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ABSTRACT

This paper examines the natural resource damage assessment regulations recently promulgated under CERCLA and their potential effectiveness. The regulations have a number of important characteristics, broad potential applicability, and their implementation has several novel features. For these reasons, the natural resource damage assessment regulations required by CERCLA potentially represent a major development in environmental policy. The regulations also may represent a major, and perhaps unprecedented, expansion of the use of economic incentives to control pollution. Examined within the paper are: the natural resource damage assessment framework provided by the Act, the conceptual and analytical underpinnings of the liability regulations developed to implement the Act, and the approach and institutional setting for administering the regulations.

INTRODUCTION

At least since the 1930s, with the work of Pigou[1] economists have been concerned with the development of efficient policy approaches for controlling pollution. The use of economic incentives in particular has long been advocated by economists as an efficient way for managing pollution.[2] The economists' argument for the need to control polluting activities is based on the idea that the free economy, left on its own, will not allocate resources efficiently because the costs which result from discharges or releases into the environment are faced by society as a whole, rather than by the polluting firm. This is the concept of the external cost, or exter-

*The authors are Professor and Associate Professor in the Department of Resource Economics at the University of Rhode Island. The underlying research was funded by U.S. Department of Interior. The authors also acknowledge support on general issues relating to environmental policy from the Rhode Island Agricultural Experiment Station (AES contribution #2402). All opinions are those of the authors, and do not necessarily reflect the opinions of the funding agencies.

1. Arthur C. Pigou, The Economics of Welfare (4th ed. 1932).
2. Allen V. Kneese & Charles L. Schultze, Pollution, Prices, and Public Policy (1975).

nality, whereby some costs which are caused by firm's production decisions are borne by others who are external to the firm. The economists' prescription is to require the responsible firm to pay for damages from the pollution incident, so that the firm faces the cost resulting from its discharge or release. This type of charge is referred to as a Pigouvian tax, and economists have recommended its use as a way of providing economic incentives for polluters to control their emissions.[3]

In contrast with the use of economic incentives, command-and-control regulations, which are the mainstay of traditional environmental legislation, require the firm to institute measures of pollution control, but do not require the polluter to bear the costs of emissions which are allowed, for example the National Pollution Discharge Elimination System[4] permits. While some potentially cost-effective approaches advocated by economists, such as transferable discharge permits, have received considerable attention and limited application,[5] a tax for discharges or releases generally has not been used as a policy instrument for controlling pollution.

Many factors explain why economists' recommendations in this area have been embraced less than enthusiastically. Not the least of these is the lack of appreciation by those in the political arena for the role that market incentives can play in guiding resource allocation decisions, a problem that Schultze[6] refers to as "the mystery of the market." More fundamentally, however, it is well known that the development of a workable system of pollution taxes which are based on internalizing pollution damages places a considerable burden not only on economists, but also on natural scientists and others whose cooperative efforts are required to develop the necessary quantitative relationship between a pollution incident and an economic measure of the resulting damage. Furthermore, the actual implementation of a system of charges or taxes requires the existence of an appropriate legal and institutional regime (1) to define the legal basis for financial responsibility, (2) to define the nature and scope of the damages to be covered, and (3) to provide an institutional setting within which an approach based on pollution charges can be administered and enforced. These factors, among others, have presented formidable obstacles to the development of a system of charges or taxes for controlling pollution.[7]

3. Pigou, The Economics of Welfare (cited in note 1).

4. Hereinafter NPDES.

5. Erhard F. Joeres, Martin H. David (eds.), Buying a Better Environment: Cost Effective Regulation through Permit Trading (1985); see also T. H. Tietenberg, Emissions Trading: An Exercise in Reforming Pollution Policy (1985).

6. Charles L. Schultze, The Public Use of the Private Interest (1975).

7. See, for example, Russell, What Can We Get from Effluent Charges, 5 Policy Analysis (1979) for a discussion of many of the issues and problems involved with the development of an effluent charge system.

Although only limited attempts have been made to impose charges which are based on damages, the use of strict liability in environmental legislation can lead to an outcome which in many important respects simulates a workable system for charging or taxing polluters for damages from pollution incidents.[8] Various pieces of environmental legislation provide strict liability for damages from spills of oil or hazardous substances. These include the Outer Continental Shelf Lands Act Amendments of 1978,[9] the Comprehensive Environmental Responses, Compensation and Liability Act of 1980,[10] CERCLA's recent amendments, the Superfund Amendments and Reauthorization Act of 1986[11] and the Water Quality Act of 1987 as amended.[12] While the purview and specific provisions of these legislative initiatives differ, each of these laws establishes strict liability for damages and, thereby, potentially provides a national framework which rests on the use of financial incentives.[13] However, the liability relates only to oil spills or hazardous substance releases, and not, for example, to emissions permitted under the NPDES. Furthermore, the natural resource damage liability provisions under CERCLA and the CWA, for example, are restricted to damages to publicly owned or controlled natural resources and do not include damages to private parties, unlike the OCSLA.

