Contingent valuation allowed as method to estimate use values

The DOI natural resource damage assessment methodology

The DOI methodology uses the following basic formula to estimate natural resource damages (NRD):

NRD = direct and indirect costs for restoration, rehabilitation, replacement, and/or acquisition of equivalent resources + the value of the services lost to the public

(1) Costs for restoration, rehabilitation, replacement, and/or acquisition of equivalent resources

- Direct costs are those which are directly attributable to the selected alternative. Indirect costs are those which are incurred through activities or items that support the selected alternative (e.g., overhead).

- As indirect costs may be difficult to estimate, officials may apply a specific rate for them if the benefits from actually estimating indirect costs would not exceed the costs of doing so. (DOI does not specify an indirect cost rate that could be used here, nor does it advise how to choose such a rate.)

- To estimate "restoration" costs, officials may use the following methodologies:

  - <u>Comparison methodology</u>. Constructing a simplified restoration scenario for which a cost estimate can be determined and then applying the estimate to a unique or more complex scenario;
  - <u>Unit cost methodology</u>. Deriving an estimate based on the unit cost of a particular item or activity using data from technical literature or previous cost expenditures;
  - <u>Probability methodology</u>. Using deterministic information to develop a likely cost estimate or range of estimates for the selected restoration alternative;
  - <u>Factor methodology</u>. Deriving a cost estimate by summing the product of several items or activities related to the selected restoration alternative (also called the "ratio" or "percentage" methodology);
  - <u>Standard time data methodology</u>. Using time data on standard tasks typically undertaken in performing restoration-related work to estimate labor costs; and
  - <u>Cost- and time-estimating relationships</u>. Statistical regression models showing relationships between cost or time and physical or performance characteristics of the selected restoration alternative.

(2) Value of the services lost to the public

- DOI refers to these costs as "compensable value."

- Compensable value is measured as changes in consumer surplus, economic rent, and any fees or other payments collected by a government agency or Indian tribe for private-party use of natural resources, as well as any economic rent accruing to private parties because no fee or price is charged for use of the resources.

- To estimate the compensable value (or willingness to pay) for natural resources, officials may use the following methodologies:

  - <u>Market price methodology</u>. Using the diminution in the market price of the damaged resources (if the resources are traded in a competitive market);

Bibliography Reference #26: *Hazardous Substances Natural Resource Damage Assessment Regulations (3/25/94 final rule)* **(continued)**

- Appraisal methodology. Taking the difference between the with- and without-injury appraisal values of the resources as determined by the sales approach described in the Uniform Appraisal Standards (this approach may be used when resources traded in markets are similar to the damaged resources);
- Factor income methodology. Estimating the in-place value of the resources by determining the economic rent associated with the use of the resources in the making of a product with a well-defined market price;
- Travel cost methodology. Using incremental travel costs to an area as a proxy for the value of the area's services (in this case, compensable value is the difference between the value of the area with and without a discharge or release);
- Hedonic pricing methodology. Indirectly estimating the demand for nonmarketed resources by analyzing commodities traded in a market (e.g., housing values at different distances from amenities);
- Unit value methodology. Using preassigned dollar values (not specified by DOI) for nonmarketed recreational and other experiences by the public that closely resemble the services lost due to the natural resource damages; and
- Contingent valuation methodology. Determining the value of natural resources through carefully designed surveys.

Notes

- Officials may use methodologies not listed above if they are cost-effective and are based upon standard, accepted cost estimating practices.

- Officials may use multiple methodologies as long as there is no double-counting.

Bibliography Reference #27: *BEN: A Model to Calculate the Economic Benefits of Non-Compliance*	
Originating Organization Office of Enforcement, U.S. Environmental Protection Agency, Washington, D.C. Contacts: Jonathan Libber (202) 564-6011 and David Hindin (202) 564-6004	***Availability*** Available through the National Technical Information Service 5285 Port Royal Road Springfield, VA 22161 telephone: (703) 487-4650 Accession number: PB95-502514INC
Description of Environmental Liabilities Covered BEN addresses the economic benefits realized by organizations by delaying or avoiding compliance with environmental requirements. (These benefits are used as the basis for developing the benefit portion of the settlement penalty figures.) "Delayed" costs include capital investment in pollution control equipment and one-time costs of compliance (e.g., land purchases). "Avoided" costs include annual expenses (e.g. O&M costs for pollution control equipment and other recurring costs such as off-site disposal).	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Simple to use (requires a small amount of user input) Allows for use of standard or user-specified parameter values Can be used to estimate economic benefits of non-compliance for many types of organizations (e.g., corporations, partnerships, non-profit organizations) Cost inputs must be supplied by the user Does not capture economic benefits associated with the competitive advantage that violators may have achieved through noncompliance (e.g. increased market share, revenues from sale of banned products)	

Summary of the BEN Computer Model

(1) The BEN model uses 13 inputs from the user

1. Case name, profitability status (profit or non-profit), and tax filing status (corporation or other than corporation)
2. Initial capital investment in pollution control (and whether the investment is recurring or non-recurring)
3. One-time non-depreciable expenditure (and whether the expenditure is tax-deductible)
4. Annual expense associated with pollution control equipment

5. Non-compliance date
6. Compliance date
7. Penalty payment date
8. Useful life of pollution equipment*
9. Marginal tax rate 1986 and before* 10.Marginal tax rate 1987 to 1992*
11. Marginal tax rate 1993 and beyond*
12. Annual inflation rate*
13. Discount rate*

NOTE: BEN includes standard default values (which may differ for profit and non-profit organizations) for the variables marked with an asterisk (*), although the user may enter alternate values if desired.

(2) BEN uses a four-step process to compute the economic benefit of non-compliance:

Step 1. Calculates the present value (as of the non-compliance date) of the incremental after-tax cash flows that the violator would have experienced if it had complied on time. ("On-Time" case)

Step 2. Calculates the present value (as of the non-compliance date) of the cash flows experienced by the violator when making the expenditures necessary to comply after the delay. ("Delay" case)

Step 3. Calculates the violator's economic benefit as of the non-compliance date (the "initial economic benefit"), which is the difference between the cash flows in the On-Time case and the cash flows in the Delay case.

Step 4. Calculates the violator's economic benefit as of the penalty payment date, which is derived by increasing the initial economic benefit at the discount rate for the number of months between the non-compliance date and the penalty payment date.

(3) BEN can also be used to estimate economic benefits in special cases:

- Multiple BEN runs can be combined in situations where violators fail to comply with more than one requirement.
- Using some of BEN's intermediate calculations, the user can address situations where a violator completely avoids one-time capital expenditures or non-depreciable costs (e.g., if EPA seeks to close down the violator's operation due to non-compliance).
- BEN can be used to estimate economic benefits in situations where annual expenditures are delayed (as opposed to avoided in standard cases).
- Cost figures in BEN can be adjusted in cases where governmental entities or non-profit organizations have portions of their pollution control costs and other compliance expenditures covered by federal or state grants.

Bibliography Reference #28:

Pollution Prevention Benefits Manual

Originating Organization	***Availability***
Office of Policy, Planning and Evaluation and Office of Solid Waste, U.S. Environmental Protection Agency (EPA)	Contact EPA's Pollution Prevention Information Clearinghouse 401 M Street SW (MC-7409) Washington, D.C. 20460 tel: (202) 260-1023; fax: (202) 260-0178 e-mail: ppic@epamail.epa.gov

Description of Environmental Liabilities Covered

Penalties and fines for non-compliance, and future liabilities for (1) soil and waste removal and treatment, (2) groundwater removal and treatment, (3) surface sealing, (4) personal injury, (5) economic loss, (6) real property damage, and (7) natural resource damage associated with routine or accidental hazardous releases

Description of Derivation of the Monetary Values

SEE BELOW

Comments

Simple to use
Includes many liabilities
Widely applicable
Highly standardized (not site-specific)
Relies on many implicit assumptions

Estimation methodology for potential environmental liabilities

<u>Estimation of penalties and fines</u>

- The methodology provides a table listing dollar ranges of penalties and fines associated with non-compliance under various federal regulatory programs. These ranges are based on information given in the programs' documentation concerning penalties and fines, as well as data on actual penalties and fines imposed in FY1987. (The using organization can supplement this list with information from its own past experience with penalties and fines.)