This paper focuses on the natural resource damage provisions mandated by CERCLA, the newest of the major federal environmental laws, and in particular on the natural resource damage assessment regulations required by the Act and prepared by the U.S. Department of the Interior.[14] Under CERCLA and the CWA, as amended, polluters are liable not only for cleanup and reasonable assessment costs, but also for "damages for injury to, destruction of, or loss of natural resources . . ."[15] resulting

8. For an examination of the usefulness of liability see James J. Opaluch & Thomas A. Grigalunas, Controlling Stochastic Pollution Events with Liability Rules: Some Evidence from OCS Leasing, 15 Rand J. Econ. (1984). For a more general treatment of the potential for liability as incentives see Steven Shavell, Strict Liability versus Negligence, 9 J. Legal Studies 1 (1980) or Cootner & Ulen, Law and Econ. (1987). Issues such as combined ex-ante regulation and ex-post liability or the implications of risk bearing implicit in liability rules, and the potential for sharing of risks are not considered in this paper. Excellent discussions of these issues are contained in Shavell, A Model for the Optimal Use of Liability and Safety Regulation, 15 Rand J. Econ. (1984), Segerson, Risk Sharing in the Design of Environmental Policy, 68 Am. J. Agric. Econ. (1986), or Johnson & Ulen, Designing Public Policy toward Hazardous Wastes: The Role of Administrative Regulations and Legal Liability Rules, 68 Am. J. Agric. Econ. (1986).

9. Pub. L. No. 95-372, 92 Stat. 629 (1978) (OCSLA).

10. Pub. L. No. 96-510, 94 Stat. 2767 (1980) (CERCLA).

11. Pub. L. No. 99-499, 100 Stat. 1613 (1986).

12. Pub. L. No. 100-4, 101 Stat. 7 (1987) (CWA).

13. See, for example, James J. Opaluch, The Use of Liability Rules in Controlling Hazardous Waste Accidents: Theory and Practice, 13 Northeast J. Agric. Resource Econ. (1984).

14. Hereinafter DOI.

15. Pub. L. No. 96-510 at § 107.(a)(4)(C), 94 Stat. 2781 (1980) [hereinafter referred to as damages for injury to natural resources].

from a spill. Although liability for damages from oil spills is established in the CWA, CERCLA establishes the general methodological requirements to be employed for damage assessments, both under CERCLA and the CWA.[16]

Briefly, CERCLA provides for two types of natural resource damage assessment regulations. The type A regulations provide a simplified approach, involving minimal field observation to be used for minor incidents, while the type B regulations describe methods for site-specific, natural resource damage assessments with potentially extensive field observations, to be used for major incidents.

The two-tiered damage assessment approach mandated by Congress recognizes that undertaking a damage assessment can be very expensive, and that unless restricted, assessment costs can easily exceed the value of the damages which can be ascertained. For example, a careful study of the December 1985, 5,700 barrel ARCO ANCHORAGE crude oil spill could detect damages of only $32,930, while assessment costs amounted to about $245,000.[17] Even given a willingness to incur substantial assessment costs, environmental damages are often quite difficult to observe and measure. Hence, the results of damage assessments should be thought of as an estimate of damages, rather than as the true dollar value of the actual loss.

Clearly, the intent of CERCLA is to compensate governments, in their role as trustees, for natural resources injured by the release or discharge. Thus, the primary goal of the Act is to encourage distributional equity by compelling the responsible party to pay damage compensation for the injuries resulting from its actions. The amount recovered is to be ". . . available for use to restore, rehabilitate, or acquire the equivalent of such natural resources by the appropriate agencies. . . ."[18] However, in effect the natural resource liability provisions of CERCLA create a legal framework for what is akin to a Pigouvian tax on pollution, whereby the polluter bears the costs of damages from injury to publicly controlled natural resources resulting from an incident covered by the Act. As such, the natural resource damage assessment regulations introduce what could be an important new approach for using economic incentives to avoid pollution for a wide range of incidents.

It is difficult to overstate the potential importance of the natural resource damage liability provisions of CERCLA. As described below, the regu-

16. Throughout the remainder of the paper the damage assessment regulations developed by Department of Interior for evaluating liability established both under CERCLA and CWA will be referred to as the CERCLA damage assessment process, or simply the CERCLA regulations.

17. Personal interview, Kittle (1986); State of Washington, Marine Resource Damage Assessment Report For The Arco Anchorage Oil Spill (1987).

18. Environmental Responses Act, Pub. L. No. 96-510 at § 107(f), 94 Stat. 2783 (1980).

lations apply to virtually all publicly controlled natural resources throughout the United States and its territories, and they encompass a wide span of pollution discharges. Moreover, the natural resource damage assessment regulations developed under CERCLA provide a very important advantage for trustees in that they carry the force of a rebuttable presumption.[19] That is, if the process set out in the regulations is correctly applied by the authorized official following a spill, the resulting measure of damages is presumed to be correct, unless the potentially liable party can demonstrate otherwise through a preponderance of the evidence. In most cases it will be very difficult and costly to prove that the results of a damage assessment carried out under the Act are incorrect. This is especially true for the type A approach, by virtue of the fact that it is intended to be simplified. Hence, the rebuttable presumption provision of the Act can have important implications for the effectiveness of the natural resource damage assessment regulations in general and especially for the type A approach.

In summary, given the characteristics of the Act and its broad potential applicability, the damage assessment regulations established under CERCLA clearly are a major development in environmental policy because they introduce a systematic approach for compensating for natural resource injuries. CERCLA's damage assessment regulations, as a side effect, also may represent a major, and perhaps unprecedented, expansion of the use of economic incentives to control pollution.

In light of the novel features and potential significance of CERCLA, it is appropriate to examine the natural resource damage assessment framework provided by the Act, the conceptual and analytical underpinnings of the liability regulations developed to implement the Act, and the institutional setting within which damage assessments are to be undertaken. How does the legal definition of damages set out in CERCLA correspond to economists' concepts of damages? How do the newly promulgated regulations propose to measure damages in practice, and to what extent does this approach conform to economic concepts? How will the liability regime be implemented? And, finally, will CERCLA be effective in providing economic incentives for controlling pollution?

The questions posed above, and others, are addressed in this paper, which provides a perspective on CERCLA developed during the course of a project carried out by the authors and their co-investigators to develop the technical framework, concepts and data for the first type A, simplified regulations developed by the Department of Interior (DOI).[20] These reg-

19. Id. at § 111(h)(2).

20. Economic Analysis, Inc. & Applied Science Associates, Inc., Measuring Damages to Coastal and Marine Natural Resource: Concepts and Data Relevant for CERCLA Type A Damage Assessments (1987).

ulations cover the natural resources of the coastal and marine environments and were incorporated by the DOI into Rules.[21] Emphasis is given in the paper to the type A natural resource damage assessment process established in CERCLA, including incidents covered by the CWA, not only because this was the focus of the authors' work but also because many damage assessments relating to the oceans are likely to fall in this category due to the convenience and ease of use of the type A approach in most cases. Further, since the concepts and procedure used in the type A approach are consistent with the site-specific, type B approach, many of the arguments presented would apply to all of the damage assessment regulations thus far set out under CERCLA.

Definition of Damages under CERCLA

The central economic problem faced in the implementation of CERCLA concerns the determination of a monetized value of damages for natural resource injuries. In addressing this issue, CERCLA provides that the federal government "shall promulgate regulations for the assessment of damages for injury to, destruction of, or loss of natural resources from a release of oil or a hazardous substance. . . ."[22] As noted previously, two types of regulations are to be developed:

> Such regulations shall specify (A) standard procedures for simplified assessments requiring minimal field observations, including establishing measures of damages based on units of discharge or release or units of affected area, and (B) alternative protocols for conducting assessments in individual cases to determine the type and extent of short- and long-term injury, destruction, or loss.[23]

Hence, Congress recognized that damage assessment studies based on field observations could be quite expensive and that it would be cost effective to establish a simplified approach to assess damages from minor spills. Not only are assessments involving field observations costly, but typically, a variety of inherent problems make it difficult to observe biological injuries, even if substantial losses may occur. For example, in open ocean spills it is almost impossible to observe dead fish and larvae following an incident. Even potentially more visible evidence of biological injury, such as lost birds and mammals, is difficult to find.[24] To illustrate, some $1.6 million was spent on scientific studies to investigate biological injury from the 1976 ARGO MERCHANT oil spill, yet little

21. Natural Resource Damage Assessments, 43 C.F.R. pt. 11 §§ 11.10-11.93 (1987); see also 53 Fed. Reg. 9772 (1988) for amendments to §§ 11.18 & 11.41.

22. Environmental Responses Act, Pub. L. No. 96-510 at § 301(c)(1), 94 Stat. 2806 (1980).

23. Id. at § 301(c)(2).

24. National Research Council, Oil in the Sea: Inputs, Fates, and Effects (1985).

injury could be found.[25] This is not to say that biological injuries did not occur—rather, the injuries were not observable. The ARGO MERCHANT spill occurred at sea during a storm, and several days passed before the study team could reach the spill site. Within such a time frame dead organisms sink, are eaten by scavengers and are rapidly dispersed, so that it becomes very difficult to observe biological effects in the marine environment. Thus, the availability of a type A natural resource damage assessment is based on pragmatism and cost-effectiveness considerations.

Although CERCLA calls for the development of specific regulations for assessing damages to natural resources, the Act itself provides only general guidance concerning the concepts to be used within the regulations to measure damages.[26] Thus, the Act specifies that type A and type B regulations:

> . . . shall identify the best available procedures to determine such damages, including both direct and indirect injury, destruction, or loss and shall take into consideration factors including, but not limited to, replacement value, use value, and the ability of the ecosystem or resource to recover.[27]

In implementing CERCLA a number of fundamental economic, legal, and policy issues were addressed by the DOI. These include: How are damages defined in the Act? What is the appropriate welfare concept which should be used to measure damages? What is the appropriate scope of damges to be considered?

Under the natural resource damage assessment regulations,. damages are defined as the compensation to be paid for injury to natural resources. In amount, damages are the lesser of lost use value or cost-effective restoration or replacement cost. This view of damages is consistent with the common law doctrine of making an injured party whole. That is, if the lost use value of an injured natural resource is less than the cost of replacement, the injured party would be compensated for lost use value, since it is less costly for society to give up the services of the resource than it is to replace the resource. Alternately, if restoration cost is less than the lost use value, then restoring the injured natural resources would be socially efficient, since it would be more costly for society to give up the services the resources provide than it would be to restore the resources. This view also is consistent with the economic valuation concept (compensating variation) which uses the status quo ante as the basis for assessing welfare changes following an incident.

25. Univ. of Rhode Island, Center for Ocean Management Studies, in the Wake of the Argo Merchant (1978).

26. Comment, Theories of State Recovery under CERCLA for Injuries to the Environment, 24 Nat. Res. J. 1101 (1984) (authored by Susan Zeller & Lisa Burke).