- The methodology then requires the using organization to estimate its probability of being penalized or fined by each program in a given year, based on past experience. These probabilities are multiplied by the corresponding penalty and fine dollar values to produce expected liability estimates for each applicable regulatory program. These estimates are then summed to produce the total expected value of penalties and fines.

Estimation of future liability costs

(1) Soil and waste removal and treatment = 8.9 x a x b x Q where:

a Correction factor (for type of tank)
b Fraction of total annual quantity of waste (treated, stored in tanks, or transported) expected to be released
Q Total quantity of waste treated, stored in tanks, or transported

- This equation does not apply to landfills because excavation is unlikely to be the preferred remediation option for them.

- For tanks, "a" takes on a value of 1 for above ground tanks and 2 for underground tanks; "b" ranges from .0001 to .1 depending on the type of tank.

- For transportation, "a" equals 1, and the "b" factor in the equation is a function of "D," which is a variable for the distance to the treatment or disposal facility.

(2) Groundwater removal and treatment = a + (b x c) where:

a Capital costs
b O&M costs
c Multiplicative factor to determine present value of all O&M costs

- This equation does not apply to transportation because releases during transportation typically do not result in contamination of groundwater.

- Generally, "a" is a function of "D" (distance to the nearest drinking water well -- 150m to 3,200m), "W" (width of groundwater plume at facility boundary), "V" (groundwater velocity -- 30 to 3,000 meters per year), and "CC" (unit capital cost of groundwater treatment).

- Generally, "b" is a function of "W," "D," "V," and "OM" (unit O&M cost of groundwater treatment).

- For tanks, "c" ranges from 4 to 8, "W" ranges from 3m to 100m, "CC" equals $440 per cubic meter per day, and "OM" equals $120 per year per cubic meter per day.

- For landfill disposal, "c" ranges from 5 to 25, "W" ranges from 500m to 700m, "CC" equals $340 per cubic meter per day, and "OM" equals $85 per year per cubic meter per day.

Bibliography Reference #28: *Pollution Prevention Benefits Manual* **(continued)**

(3) Surface sealing = CS x A where:

CS Unit cost of surface sealing landfills
A Area of the landfill

- This equation does not apply to tanks or transportation.

- For landfill disposal, "CS" ranges from $7,000 to $46,000 per acre. "A" ranges from 65 to 150 acres.

(4) Personal injury = a x b where:

a Average claim per person for lost time due to disability and mortality, medical costs related to illness, and medical monitoring costs
b Potentially affected population

- This equation does not apply to transportation.

- For tanks or landfill disposal, "a" equals $56,000 per person; "b" equals 10 (best case), 3,500 (typical case), or 15,000 (worst case).

(5) Economic loss = cost to replace a water supply source

- This equation does not apply to transportation.

- For tanks or landfill disposal, economic loss is calculated using a table of EPA cost estimates for different population ranges.

(6) Real property damage = a x b x c where:

a Devaluation factor
b Land value
c Area of the off-site plume

- This equation does not apply to transportation.

- Generally, "a" ranges from .15 to .30; "b" ranges from $900 to $3,500 per acre. The parameter "c" is a function of "D" (distance to the nearest drinking water well -- 150m to 3,200m) and "W" (width of groundwater plume at facility boundary).

- For tanks, "W" ranges from 3m to 100m.

- For landfill disposal, "W" ranges from 500m to 700m.

Bibliography Reference #28: *Pollution Prevention Benefits Manual* **(continued)**

(7) Natural resource damage = a x b where:

a Unit cost of dredging and disposing of contaminated material plus the cost of fish killed
b Area of surface water contaminated

- For tanks or landfill disposal, "a" equals $692,000; "b" ranges from 1 to 3 acres.

- For transportation, "a" equals $692,000. The parameter "b" ranges from (1 x d) to (3 x d), where "d" is the quantity expected to be released, expressed as a fraction of the annual quantity transported. The parameter "d" is a function of "D" (distance to the treatment or disposal facility).

Estimation of an organization's share of total future liabilities

Alpha = Q/Q_t where:

Q Waste quantity contributed by the organization
Q_t Total quantity of waste managed by the disposal/transportation agent that manages the organization's waste

Estimation of the timing in which liabilities are incurred

Penalties and fines are assumed to be incurred annually, starting in the first year. For future liabilities, the following formula is used:

Year = T + (D x RF)/V where:

T Expected time lapse between the start of the project and the initial release
D Distance to nearest drinking water well
RF Retardation factor for waste constituents
V Groundwater velocity

- Generally, "RF" ranges from 1 to 1,000; "V" equals 30 meters per year (best case), 300 meters per year (typical case), or 3,000 meters per year (worst case).

- For tanks and landfill disposal, "D" equals 150m (worst case), 1,500m (typical case), or 3,200m (best case).

- For transportation, "T" equals 1 year, and "D" equals 0.

- For tanks, "T" ranges from 1 to 20 years.

- For landfill disposal, "T" ranges from 1 to 40 years.

Bibliography Reference #29: *Post-Closure Liability Trust Fund (PCLTF) Simulation Model*	
Originating Organization Office of Solid Waste, U.S. Environmental Protection Agency	***Availability*** Available through the National Technical Information Service 5285 Port Royal Road Springfield, VA 22161 telephone: (703) 487-4650 Accession number: PB86-212479/XAB
Description of Environmental Liabilities Covered This model addresses liabilities for which the PCLTF funds may be used (i.e., monitoring hazardous waste sites and responding to any releases, studying damages to natural resources and restoring or replacing such resources, assessing health effects and compensating for personal injury or loss, and routine care and maintenance of facilities by parties other than facility owners and operators after 30 years following closure of a hazardous waste site).	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Addresses the full range of costs potentially covered by the PCLTF Addresses uncertainty in costs by using a Monte Carlo (stochastic) simulation Cannot be used to project liabilities of a single hazardous waste site	

Description of the Post-Closure Liability Trust Fund (PCLTF) Simulation Model

The PCLTF Simulation Model was designed for use in estimating the adequacy of revenues to be raised for the Post-Closure Liability Trust Fund to cover anticipated payouts from the fund, over a long time frame. To make this comparison, the model needs to estimate both the fund revenues and the fund payouts. Fund revenues are from taxes on future land disposal of hazardous waste. Fund payouts may be made for certain costs arising from future problems at permitted hazardous waste land disposal facilities where (1) there is no responsible party or the responsible party is insolvent, and (2) costs are not to be borne by a state fund or the Superfund. Fund payouts may be made for the following types of costs: monitoring hazardous waste sites and responding to any releases, studying damages to natural resources and restoring or replacing such resources, assessing health effects and compensating for personal injury or loss, and routine care and maintenance of facilities by parties other than facility owners and operators after 30 years following closure of a hazardous waste site.

The model documentation does not discuss how fund revenues are estimated. The model estimates fund payouts using a Monte Carlo simulation that incorporates the uncertainties inherent in many of the factors that determine claims on the fund. The model produces output in the form of a distribution of potential outcomes.

Fund payouts are modeled based on (1) five categories of data regarding facilities, releases, and claims, and (2) six types of relationships among data in the five data categories. The five categories of data are as follows:

1. Facility population
2. Facility-level characterization
3. Release data
4. Monitoring and release response actions and claim data
5. Funding sources

The six types of relationships among these data are as follows:

1. Economic relationships
2. RCRA policies
3. Financial relationships
4. Physical relationships
5. Legal issues
6. Allocation policies

Additional details about the five categories of data are as follows:

- Facility population includes surface impoundments, landfills, land treatment, and injection wells.
- Because facility-specific data were not available for most facilities, a distribution of facility characteristics within the facility population was estimated (consequently, the model results are not site-specific). The facility characteristics include the time of occurrence of certain milestones (e.g., end of the post-closure care period) that influence the allocation of costs among potential funding sources (see below).