27. Environmental Responses Act, Pub. L. No. 96-510 at § 301(c)(2), 94 Stat. 2806 (1980).

CERCLA specifically allows restoration and replacement cost to be considered in determining the amount of damages, and this view is incorporated in the regulations for type B assessments.[28] Despite this fact, the type A regulations exclusively employ lost use value to measure damages. This position was adopted in the damage assessment regulations because of the practical impossibility of considering site-specific restoration and replacement strategies and their associated costs for all conceivable injuries within the context of a type A framework, which is simplified and national in scope. However, consonant with the intent of the Act, the type A rule requires trustees to devote the proceeds of damage assessments obtained through the lost use value approach to restoration or replacement.[29]

Given the legal definition of damages as set out in the natural resource damage assessment regulations, establishing the relevant concept for measuring damages is important. It is important both for conceptual defensibility and because the choice of the concept will influence the magnitude of damages measured. Economists employ two alternative valuation concepts which differ in terms of the standard on which the measure of damages is to be based. These alternative concepts are willingness-to-accept compensation (WTAC) and willingness-to-pay to avoid the incident (WTP). WTAC is the minimum amount that individuals would have to be compensated, given that the spill occurred, in order to be as well off as in the pre-spill situation. The alternative concept of welfare measurement, WTP, is the maximum amount the individuals would be willing to pay to avoid the incident.

Empirical studies suggest that using WTAC can result in a substantially higher measure of damages than using WTP, significantly greater than would be predicted by theory.[30] Since CERCLA is concerned with polluter compensation for damages, in principle WTAC would seem to be the appropriate conceptual measure for valuing damages.

Despite the fact that WTAC seems to be the conceptually correct measure of welfare change, the type A natural resource damage assessment regulations are based on WTP for two important reasons. First, the technical document upon which the regulation is based draws upon empirical results from studies of coastal and marine natural resources in the available literature—studies which have employed the concept of WTP rather than WTAC. Second, the state-of-the-art 'for valuing environmental goods is such that greater uncertainty is associated with WTAC values as opposed

28. Natural Resource Damage Assessments, 43 C.F.R. pt. II, § 11.15 (1987); see also 53 Fed. Reg. 5172 (1988) for amendment to § 11.15.

29. Id. at 9050.

30. Cummings, Brookshire & Schultze, Valuing Environmental Goods: An Assessment of the Contingent Valuation Method 107, 217-21 (1986).

to WTP measures, which led a recent, comprehensive review of contingent valuation techniques to conclude that at the present time, WTP rather than WTAC should be used for policy purposes.[31] For these reasons, the natural resource damage assessment regulations use WTP, and not WTAC, to measure damages.

In addition to use value, two other categories of natural resource values may be pertinent to measurement of natural resource damages: option value and existence value. Option value (actually option price) is the maximum amount an individual would be willing to pay to preserve the opportunity of using a resource at some future date, even if the individual does not currently use the resource. Existence value is the amount an individual is willing to pay simply to ensure the survival of the resource, above and beyond any use value or potential use value.[32] Arguments have been raised concerning whether or not option and existence values for injured natural resources should be considered when measuring damages using the type A approach.[33]

Including option and existence value has considerable appeal on conceptual grounds. However, the type A regulations do not include these concepts of value. Option and existence values are less well defined than use value and a greater magnitude of uncertainty surrounds their measurement.[34] In the context of the type A procedure, the use of option and existence values is particularly problematic. Not only does considerable uncertainty surround their measurement, but equally important, virtually no empirical studies are available which address option and existence values for coastal and marine natural resources in a form which allows one to infer a marginal value which can be ascribed to a relatively small change in the stock of a natural resource. For these reasons, non-use values are not included in the type A regulations. However, option and existence values can be included when the site-specific, type B approach is used, if a use value for the injured resource cannot be determined.[35]

CERCLA's provisions for establishing measures of damages based on units of release or units of affected area recognize the need to use average values and approximations rather than site-specific values as a simplified approach for measuring damages. Yet, the DOI has interpreted CERCLA

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31. Id. at 104.

32. See, for example, John V. Krutilla, Conservation Reconsidered, 47 Am. Econ. Rev. (1967); Freeman, The Benefits of Environmental Improvement: Theory and Practice (1979); Boyle & Bishop, The Total Value of Wildlife Resources: Conceptual and Empirical Issues, Proceedings of Workshop on Recreation Demand Modeling, Assoc. of Environmental and Resource Economics (1985); Freeman, Uncertainty and Environmental Policy: The Role of Option and Quasi-Option Value in Advances in Micro-Economics (1986).

33. Natural Resource Damage Assessments at 9083 (cited in note 21).

34. Cummings, Brookshire & Schultze, at 222-23 (cited in note 30).

35. Natural Resource Damage Assessments at 9084 (cited in note 21).

to call for the development of regulations for assessing damages—not penalties. The measurement of damages requires that appropriate data and concepts be employed to proceed in sequence from an incident, to its effect on ambient conditions, to biological and physical injuries and, ultimately, to the measure of damages which is quantified in monetary terms. Penalties, on the other hand, typically involve a punitive element and may bear little or no relation to a measure of damages arrived at through the use of appropriate valuation concepts and data.

Clearly, the damages resulting from an incident could vary greatly, depending upon the amount and characteristics of the substance spilled, the environment in which the spill occurs, the specific natural resources in the area and the conditions (e.g. wind and currents) at the spill location at the time of the incident. Hence, what is called for is an approach which incorporates these, and other, important determinants of damages in a framework which is simplified and consistent with the requirements and definitions of CERCLA. The next section outlines the framework adopted to measure damages for the type A approach.

Measuring Damages for Type A Assessments under CERCLA

The CERCLA type A natural resource damage assessment model. To implement the CERCLA natural resource damage assessment regulations, the authors and their co-investigators developed the technical approach, concepts and data for the first type A damage assessment framework under the Act for the DOI.[36] The approach involves a computerized model, the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME). As the title implies, the NRDAM/CME is to be used to measure natural resource damages for spills in ocean-related environments. The type A approach for lakes, rivers, and inland areas has not yet been developed.

The NRDAM/CME is an integrated, interdisciplinary model which is composed of physical fates, biological effects and economic damages submodels. Figure 1 illustrates the general logic of the approach. What follows is a brief, non-technical description of the NRDAM/CME. A more comprehensive presentation of the model, its assumptions, and data bases can be found elsewhere.[37]

Physical fates submodel. The physical fates submodel is a relatively sophisticated, three-dimensional pollutant dispersion model.[38] The sub-

36. Economic Analysis, Inc. & Applied Science Associates, Inc. (cited in note 20).

37. Id., see also Thomas A. Grigalunas, James J. Opaluch, Deborah French & Mark Reed, Measuring Damages to Marine Natural Resources From Pollution Incidents Under CERCLA: Application of An Integrated Ocean Systems/Economic Model (staff paper, Dept. of Resource Econ., Univ. of Rhode Island (1987)).

38. The physical fates submodel was developed by Dr. Mark Reed, Applied Science Associates, Inc., and is described in detail in Economic Analysis, Inc. and Applied Science Associates, Inc. (cited in note 20).

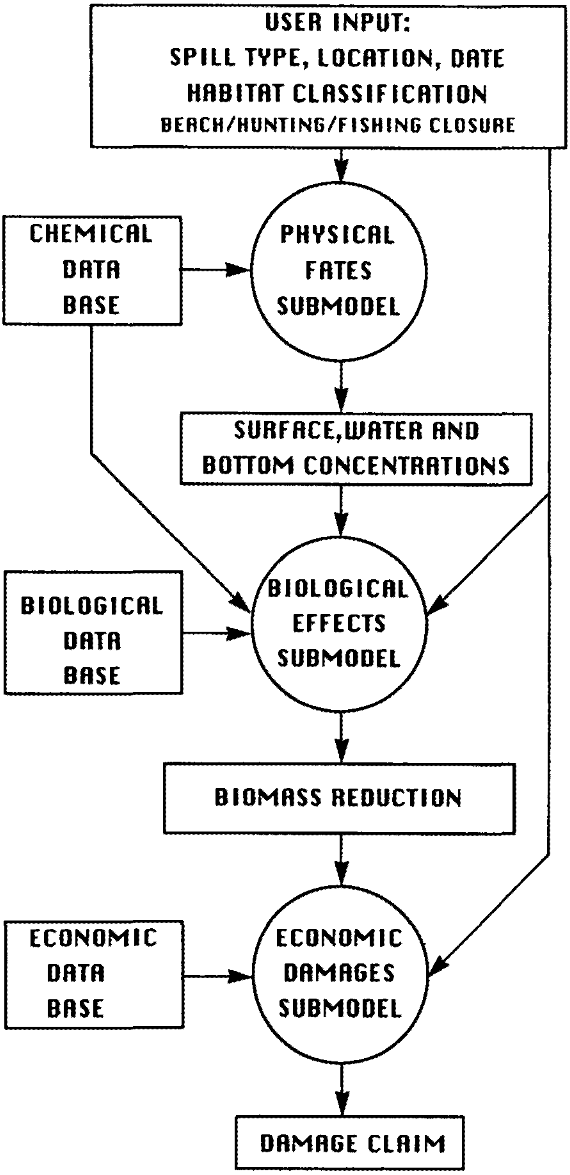

FIGURE 1

Overview of Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments.

model simulates the fate of the pollutant in the marine environment, given the physical and chemical characteristics of the substance, the characteristics at the spill site (for example, water depth), and conditions at the time of the spill (for example, currents and wind). For a subtidal spill of a substance less dense than seawater, such as crude oil, a surface slick forms, spreads and is transported by winds and currents, with continued evaporation into the atmosphere and entrainment and dissolution into the water column. If the slick meets a shoreline, it is assumed to collect there.

Dissolved land entrained fractions of spilled substances mix and are transported in the water column and may reach the bottom sediments. Materials which are heavier than seawater sink to the sea floor, dissolve into the water column and mix into the sediments. The physical fates submodel also simulates the fate of intertidal (shoreline) spills.

To employ the submodel, the user must indicate the substance and amount spilled, when and where the spill occurred, in addition to descriptors of the location of the spill including information such as water depth, bottom type, currents, wind speed, and air temperature. For intertidal spills, the user is asked to input, among other things, shoreline type affected (for example, sandy beach or rocky shoreline), wind speed and air temperature. Using information on the substance spilled, the model obtains a set of physical and chemical parameters from the chemical data base. These parameters, which are required to run the submodel, are provided for 469 substances included in the NRDAM/CME chemical data base.

For all incidents, the user specifies the extent and date of cleanup, if any. Prior to the cleanup date, damages are measured, taking into account the entire amount of spilled material. Subsequent to the cleanup date, damages are measured considering only the amount of material remaining after cleanup. However, the submodel does not consider any injury resulting from the effects of actions such as the addition of dispersants to oil spills. A mass balance is calculated at each time step to account for the entire mass spilled.

The physical fates submodel calculates the area covered by surface slick, if appropriate, and the concentrations in the water column and sediments over space and time. For spills occurring in an intertidal area, the submodel computes the area and length of shoreline affected over time. This information is passed to the biological effects submodel.