- Seven types of releases were projected based on a model of releases developed by Battelle Pacific Northwest Laboratory. (Note: That model has since been updated.) Of the seven release types, three types were releases detected by an on-site monitoring well; three types were releases to the closest off-site potable well or naturally occurring body of surface water; and one was the overflow of contaminated leachate from the facility.

- Five types of monitoring actions are considered: (1) routine monitoring for indicator parameters at the on-site monitoring well, (2) monitoring for hazardous waste constituents at the on-site monitoring well, (3) plume delineation and tracking on site, (4) monitoring for hazardous waste constituents off site, and (5) plume delineation and tracking off site.

- Three types of response actions are considered: (1) cap repair, (2) fluid removal and treatment on site, and (3) fluid removal and treatment off site.

- Four types of third-party claims are considered: (1) claims for personal injury, (2) damage to real property, (3) economic loss, and (4) damage to natural resources.

- Four funding sources are considered: (1) the PCLTF, (2) state funds, (3) Superfund, and (4) owners/operators. (If no funding source is available for a given action, the model assumes that the action is not taken.)

Additional details about the six types of relationships among the five categories of data are as follows:

- The most important economic relationship is between the demand for land disposal and the simulated facility population. The model ensures that there is sufficient disposal capacity to meet demand by adding new disposal capacity as existing facilities close.

- Specific assumptions are made regarding the policies for approving final RCRA permits for interim status facilities (a final RCRA permit is a condition of coverage by the PCLTF). The model also allows use of alternative policy assumptions.

- "Action rules" in the model regarding detection monitoring, compliance monitoring, corrective action, and post-closure care reflect EPA policies current at the time the model was developed. The model may, however, be run with modified "action rules."

- The likelihood of a firm going bankrupt is assessed annually and is modeled as a function of (1) the monitoring, response, and claims expenditures being incurred by the firm and (2) the financial status of the firm.

- Allocation policies identify the manner in which costs generated at the facility level are allocated to the possible funding sources. A set of allocation rules is incorporated in the model to identify how each cost arising at the facility level is to be allocated in various situations.

- Legal validity of claims will vary by state, according to state law. Thus, legal validity of claims is represented using a set of seven representative legal regimes (based on a review of existing state laws). The seven legal regimes were probabilistically assigned to the states.

- The effectiveness of response actions that are only partially completed is assumed to be a function of the portion of the action completed.

When the PCLTF was run using a set of inputs believed by EPA to best reflect the then-current PCLTF statute, the fund was projected to have sufficient revenues to cover potential costs over the next 20 to 40 years. After that time, expenditures were expected to exceed revenues, in part because the tax rate was fixed in nominal terms.

Bibliography Reference #30: *Analysis of Kansas State Fund for Approval as Alternative Financial Assurance Mechanism* (Draft document)	
Originating Organization U.S. Environmental Protection Agency, Region VII	**Availability** Contact: Paul Bailey ICF Incorporated 9300 Lee Highway Fairfax, VA 22031 tel: 703-934-3225 fax: 703-934-9740 e-mail: pbailey@icfkaiser.com
Description of Environmental Liabilities Covered Corrective action costs. These include costs for site investigation, remediation, monitoring, and soil removal and treatment. Third-party liability costs. These are costs for bodily injury and/or property damages. Administrative costs. These include costs for staffing and resource requirements, and are broken down into start-up and ongoing costs. Ongoing administrative costs are divided into fixed and variable components.	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Relies mostly on observed data Relatively straightforward Includes many liabilities Does not account for inflation Does not include defense costs	

Description of the ICF Liability Estimation Model

The model estimates the total costs (TC) for an UST fund using the following equation:

TC = corrective action costs + third-party liability costs + administrative costs - deductibles - amounts in excess of per occurrence limits - amounts in excess of aggregate limits

where:

(1) Corrective action costs = (number of claims) * (cost per claim)

Bibliography Reference #30: *Analysis of Kansas State Fund for Approval as Alternative Financial Assurance Mechanism* (Draft document) **(continued)**

- The number of claims is based on several factors. First, state data (including the number of tanks, tank construction materials, and soil types under tanks) and information on types of piping (derived from national averages) are used to characterize the state's tank population. The results from an EPA model (see Notes) for estimating the frequency and severity of releases are then weighted by these characteristics in order to produce state-specific release information. Release detection rates are based on regulatory requirements for monitoring and leak detection. These rates are created by taking three-year rolling averages of the rates in EPA's technical UST rules.

- The average cost per claim is derived using national cost estimates from EPA's UST Model. In order to make these estimates more state-specific, they are adjusted using actual state data on site investigation, capital, and O&M costs. Corrective action costs are assumed to be exponentially distributed. Also, a linear relationship between the costs of average cleanups and median-to-large cleanups is assumed.

(2) Third-party liability costs = (number of claims) * (cost per claim)

- The number of claims is based on the percentage of releases that lead to claims. The model uses an estimate of 1 to 2 percent based on reports from UST insurers.

- The average cost per claim is $341,000. This value is derived from the results of an ICF study done in 1984 and is adjusted to reflect a $1 million ceiling on third-party recovery.

(3) Administrative costs = (corrective action costs + third-party liability costs) * (11%)

Subject to: Administrative costs $\leq$ $2 million per year

- The 11% parameter is based on a rate proposed to the State of Washington by an insurer.

- The $2 million limit is derived from ICF's administrative cost estimates from an earlier study. These estimates indicate that, accounting for the staff needs of the state being examined, administrative costs are unlikely to exceed $2 million per year.

<u>Notes</u>

- Deductible amounts are based on state-required levels and are adjusted by estimates of default by owners and operators.

- Per occurrence and aggregate limits are based on those specified by the individual state being examined.

- As noted above, some of the calculations in this methodology are based on results from EPA's UST Model. The UST model, which was developed in 1988, estimates the costs and benefits associated with implementing the UST regulations and remediating existing contamination of soil and/or groundwater. The model consists of three modules -- the event module, the risk module, and the cost module. The event module addresses tank failure and releases, fate and transport of released hydrocarbons, and detection. The risk module estimates the human health risks from exposure to benzene. The cost module estimates the cost of remediating contamination and replacing damaged equipment.

Bibliography Reference #32: _FORECAST: Regulatory Effects Cost Analysis Software Manual, Version 4.1_	
Originating Organization U.S. Nuclear Regulatory Commission	**_Availability_** Available from U.S. Nuclear Regulatory Commission Public Document Room Washington, D.C. 20555 tel: (202) 634-3273 or 1-800-397-4209 fax: (202) 634-3343 e-mail: pdr@nrc.gov Document #: NUREG/CR-5595, Rev. 1 Note: It is expected that by early 1997 copies of the FORECAST computer code will be available for purchase from the U.S. Department of Energy's Energy Science Technology Center at Oak Ridge, TN tel: (423) 576-2606
Description of Environmental Liabilities Covered Compliance costs associated with new or revised regulatory requirements.	
Description of Derivation of the Monetary Values SEE BELOW	
Comments Very comprehensive (i.e., includes a number of parameters and cost categories) Allows for calculation of uncertainty distributions Applicability outside the nuclear power reactor industry may be limited	

Summary of the _FORECAST_ Regulatory Effects Cost Analysis Software

The *FORECAST* Software is designed to estimate the costs and benefits to nuclear licensees and the Nuclear Regulatory Commission (NRC) associated with new or revised regulatory requirements. Among the costs that may be estimated using *FORECAST* are regulatory compliance costs for industry. In estimating regulatory compliance costs, *FORECAST* considers the following major categories of costs:

- Engineering/QA-QC costs, which are modeled as a percentage of direct costs (i.e., labor, equipment, and materials);

- Hardware and equipment costs, which are derived from the Cost Factor Data Base (see Notes) or entered by the user;

Bibliography Reference #32: *FORECAST: Regulatory Effects Cost Analysis Software Manual* **(continued)**

- Health physics costs, which are based on radiation exposure and include costs for anti-contamination clothing, health physics personnel, shielding, and other factors;
- Installation labor costs associated with physical modifications (including base wages, fringe benefits, overhead, and fee);
- Procedural/analytical costs, which represent established industry costs for procedural, administrative, and analytical activities (e.g., technical specification changes, revisions to existing procedures and development of new procedures, staff training and retraining, recordkeeping and reporting, in-depth technical analyses, computations and scientific analyses, and other administrative duties);
- Radioactive waste disposal costs, which are calculated based on a 1,000-mile transport distance from the plant to the disposal site;
- Reactor defueling/refueling costs;
- Reactor shutdown and start-up costs;
- Removal labor costs associated with physical modifications (including base wages, fringe benefits, overhead, and fee); and
- Replacement energy costs incurred during shutdown, which are derived from a database of all power plants in the United States.

In addition to these cost categories, *FORECAST* also addresses the following types of costs:

- Averted on-site property costs due to accidents, including costs for (1) facility cleanup and decontamination and (2) long-term replacement energy; and
- Averted off-site non-health costs, including costs for protective emergency actions, decontamination and interdiction of property, disposal of contaminated food and milk, long-term relocation of people, and long-term interdiction/condemnation of property.
- Averted public and occupational health related costs due to accidents calculated at $2,000/person-rem. (See reference #33 for derivation of this value)

Notes

(1) The default parameter values used in *FORECAST* are primarily taken from the Cost Factor Data Base (which includes the Energy Economic Data Base), along with plant-specific data on replacement energy costs and other default data. The Energy Economic Data Base includes nuclear plant greenfield (new plant) construction costs as of 1989.

(2) Regulatory compliance costs can be modeled in *FORECAST* as both one-time costs and recurring costs. All recurring costs estimated by *FORECAST* are discounted to the present using the discount rate selected by the user (or the default rate of 7%).

Bibliography Reference #36: *Measuring Property Value Impacts of Hazardous Waste Sites*

Originating Organization	***Availability***
Kenneth T. Wise and Johannes P. Pfeifenberger Brattle/IRI, Cambridge, Massachusetts	Available through Air and Waste Management Association One Gateway Center Pittsburgh, PA 15222 tel: (412) 232-3444, fax: (412) 232-3450 Number 95-MP24.02 (June 1995)

Description of Environmental Liabilities Covered Decreases in property values due to "stigma" (i.e., perceptions of problems/risk) associated with proximity to hazardous waste sites.
Description of Derivation of the Monetary Values SEE BELOW
Comments Relatively straightforward methodology Statistically-based Solely structures an analysis and does not provide any quantitative data on property value decreases nor specific algorithms for estimating such effects Methodology presumes that housing prices in the subject and control areas would move in a predictable relationship Unobservable variables that are similar within neighborhoods and subdivisions (e.g., sewer systems, quality of roads) can add statistical noise and bias in the hedonic analysis and must be carefully controlled for

Summary of the Methodology

This methodology provides a general framework for measuring property value impacts of hazardous waste sites on a given area (termed the "subject area") utilizing transactional data to identify (1) if a site-related impact occurred, (2) when the impact occurred, and (3) whether the effect changed over time and distance. Property values are measured as housing prices. The methodology proceeds in five basic steps:

Step 1: Select a "control area."

- A control area is an area that is similar to the subject area based on factors such as house size, house age, house style, local services received, and development rates.

- The control area is key for estimating what housing prices would have been absent any possible impact.

Step 2: Determine the true price appreciation for houses.

- This step in the methodology calls for the use of hedonic analysis. Specifically, statistical analysis is applied to transaction data in order to determine the contribution of different attributes of a home (e.g., house size, lot size, location, condition) to its value.

Step 3: Find evidence of a price impact.

- The methodology calls for the hedonic model used in Step 2 to be used to identify the relationship between price movements in the subject and control areas that existed before any impact could be expected.

- The model compares actual price data for the subject area to the prices predicted by the relationship between prices in the subject and control areas. Statistically significant differences represent evidence of an impact.

- To link the price impact to the hazardous waste site, events related to the site (e.g., negative news coverage) must be analyzed.

Step 4: Determine the persistence of the price impact.

- Due to differences in volume, quality, and transmission of information about the hazardous waste site over time, the methodology calls for the application of a flexible model specification that efficiently uses available data to determine the nature of the price effect over time (i.e., steady decline, initial drop followed by a further decline, drop with a constant impact, of drop followed by a trend back).

Step 5: Examine distance effects.

- This step also calls for the application of a flexible model specification that efficiently uses available data. Potential statistical analysis methods in this step could include dividing the subject area using simple concentric rings around the waste site or using non-linear or piece-wise linear distance specifications. Additional variables measuring the interaction between time and distance may also be necessary.

Appendix A:
Timing, Likelihood, and Uncertainty Issues

When incorporating the monetary values of environmental liabilities into planning, decision-making, and operations, organizations may want to express or adjust the estimated dollar value magnitudes to reflect the timing, likelihood, and/or uncertainty associated with such future expenditures. This appendix introduces these topics.

1. <u>Timing</u>

By definition, all environmental liabilities involve *future* costs. A common approach to evaluating future payments is to calculate their net present value. This requires an estimate of both the magnitude and the *timing* of future outlays (as well as selection of an appropriate discount rate). Sometimes, particularly for compliance and remediation obligations, the outlays may occur within three to five years. Such obligations, however, also may not occur until a point quite remote in the future. For example, the cost of the compliance obligation to decommission a nuclear power plant or close a landfill following the end of its useful life may be twenty-five or more years away. Similarly, a remediation obligation to cleanup a contaminated site may not arise for decades. Compliance and remediation obligations also may be both years away and continuous in nature: in most cases, regulations require companies to provide for at least thirty years of "post-closure care" following the closure of certain waste disposal facilities. To remediate contaminated ground water in some locations could require fifty or more years of removal and treatment. Thus, these obligations may well entail a stream of future payments extending over time, as opposed to a lump sum outlay.

Compensation and natural resource damage liabilities can arise in the near-term or can have long time frames as well. Compensation and natural resource damage liability can be triggered by sudden accidents that can occur at any time. Conversely, existing or future releases of contaminants and exposure of persons and property can continue over many years before any adverse environmental aspects or health effects, such as many forms of cancer, manifest themselves (termed the "latency period"). Thus, compensation and natural resource damage claims may not materialize until years in the future after the use or release of a chemical or waste. And the process of investigating and litigating claims (e.g, linking health effects to prior exposures) can take several more years. On the other hand, claims for medical monitoring costs may be brought following mere exposure and in the absence of clear health impacts, meaning that some portion of the potential liability may arise earlier than other components.

In addition to understanding the potential timing of environmental liabilities, it is important to distinguish between (1) future costs that cannot be avoided or prevented due to events that have already taken place and (2) future costs that can be

> **Retroactive, Retrospective, and Prospective Liability**
>
> "Retroactive liability" is a term most often used in connection with Superfund to refer to liability resulting from past activities that ceased before establishment of the law creating the liability. Retrospective liability is a broader term that encompasses liability for past deeds that cannot be avoided or prevented. While all retroactive liabilities are retrospective in nature, retrospective liabilities are not necessarily retroactive. It is important to note that Superfund liability (and other laws) also applies *prospectively*, and, in so doing, creates incentives for proper management of hazardous substances.

avoided or prevented. Most reported accounting and insurance discussions of environmental liability relate to the first category, while most planning and risk management articles apply to the second category. The terms "retrospective" and "prospective" liability are sometimes used as labels for these two different situations. A related term "retroactive liability" has a special connotation and usage (see sidebox).

Understanding the timing of environmental liabilities is important in weighing the costs of taking actions to reduce or prevent those liabilities. Although there may be some opportunities to manage future costs resulting from activities and releases that have already occurred, different ways of doing business now and in the future can greatly affect a company's other environmental liabilities. In thinking about (and valuing) environmental liabilities, it may be useful to distinguish among:

(1) liabilities or potential liabilities due to past activities that have ceased
(2) liabilities or potential liabilities due to current activities, and
(3) potential liabilities due to future activities that have not yet begun.

The latter two categories represent opportunities for companies to prevent the incurrence of environmental liability costs. By considering potential liability costs in forward-looking business decisions, planners, managers and managerial accountants may realize the financial benefits of altering current practices or of avoiding new activities that might cause the incurrence of environmental liabilities.

2. Likelihood

Managers may want to consider *likelihood* when weighing the monetary value of their potential environmental liabilities against the costs of potential management options for preventing (or reducing the likelihood of) those liabilities.[22] A common approach to evaluating a potential environmental liability is to calculate its **expected value**, which is the product of its forecasted magnitude and its likelihood of occurrence.[23] In this way, the monetary estimate is adjusted (i.e., reduced) to reflect the probability that a future expenditure will be made. For example, if a potential environmental liability has an *estimated value* of $1 million and the likelihood of its occurrence is 10%, then the *expected value* of that liability is $100,000. The likelihood that a future expenditure will be made depends on whether the potential liability is certain to be incurred or, alternatively, depends on the uncertain occurrence or nonoccurrence of one or more future events.

What complicates management's evaluation of the likelihood of environmental liability costs is that the uncertainties can include both *factual* questions (e.g., Will the tank car leak? Will children be exposed to substance X? Will they be harmed? Will ground water be contaminated?) and *legal* questions (e.g., Does this law apply to this facility? Will there be a requirement to remediate this property? Are these damage claims compensable? Who is or will be legally responsible?) Thus, estimating the likelihood of a potential liability may require

---

[22]Where managers decide not to adjust the estimated liabilities to reflect their likelihoods of occurrence, as described below, adjustments to reflect the timing of future expenditures may nevertheless be made.

[23]More precisely, the expected value is the probability-weighted product of an array of forecasted magnitudes and the corresponding likelihoods of those magnitudes.

engineering, scientific, statistical, and legal analysis and judgment. Both the factual and legal questions may be difficult to answer with certainty, particularly when managers are making projections for forward-looking decisions; although, with time, better data tend to make the factual questions easier to address and legal precedents tend to make the legal questions easier to answer.

Likelihood of Compliance Liabilities

Of all the environmental liabilities discussed here, compliance liabilities have the lowest level of associated uncertainty. If a law applies to a facility, activity, or substance, expenditures to come into compliance must be made by a specified date. Therefore, there may be no need to adjust the estimated cost of compliance to reflect the likelihood of the incurrence of the liability.[24] For example, regulations require that those who open a hazardous waste surface impoundment must, at some point in the future, properly close it. There is no way to avoid that closure obligation; it is not contingent on any future event. However, if the closure does not meet "clean closure" standards, then post-closure care must be provided; this post-closure care requirement is contingent upon the results of the closure procedure. In this example, because the likelihood of closure is certain, its estimated cost need not be adjusted, but the potential cost of post-closure care can be adjusted to reflect the probability that post-closure care costs will be incurred. Another example: to avoid reporting and emissions control requirements that will apply to users of a particular ozone depleting substance, a business may switch to an alternative substance (or process) that is not regulated. This is an example of a compliance obligation that is not contingent on a future event, but rather, becomes inapplicable (i.e., avoidable) once use of the substance stops. In this example, because the future compliance expenditures will certainly be incurred, it would be inappropriate to adjust the estimated compliance cost for likelihood; the full cost of compliance should be considered when evaluating alternative practices.

Likelihood of Potential Remediation Liabilities

Potential remediation liabilities for future contamination have different types of associated uncertainty. Potential factual uncertainties could include, at a minimum, whether there will be a release or threat of release to the environment, transport through the environment, and/or discovery of the release. Depending on the situation, potential legal uncertainties could include whether there will be an obligation to remediate and whether that liability will be shared with others (often termed "joint and several" liability). The latter contingency may be relevant for a company that sends its waste off-site for disposal at a commercial facility that also accepts wastes from others. (On the other hand, liability for remediation of contamination resulting from on-site waste disposal would not likely be shared with others unless the property is subsequently sold.) In these situations, the estimated monetary magnitude of the potential remediation liability could be adjusted to reflect both the likelihood that the liability will arise and the proportionate share of any liability for which other companies might be legally responsible.

However, it may be appropriate to view potential remediation liabilities for future contamination as certain to arise for such practices as the underground storage of petroleum

---

[24]As discussed earlier in this appendix, managers may choose to adjust the estimated cost of compliance to reflect the timing of the future expenditures.

products or other substances; the underground injection of wastes; or placing solid and liquid wastes into landfills and surface impoundments. Over time, leaks from containment may become increasingly likely. Given design limitations, releases may become quite probable. A conservative management approach might treat such future remediation expenditures as a certainty by not adjusting the magnitude of the potential liability by the likelihood of its occurring; this would provide managers with greater incentives to find alternatives to the use of such practices because a higher monetary value would be associated with the potential liability.[25] Some of reported tools employ this approach.

Likelihood of Compensation Liabilities

Compensation liabilities are not usually considered certainties due to the many factual and legal hurdles that must be crossed prior to the incurrence of a liability. As with remediation liabilities, compensation liabilities may depend on such factors as the existence of releases (e.g., accidental, intermittent, or continuous), exposure of human beings or their property to releases, and prevailing legal rules. For a compensation claim to become a compensation obligation, either the parties must agree to a settlement or one or more courts must find that the claim satisfied a variety of legal and factual tests. In evaluating such potential liabilities, companies can adjust their liability cost estimations to reflect their probabilities of occurrence. For example, the expected value of a potential compensation liability of $10 million with a one percent likelihood is $100,000. Alternatively, just as a company in its planning and decision-making might want to treat certain remediation liabilities for future contamination (e.g., from underground storage or disposal of substances) as eventual certainties, a company with a conservative management approach might choose to treat selected compensation liabilities (e.g., medical monitoring for people exposed to *regular releases* of hazardous air pollutants) as certain to arise in order to provide a greater financial incentive for developing alternative practices that would eliminate or reduce such regular releases.[26]

Likelihood of Penalties and Fines for Noncompliance

Penalties and fines are doubly uncertain. First, for most companies, noncompliance itself is an uncertain and unlikely event, unless a firm has a corporate policy to deliberately flout environmental laws. Noncompliance may be likened to accidental releases -- neither is explicitly intended but management can influence to some degree (e.g., through training, technology) the probabilities that these events will occur. Second, penalties and fines are triggered only in the event of discovery (such as through an official inspection or review of required submissions of information) of noncompliance. Thus, the magnitude of the potential liability due to fines and penalties can be adjusted (1) to reflect the likelihood of being out of compliance and (2) to reflect the probability of discovery of the noncompliance. If a company, however, prefers to base its planning and decision-making on the presumption that any non-compliance will be discovered, it would choose not to make any adjustments for the likelihood of discovery.

Likelihood of Natural Resource Damages

---

[25]However, as discussed earlier in this appendix, managers may choose to adjust the estimated cost of remediation to reflect the expected timing of the future expenditures.

[26]The comment in footnote 25 applies as well to compensation liabilities.