Biological effects submodel. This submodel[39] receives data from the

39. The biological effects submodel was developed by Dr. Deborah French, Applied Science Associates, Inc., and is described in detail in Economic Analysis, Inc. and Applied Science Associates, Inc. (cited in note 20).

physical fates submodel, the toxicological section of the chemical data base, the biological data base, and user input (Figure 1). The biological submodel calculates specific short-term, long-term, direct and indirect loss of fish, shellfish, waterfowl, shorebirds, seabirds, and fur seals, as described below.

Short-term biological losses are defined as losses at the time of the spill and while toxic concentrations remain in the environment. These short-term losses fall into two categories: (1) death of adult organisms, juveniles, larvae, and (2) lost primary and secondary productivity. Long-term losses include lost recruitment due to larvae and juveniles previously killed and reduction in future biomass due to loss in potential growth of the adults killed.

Briefly stated, death of fish and invertebrate adults, juveniles, and larvae is based on exposure of these organisms to the spilled substance. The physical fates submodel calculates the area and concentration of the spilled substance as a function of time. The adult biomass and larval numbers of each species are received from the biological data base. The biological effects submodel then calculates the biomass or number (for larvae) of each species killed as a function of concentration, time of exposure, and temperature, using a standard toxicity model using quality-controlled toxicity data.

Information which would allow for the measurement of mortality to birds and fur seals, using an approach based on a toxicity model comparable to that used for fish, does not exist. Hence, a different approach must be used to measure mortality for these species. Biological injuries to birds and fur seals from surface slicks and intertidal spills are based on the area of the slick or the intertidal area covered over time, as determined by the physical fates submodel. This area then is multiplied by the number of birds (by species) and fur seals per unit area to determine the number affected. Based on available information, the mortality rate for birds and fur seal contacted by surface slicks is assumed to be 58 percent and 63 percent, respectively.

Indirect damages occur when organisms which have no direct economic value are killed by a spill. These biological injuries are accounted for via a simple food web model. Lost primary productivity is determined using standard values from the chemical data base. This loss is partially passed through zooplankton and partially through benthos (bottom-dwelling animals) and, ultimately, is expressed as a loss in economically valued species due to their loss of potential food.

Long-term losses include lost recruitment of larvae and juveniles into the adult population and lost future growth of adults. The recruitment and growth section of the biological effects submodel employs standard fisheries models, based on the dynamic cohort or age-class model.[40] The cohort approach models biomass in terms of number of individuals within an age class and the weight of the average individual determine the biomass of the cohort. This cohort analysis is used to model the recovery of the stock over time following the spill and determines the biomass which would have been caught in the future but was instead killed by the spill. Birds, including waterfowl, shorebirds, and seabirds, are modeled in a manner which is analogous to fish, except that the population is measured in terms of numbers rather than biomass.

Several types of possible biological injury are not included in the submodel. Changes in food web structure and chronic effects of sublethal levels of contaminants in tissues or the environment are considered beyond the scope of the model because of insufficient data to model these effects. Bioaccumulation through the food chain also is not covered in the submodel because of insufficient information in this area.

To define biological resources in contact with the spill, the submodel employs a substantial data base which includes: adult and juvenile biomass for nine species categories of finfish and shellfish; larvae numbers for these species per meter squared; a measure of primary, zooplankton and benthos productivity; and numbers of fur seals and birds (by category) per square kilometer. The data base specifies the abundance of species groups in each of ten provinces/ecosystem types defined by Cowardin and others[41] for the marine environment of the U.S. and its territories (Figure 2). Abundance of the species groups varies by season, bottom type, marine vs. estuarine and tidal vs. subtidal environments. In total, 364 different ecosystem/season categories are considered in the submodel.

In summary, the biological effects submodel calculates specific short- and long-term and direct and indirect biological injuries resulting from a particular incident. These losses are used in a dynamic model of the populations, to determine their recovery over time. The resulting loss in catch of finfish and shellfish, hunting of waterfowl and viewing of birds is calculated by species category by year and passed to the economic damages submodel.

Economic damages submodel. Damages are measured as the reduction in the *in situ* value of the injured natural resources. The reduction in the *in situ* use value is measured by the change in the value of harvesting or enjoying the services of the injured natural resource less the change in the cost of harvesting or viewing the resource or visiting the area

40. See, for example, Ricker, Computation and Interpretation of Biological Statistics of Fish Populations, 191 Bull. Fish Research Board of Canada (1975).

41. Cowardin, Carter, Golet & Laroe, Classification of Wetlands and Deep Water Habitats of the United States, Office of Biological Services, U.S. Fish and Wildlife Service (1979).