Natural resource damages that result from accidental releases, such as spills during transport, are by their nature unlikely events. Similarly, natural resource damages caused by releases of hazardous substances due to fires, explosions, or earthquakes are uncommon events. Thus, it may be appropriate to adjust the potential magnitude of such natural resource damage liabilities to reflect the probability of their occurrence. Finally, because natural resource damage liability is so new, claims are likely to be litigated, perhaps further coloring natural resource damages as unlikely to occur. On the other hand, natural resource damages may be caused by the regular release of pollutants into the environment; although any resulting natural resource damage may be unintentional, the releases themselves are not accidental in these cases. For such intentional releases, a company might decide to view liability for natural resource damages as the certain outcome of its practices and recognize those costs as fully avoidable (i.e., no adjustment for likelihood) when evaluating alternative pollution prevention and control practices.[27]

3. Uncertainty

Estimates or projections of future costs have **unavoidable uncertainties**. There may be uncertainties regarding (1) magnitude, (2) probability of occurrence, and/or (3) timing of a liability. These uncertainties may be due to inherent variability or to a lack of information. Several of the liability valuation approaches can develop results in ways that make uncertainties more transparent. For example, levels of estimated liability costs can be paired with their respective probabilities of occurrence; this is termed a probability distribution. Developing a probability distribution provides information on the potential range of liability costs and facilitates the calculation of the "expected value" of a liability costs, which may differ from the "most likely" value. Such a probability distribution can easily be converted into a "cumulative frequency distribution," which indicates the likelihood that liability costs will be at or above a given value. For example, to reflect uncertainties in the potential for accidental releases and the resulting cost of remediation, decision analysis techniques have been used as a means for assessing the likelihoods of remediation costs exceeding various dollar levels. Compensation liabilities have been treated in a similar fashion. The approach also is applicable to liability for fines and penalties. This statistical approach provides more information than a single point "best estimate" of the cost or a multiple point estimate of "worst case," "most likely," and "best case" estimates. Managers can select their own levels of risk adverseness from such distributions.

---

[27] See footnotes 25 and 26.

Appendix B:
Annotated Bibliography
Environmental Liability Valuation
(* Asterisked references are profiled in Section 5 of this report.)

*1. Aldrich, James R. Air Force Institute of Technology, Wright-Patterson Air Force Base, OH. "Expected Value Estimates of the Long-Term Liability from Landfilling Hazardous Waste." Technical Paper. *Journal of the Air & Waste Management Association*, June 1994, 44:800-803. ISSN 1047-3289. This paper develops liability factors for use in justifying pollution prevention investments based on the premise that the key element in predicting future liability costs is the cost of waste destruction. See also "Estimating the Long-Term Liability from Landfilling Hazardous Waste." Ph.D. dissertation, University of Cincinnati, 1993. Dissertation available from UMI Dissertation Services, Ann Arbor, Michigan, 1-800-521-0600, Order Number 9313811.

*2. American Institute of Chemical Engineers (AIChE). *Dow's Fire & Explosion Index Hazard Classification Guide*. New York: AIChE, 1994. Technical manual, seventh edition. The primary purpose of this tool is to serve as a guide to determine the hazards associated with the use of flammable materials. It also serves as a tool for evaluating fire and explosion loss potential of process areas and for identifying ways to lessen the severity and resultant dollar loss of potential incidents. Designed for operations where at least 1,000 lb (454 kg) of a flammable, combustible, or reactive material is stored, handled, or processed.

3. Atomic Industrial Forum, Inc. *Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates.* 1986. The 2-volume report on nuclear power plant decommissioning estimates is available for $15 from the Nuclear Energy Institute (NEI), the successor to the Atomic Industrial Forum. Contact Stacy Bonds, NEI Publications, 1776 I Street NW, Washington, D.C. 20006-3708. Telephone: (202) 739-8148. Newer tools have since been developed by TLG Associates, Inc. and the U.S. Nuclear Regulatory Commission to help project these costs.

4. Bailey, Paul E. ICF Incorporated, Fairfax, VA. "Quantifying Environmental Exposures for Business Decisions: Approaches to Monetizing Environmental Liabilities." Presented at the 87th Annual Meeting & Exhibition, Air & Waste Management Association (A&WMA), Cincinnati, OH, June 1994. 94-TA31.06. Available from A&WMA, One Gateway Center, Pittsburgh, PA 15222, tel: (412) 232-3444, fax: (412) 232-3450. This paper compares "top-down" and "bottom-up" approaches for valuing a variety of environmental liabilities. See also reference 21 below.

5. Bailey, Paul E. and Karam, Joseph G. "Expressing Environmental Liabilities in Dollars and Cents: What Corporations Can Do Now." *Environmental Finance,* Winter 1991/92. This article discusses the nature of environmental liabilities, reasons for placing a monetary value on them, and the state of the art. Approaches to valuing remediation liabilities, penalties and fines, and personal injuries to nonemployees are illustrated.

*6. Chansky, Joel S. Milliman & Robertson, Inc. "An Actuarial Approach to Quantifying Environmental Exposure." Presented at the 87th Annual Meeting and Exhibition, Air and Waste Management Association, Cincinnati, OH, June 1994. This paper describes a risk modeling approach to environmental exposures where there may not be a credible body of historical data from which to make financial projections; the approach is applied to underground storage tanks.

*7. Chansky, Joel S. and Gulledge, William. Milliman & Robertson, Inc., Wakefield, MA and Environmental Insurance Management, Inc. McLean, VA. *Missouri Underground Storage Tank Insurance Fund*. October 1990. This insurance fund covers tanks without existing leaks, their remediation, and associated property damage only.

*8. Englehardt, James D. University of Miami, Department of Civil and Architectural Engineering. "Information-Limited Benefit-Risk Analysis for Sustainable Process Design." *ASCE Journal of Environmental Engineering.* Forthcoming, scheduled to be published in January, 1997. This article illustrates the application of Bayesian inference, viewed as superior to conventional statistical and fuzzy methods, in assessing uncertain and variable economic risks, including environmental, health, and safety liabilities. See also "Economic Evaluation and Risk Analysis for Industrial Waste Management Design." Ph.D. dissertation, University of California Davis, 1991.

9. Florida. *Florida's Pollutant Discharge Natural Resource Damage Assessment Compensation Schedule* (*Laws of Florida*, Chapter 92-113). Assesses damages for injury to natural resources as a result of a pollutant discharge into coastal waters of Florida. The equations used in the model are very simple and generalized, as are the model inputs.

*10. General Electric Corporate Environmental Programs. "Financial Analysis of Waste Management Alternatives." 1987. Developed with ICF Incorporated. This workbook was developed to aid plant professionals in selecting and justifying waste management investment decisions by describing a process for determining the direct costs and potential liabilities in dollars of various waste management practices. A scaling/scoring approach is used to adjust reference liability costs.

11. Huffman, Larry; Karam, Joseph; and Bailey, Paul. "Estimating the Costs of Corrective Action at Land Disposal Facilities." *Remediation*, Winter 1990/91. This paper presents parametric cost curves for estimating future corrective action costs for municipal solid waste landfills, depending on landfill area, average waste thickness, and the presence or absence of a clay liner The curves are constructed from engineering-based cost estimates.

*12. Indiana. *State of Indiana - Analysis of Funding Requirements for the Petroleum Underground Storage Tank Excess Liability Fund*. Chicago, IL. January 1990. Prepared by Tillinghast, a Towers Perrin company. This UST fund covers remediation liabilities as well as compensation liabilities for all tanks.

*13. James, Steven E. and Schaarsmith, James H. "Use of Decision Science Techniques in Management of Environmental Financial Risks." *Journal of Environmental Practice*, September/October 1994. This article discusses the use of decision analysis techniques in valuing environmental liabilities. Some results are presented from a study performed for a large mining and basic minerals company.

*14. Koch, Gayle S.; Ammann, Paul R.; and Wise, Kenneth T. The Brattle Group, Cambridge, Mass. "Using Decision Analysis to Manage Environmental Costs." Presented at the 87th Annual Meeting and Exhibition, Air and Waste Management Association, Cincinnati, OH, June 1994. This paper describes types of environmental uncertainties and illustrates decision analysis with several case study summaries.

15. Meyers, Michael. Strata Environmental Services, Inc. Knoxville, Tenn. "The Shape of Risk: A Protocol for Environmental Financial Risk Management." *Environmental Law and Practice,* May-June 1994, pp. 44-57. This article proposes fuzzy set logic analysis as an alternative to probabilisitc risk assessment when conducting environmental financial risk analysis.

*16. Miakisz, Joseph A. "How Niagara Mohawk Incorporates Environmental Factors into Policies, Plans, and Procedures." *Total Quality Environmental Management*, Summer 1995. This article describes how Niagara Mohawk Power Corporation has incorporated environmental considerations in its valuation of new and existing generation sources. The article discusses how both existing and future environmental requirements are incorporated into the planning process.

*17. Moilanen, Tuula and Martin, Christopher. *Financial Evaluation of Environmental Investments*. Houston: Gulf Publishing Company, 1996. This book presents a model and methodology for assessing the expected monetary values of environmental investments, including an illustration of one equation used to put a monetary value on future liability costs for insurable compensation.

18. Mukhopadhyay, Nik and Moretti, Edward C. Center for Waste Reduction Technologies, American Institute of Chemical Engineers (AIChE). *Current and Potential Future Industrial Practices for Reducing and Controlling Volatile Organic Compounds*. 1993. This book presents order-of-magnitude cost estimates of the capital and annualized costs of three end-of-pipe VOC abatement technologies under several operating conditions. For two of the technologies, the costs were estimated using the EPA's HAP-PRO software package Capital costs include direct capital and installation costs and some indirect costs. Operating costs include direct, indirect, operating and maintenance, and replacement parts and labor. For the other technology, costs were not derived from HAP-PRO, but from technical literature and a survey respondent. Available through AIChE's Center for Waste Reduction Technologies. Contact the AIChExpress Service Center, 345 E. 47th Street, New York, NY 10017-2395. Telephone: 1-800-AIChemE, fax: (212) 705-8400, e-mail: xpress@aiche.org. ISBN0816906157 (Publication # C-2).

19. New York State Department of Environmental Conservation. DEC Publication - Division of Hazardous Substances Regulation Bureau of Radiation. *Draft Generic Environmental Impact Statement for Promulgation of 6 NYCRR, Subpart 383-6, Financial Assurance Requirements for Low-Level Radioactive Waste Disposal Facilities.* September 1990, Vol. II. Prepared with ICF Incorporated. This study applied the BIPDAM (Bodily Injury, Property Damage Assessment Model) methodology to value environmental liabilities associated with the disposal of low-level radioactive waste in New York. Available through Paul Merges, Chief, Bureau of Pesticides and Radiation, New York Department of Environmental Conservation, Room 402, Albany, New York 12233-7250; telephone: (518) 457-2225; fax: (518) 485-8390; e-mail: paul.merges@dec.mailnet.state.ny.us.

*20. New York State Department of Environmental Conservation. DEC Publication - Division of Hazardous Substances Regulation Bureau of Radiation. *Risk Assessment and Financial Surety Requirements Analysis for Transportation of Low-Level Radioactive Waste in New York State. Volume II - Generic Environmental Impact Statement for Promulgation of 6 NYCRR Part 381: Regulations for Low-level Radioactive Waste Transporter Permit and Manifest System.* February 1988. Prepared with ICF Incorporated. This report developed and applied the BIPDAM (Bodily Injury, Property Damage Assessment Model) methodology for valuing environmental liabilities associated with the transport of low-level radioactive waste in New York State, taking into account different vehicle categories, waste shipment characteristics, transport routes, accident events, and environmental settings. See, especially, "Appendix C - Derivation of Unit Cost Estimates."

*21. Schoemaker, Paul J.H. and Schoemaker, Joyce A. "Estimating Environmental Liability: Quantifying the Unknown." *California Management Review*, Spring 1995. This paper describes an approach for valuing environmental liabilities developed for a manufacturing company engaged in litigation with its insurers. A top-down approach was used for hazardous waste sites and a "case method" was used for tort liability. The paper also describes a scenario process used to assess potential future trends. See also reference 4 above.

*22. U.S. Air Force. *Hazardous Materials Cost Trade-Off Analysis Tool (HMCTAT).* This tool, scheduled for release in December 1996, is a revised and enhanced Windows format version of the DOS, version 3.3, Hazardous Materials Life Cycle Cost Estimator (HMLCCE). This tool facilitates trade-off analyses for weapon system processes that use hazardous materials; among the costs considered are potential legal/environmental liability costs.

*23. U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). *Natural Resource Damage Assessments. Notice of Proposed Rulemaking.* 59 *FR* 1062. 15 CFR Part 990. January 7, 1994. This proposed rule summarized written comments and issues raised during the public meetings and workshops, and responded to those comments. It was reproposed August 3, 1995 (60 *FR* 39804), and a final rule was promulgated January 5, 1996 (61 *FR* 440), effective February 5, 1996. See also 59 *FR* 32148 (June 22, 1994) (summary of comments received at regional workshops and notice of availability of summary report) and 58 *FR* 4601 (January 15, 1993) (report of the panel commissioned to evaluate the reliability of contingent valuation in calculating passive use values for natural resources). See also Appendix C of this report.

*24. U.S. Department of Defense (DoD). Environmental Leadership Project Office. *A Comparison of the True Costs of Landfill Disposal and Incineration of DoD Hazardous Wastes*. Draft, prepared by ICF Technology, a division of ICF Incorporated. Washington, D.C. September 1984. This study analyzes the true costs of landfilling and incineration, including closure/post-closure costs, remediation costs, and liability costs, for certain hazardous wastes. The analysis is very detailed and well documented.

*25. U.S. .Department of Defense (DoD). Environmental Leadership Project Office. "Least-Cost DoD Hazardous Waste Management Strategies." Final Draft Report, prepared by ICF Incorporated. Washington, D.C. June 1987. The purpose of this study was to examine available alternatives for managing hazardous wastes and to develop an optimal strategy for DoD as a whole, taking into account the potential costs of future liabilities. This study covered a wider range of wastes and waste management alternatives than the study described in reference 24 above.

*26. U.S. Department of the Interior. *Hazardous Substances Natural Resource Damages Assessment Regulations.* 43 CFR Part 11. 59 FR 14261, March 25, 1994. (Revised Type B procedures, except for lost nonuse values.) See also 61 FR 20559, May 7, 1996 (Type A procedures); 59 FR 40319, August 8, 1994 (Proposed revised rule for additional Type A procedure for assessing natural resource damages in Great Lakes Environment); 59 FR 63300, December 8, 1994 (Proposed revised Type A procedure for coastal and marine environments); and 51 FR 27673, August 1, 1986 (Initial Type B procedure for site-specific assessments; Supplementary Technical Information Documents identified). See also *Natural Resource Damage Assessments; Final Rule,* 52 FR 9042, March 20, 1987 (Initial simplified Type A procedures). Also see Appendix C.

*27. U.S. Environmental Protection Agency. Office of Enforcement. *BEN: A Model to Calculate the Economic Benefits of Noncompliance (User's Manual)*. Revised December 1993. EPA 300-B-94-002. This document describes the BEN computer model, which EPA developed to calculate the economic benefit of noncompliance with environmental requirements.

*28. U.S. Environmental Protection Agency. Office of Policy, Planning, and Evaluation and Office of Solid Waste. *Pollution Prevention Benefits Manual - Volume I: The Manual and Volume II: Appendices*. October 1989. Prepared by ICF Incorporated. This manual presents a two-step approach to the evaluation of pollution prevention projects: (1) cost calculations and (2) financial calculators. The manual introduced a four-tiered approach to assessing costs, with liability costs comprising the third tier. The manual contains a detailed hypothetical facility example as an illustration.