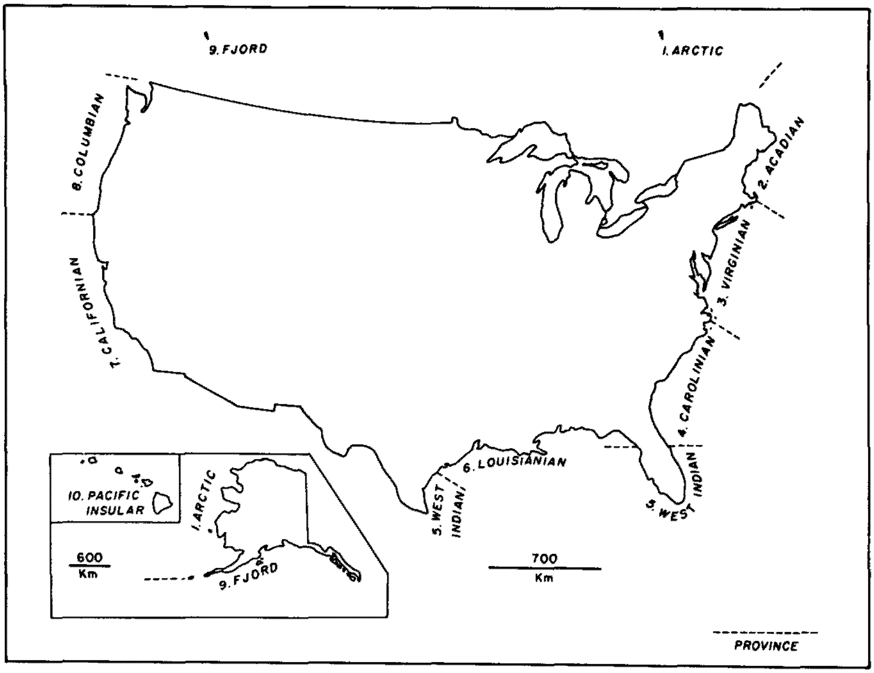

FIGURE 2

Boundaries of Ten Marine and Estuarine Provinces (from Cowardin et al., 1979).

concerned. Damages are measured over the period of resource recovery, with all damages converted to a present value using a real discount rate of ten percent, as specified in the Office of Management and Budget Circular A-94, as revised.[42]

In the economic damages submodel, damages are measured for injuries to: (1) lower trophic biota; (2) commercial and recreational fisheries; (3) waterfowl, shorebirds, and seabirds; (4) fur seals; and (5) public beaches. Such potential losses as reduced profits suffered by fish processors or coastal tourism hotel operators following an oil spill are not included because they are private losses outside the scope of CERCLA as interpreted by the DOI. The methodology used to measure each of the categories of damages included in the economic damages submodel is described

42. U.S. Executive Office of the President, Office of Management and Budget Circular No. A-94 Mar. 27, 1972.

briefly below. A more technical and extensive presentation of the methodology and data is presented elsewhere.[43]

Briefly, the lost *in situ* use value of commercial fishing is the loss in economic rent due to the reduced catch. Hence, only the lost catch is valued. The biomass which would have died from natural causes in the absence of the spill is not included in the measure of damages. For recreational fisheries, lost *in situ* value is the loss due to the reduced catch rate from smaller stocks, that is, lost consumer surplus.

A standard bioeconomics model is used to derive the measure of damages to fisheries. The short- and long-term and direct and indirect losses of fish and shellfish which would have been harvested in the absence of the incident is an output of the biological effects submodel. Injured species are allocated between commercial and recreational fish, using catch data by species for each section of the United States obtained from the National Marine Fisheries Service (NMFS). For lost commercial catch, species-specific ex-vessel prices (NMFS) for each area, averaged over 1982–1985, are used to value the lost commercial catch. For lost recreational catch, marginal values for sportsfishing are adapted from the economics literature.[44]

Using the measure of injury to waterfowl, shorebirds and seabirds from the biological effects submodel, damages over time are measured for the lost consumptive (that is, hunting, for ducks and geese) and non-consumptive (that is, viewing, for all species) *in situ* use value. Values for hunting are adopted from available, flyaway-specific estimates of the value of an additional (that is, the marginal) waterfowl (duck or geese) harvest.[45] The value for non-consumptive use is derived from an estimate of the marginal change in visitor days associated with a change in the bird population for a wildlife refuge.[46] The resulting estimate of lost visitor days then are evaluated using a unit day value from the Water Resources Council.[47] Damages from injury to fur seals uses a commercial harvest value.

Damages from injury to lower trophic, non-commercial organisms are based on the ultimate loss in the *in situ* use value of consumer species (commercial and recreational fisheries, waterfowl, shorebirds, seabirds,

43. Economic Analysis, Inc. & Applied Science/Associates, Inc. (cited in note 20); and Grigalunas (cited in note 37).

44. See Norton, Smith & Strand, Stripers: The Economic Value of the Atlantic Coast Commercial and Recreational Striped Bass Fisheries (1983); Rowe, Valuing Marine Recreational Fishing on the Pacific Coast (1985).

45. Hay & Charboneau, Estimating the Marginal Value of Waterfowl for Hunting (unpublished manuscript), U.S. Fish and Wildlife Service (1974).

46. G. Brown & Hammack, Commonwealth v. Steuart Economic Valuation of Waterfowl (unpublished manuscript) (1977).

47. "The Unit Day Value Method," 44 Fed. Reg. 242 (1979).

and fur seals) which occurs when an incident affects the productivity of the food web. As noted previously, the biological effects submodel quantifies biological injuries from lost primary and secondary productivity using a simplified ecological model. The resulting damages are measured using the concepts and data applicable to commercial and recreational fisheries, waterfowl, shorebirds, seabirds, and fur seals outlined in the preceding paragraphs.

In addition to damages resulting from mortality, damages also can be measured from closure of a fishing (for example, a shellfishing area) or waterfowl hunting area. This could be important, for example, if a public official has reason to believe that a threat to human health exists from consumption of affected natural resources following a spill. In this case, the NRDAM/CME user would indicate the area and duration of closure for each affected species category. The model then would calculate the resulting loss of catch as a result of the closure as well as damages attributable to mortality.

Finally, damages caused by closure of a public beach are also measured by lost *in situ* use value. The user specifies the location and date of the incident, the length and type of public beach closed (national or other public) and the duration of the closure. The economics data base contains information on seasonal use of public beaches per meter, by type of public beach, for province. Given this information, the total number of visits lost due to a closure of a given length of beach for a specified period can be determined. Damages are measured by multiplying the visits lost by an average of the estimates of consumer surplus per saltwater beach visit obtained from the literature.