*29. U.S. Environmental Protection Agency. Office of Solid Waste. *Post-Closure Liability Trust Fund Simulation Model: Volume 1. Model Overview and Results. Volume 2. Graphs and Tables of Model Results. Volume 3. Model Description*. May 1985. Prepared by ICF Incorporated. This multivolume report documents a major study to forecast the potential environmental liabilities of active hazardous waste management facilities in compliance with applicable standards and following the end of their useful lives. The study evaluated legal regimes as cost allocators, developed liability cost estimates, and employed a sophisticated Monte Carlo simulation model to address uncertainties.

*30. U.S. Environmental Protection Agency, Region VII. *Analysis of Kansas State Fund for Approval as Alternative Financial Assurance Mechanism*. Draft document. Prepared by ICF Incorporated. July 1991. This UST fund covers remediation liabilities as well as compensation liabilities for all tanks.

31. U.S. Environmental Protection Agency, Region VII. *Evaluation of Fund Amount for the Nebraska Petroleum Release Remedial Action Cash Fund*. Draft document. Prepared by ICF Incorporated. November 1990. For qualifying operators or owners (e.g., in compliance with applicable regulations at the time the release occurred) of both above and below ground tanks, this fund covers costs of remediation only, not third-party liability costs.

*32. U.S. Nuclear Regulatory Commission (NRC). *FORECAST: Regulatory Effects Cost Analysis Software Manual*, Version 4.1. NUREG/CR-5595 Rev. 1. July 1996. *FORECAST* runs on Microsoft Windows™ Version 3.1. Prepared by Science and Engineering Associates, Inc. This generic costing tool applies to most nuclear plant physical and procedural or analytical modifications that may be required because of a regulatory change. NUREG/CR-4627 *Generic Cost Estimates. Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses, Rev. 2* (Feb. 1992) includes a complete set of abstracts of the NRC's generic cost analysis methodology. Both of these documents are available for a fee from U.S. NRC, Public Document Room, Washington, D.C. 20555, tel: (202) 634-3273 or 1-800-397-4209, fax: (202) 634-3343, e-mail: pdr@nrc.gov.

33. U.S. Nuclear Regulatory Commission. *Reassessment of NRC's Dollar Per Person-Rem Conversion Factor Policy*, NUREG-1530. December 1995. This report describes how and why NRC decided to revise its dollar per person rem conversion factor, which it uses as the monetary valuation of the health consequences associated with radiological exposure. Available for a fee from U.S. NRC, Public Document Room, Washington, D.C. 20555, tel: (202) 634-3273 or 1-800-397-4209, fax: (202) 634-3343, e-mail: pdr@nrc.gov.

34. Washington. *Preassessment Screening and Oil Spill Compensation Schedule Regulations* (Washington Administrative Code, Chapter 173.183-185). This compensation schedule assesses damages resulting from an oil spill into fresh waters, marine waters, and estuarine waters. Although the questions used in the model are specific to Washington state, they are also relatively straightforward.

35. Wisconsin, State of. Department of Industry, Labor & Human Relations and Department of Natural Resources. Skornicka, Carol and C.D. Besadny, Secretaries. *Joint Agency Report on the Petroleum Storage Remedial Action Fund (PECFA)*. October 1991. This UST fund covers remediation liabilities for all petroleum tanks but does not cover compensation liabilities.

*36. Wise, Kenneth T. and Pfeifenberger, Johannes P. Brattle/IRI. "Measuring Property Value Impacts of Hazardous Waste Sites." Presented at the 88th Annual Meeting and Exhibition, Air & Waste Management Association, Cincinnati, OH, June 1995. This paper describes the use of statistical analysis of housing sales data to estimate the impact of proximity to a hazardous waste site on property values, including a case study illustration.

37. Wise, Kenneth T.; Koch, Gayle S.; and Ammann, Paul R. "Evaluating Environmental Costs: Accounting for Uncertainties." *Chemical Waste Litigation Reporter*, Washington, D.C., February 1994. This paper describes how decision analysis can be used to evaluate remediation liabilities, including future remediation costs resulting from past operations. The result is a distribution of potential costs as well as an expected cost, illustrated by a hypothetical example.

Appendix C:
Natural Resource Damage Valuation Guidance Documents

U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). 1996. *Natural Resource Damage Assessment Guidance Document: Injury Assessment (Oil Pollution Act of 1990).* National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program, Silver Spring, MD. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB96-199427.

NOAA. 1996. *Natural Resource Damage Assessment Guidance Document: Specifications for Use of NRDAM/CME Version 2.4 to Generate Compensation Formula (Oil Pollution Act of 1990).* National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program, Silver Spring, MD. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB96-199435.

U.S. Department of the Interior (DOI). 1996. *The CERCLA Type A Natural Resource Damage Assessment Model for the Great Lakes Environments* (NRDAM/GLE). U.S. Department of the Interior, Office of Environmental Policy and Compliance, Washington, D.C., Vol. I-III. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB96-501770 (4/96). Computer diskettes containing the version 1.2 natural resources damage assessment models can be obtained from the Department of the Interior. (The version 1.31 computer model is available in draft status.)

DOI. 1996. *The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments* (NRDAM/CME). U.S. Department of the Interior, Office of Environmental Policy and Compliance, Washington, D.C., Vol. I-VI. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB96-501788 (4/96). Computer diskettes containing the version 1.2 natural resources damage assessment models can be obtained from the Department of the Interior. (The version 2.2 computer model is available in draft status.)

DOI. 1987. *Type B Technical Information Document: Application of Air Models to Natural Resource Injury Assessment*. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB88-100128 (6/87).

DOI. 1987. *Type B Technical Information Document: Approaches to the Assessment of Injury to Soils Arising from Discharges of Hazardous Substances and Oil*. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB88-100144 (6/87).

DOI. 1987. *Type B Technical Information Document: Injury to Fish and Wildlife Species*. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB88-100169 (6/87).

DOI. 1987. *Type B Technical Information Document: Guidance on Use of Habitat Evaluation Procedures and Habitat Suitability Index Models for CERCLA Applications*. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB88-100151 (6/87).

DOI. 1987. *Type B Technical Information Document: Techniques to Measure Damages to Natural Resources*. Available for a fee from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: (703) 487-4650. NTIS accession number: PB88-100136 (6/87).

See also the following:

American Petroleum Institute (API). *Measuring Natural Resource Damages: An Economic Appraisal.* API Publication No. 4490. Washington, D.C. 1989.

Kopp, Raymond J. and V. Kerry Smith (eds.). *Valuing Natural Assets and the Economics of Natural Resource Damage Assessment.* Resources for the Future, Washington, D.C. 1993.

Appendix D:
Authoritative Literature on Accounting for Environmental Liabilities in Financial Statements

American Institute of Certified Public Accountants. *Statement of Position 96-1: Environmental Remediation Liabilities (Including Auditing Guidance).* October 10, 1996.

Financial Accounting Standards Board (FASB).

FASB Statement No. 5: Accounting for Contingencies.
FASB Interpretation No. 14: Reasonable Estimation of the Amount of a Loss - An Interpretation of FASB Statement No. 5.
Exposure Draft, Accounting for Certain Liabilities Related to Closure or Removal of Long-Lived Assets.[28]

Financial Accounting Standards Board, Emerging Issues Task Force (EITF).

EITF Issue 89-13: Accounting for the Cost of Asbestos Removal. 1989.
EITF Issue 90-8: Capitalization of Costs to Treat Environmental Contamination. 1990.
EITF Issue 93-5: Accounting for Environmental Liabilities. 1993.

Governmental Accounting Standards Boards (GASB). *GASB Statement No. 18: Accounting for Municipal Solid Waste Landfill Closure and Post-Closure Care Costs.* 1993.

U.S. Securities and Exchange Commission (SEC). 17 CFR Part 211. *SEC Staff Accounting Bulletin No. 92: Accounting and Disclosures Relating to Loss Contingencies.* 1993.

---

[28]An exposure draft is not considered authoritative.