Some Example Results[48]

Using the approach outlined briefly above, Table 1 shows the measure of damages in each season for a hypothetical, subtidal spill of 100 metric tons of diesel fuel, one of the most common substances spilled. The spill is assumed to occur in an estuarine environment in each of the ten provinces considered in the NRDAM/CME. For simplicity, it is assumed that the oil does not come ashore; hence, no intertidal damages are measured. Also, the results are based on the assumption that no cleanup occurs.

As can be seen, for a given season the measure of damages across provinces differs widely, reflecting the variation in resource abundance, use, and value and, in general, environmental sensitivity from province to province. Even within a province, the measure of damages from a

48. The model results are based on Version 1.1 of the NRDAM/CME.

TABLE 1
Economic Damages from 100 Metric Ton Spills of Diesel Fuel in Estuarine Environments by Province and Season (Expressed in 1986 Dollars)

		Spring	*Summer*	*Fall*	*Winter*
Acadia	$	19,649.	28,429.	19,211.	14,723.
Virginia	$	25,907.	47,049.	29,495.	21,599.
Carolina	$	155,532.	214,832.	73,256.	101,491.
Louisian	$	181,142.	260,555.	105,506.	217,420.
West Indian	$	21,570.	5,914.	10,724.	21,042.
Californian	$	373,341.	168,699.	52,241.	367,887.
Columbian	$	57,655.	190,777.	80,540.	94,230.
Fjord	$	41,208.	49,411.	39,295.	19,500.
Arctic	$	65,095.	106,535.	48,205.	1,216.
Pacific Insular	$	30,403.	6,852.	1,705.	4,450.

given spill varies substantially reflecting, for example, the seasonal presence of adult and juvenile finfish, larvae, and birds.[49]

In summary, the example results illustrate that damages depend greatly on such factors as the substance and amount spilled, the location and the season of the spill, and other environmental factors (for example, winds and currents). Hence, the measure of damages arrived at through use of the NRDAM/CME—in effect, the charge or "tax" levied on the polluter—is incident specific.

Implementation of the Type A Damage Assessment Approach

In order for an incentive-based scheme to be workable—and in keeping with the requirements for type A natural resource damage assessments—the approach must be easy to use. Although the concepts underlying the NRDAM/CME are complex and the data bases are extensive, the model runs on an IBM PC (or compatible) with only limited information to be supplied by the user. Copies of the computer disks and the underlying documents have been made available to all state and federal trustees. Given the information provided by an authorized official following an incident covered by the Act, the NRDAM/CME simulates the physical fates and biological effects of the incident and provides the resulting measure of economic damages, as described in the above paragraphs.

The NRDAM/CME exploits newly available computer technologies. In this regard it provides a very flexible and inexpensive approach for implementing the CERCLA regulations. It also presents important chal-

49. Damages for other example spill sizes, substances, and environment-types can be found in Grigalunas, Opaluch, French & Reed (cited in note 37).

lenges and raises significant issues. For example, if users can acquire more recent biological, chemical, or economic data which they believe are superior to the data in the NRDAM/CME, should they be able to change the model's data base prior to measuring damages? In general, how can one ensure that the integrity of the model and its data bases is maintained? Will a polluter escape liability for a natural resource injury not included in the NRDAM/CME, for example, for a loss of marine mammals other than fur seals? Will a polluting party be compelled to pay the damage claim arrived at through use of the type A approach?

While allowing the user to update the model or its data bases would seem to be attractive since it may allow for improved accuracy, this option would raise the threat of gamesmanship and create a serious potential for abuse by one party or the other. Such debates would be difficult and costly to resolve on a case-by-case basis, thereby undermining the intent of a type A assessment. To avoid this potential problem, the Rule precludes users from changing the NRDAM/CME or its data bases.[50] If a user does change the model or its data outside of a formal rule-making process, then the important advantage provided by the force of rebuttable presumption under CERCLA no longer applies.[51] However, the damage assessment regulations are to be reviewed and to be revised, as appropriate, every two years.

Maintaining the integrity of the model would appear to be a problem, since users have access to the computer model source code. However, in practice it would be easy to verify that the model being used in an assessment is the correct version by comparing the results presented in a damage claim with those obtained by using the official NRDAM/CME computer disks available from the DOI.

In order to include damages resulting from injury to species not included in the NRDAM/CME, for example, a mammal other than fur seals or an endangered species, the Rule establishing the type A regulations does allow the authorized official to carry out parallel type A and type B assessments. Of course, double counting of injuries is a potential problem which the Rule specifically precludes.[52]

Another important feature of the Rule is that polluting parties need not accept the measure of damages obtained using the type A approach; they have the option of using the type B approach. However, those exercising this option must bear the costs of the site-specific, type B damage assessment. Moreover, they would be required to pay the measure of damages resulting from application of the type B approach. Given the relatively

50. Natural Resource Damage Assessments at 9045 (cited in note 21).
51. Id.
52. Id. at 9050.

high cost of a site-specific assessment, and given the risk to the polluting party that the type B assessment conceivably could lead to a measure of damages higher than that found with the type A approach, it is possible that in many cases, the polluting party will not contest the results of the type A approach.

Will CERCLA Provide Effective Market Incentives for Controlling Pollution?

This paper has reviewed the institutional framework provided by CERCLA and the approach adopted to implement the natural resource assessment provisions of the Act. The question remains: Will the CERCLA damage assessment regulations, as an unintended side effect, provide effective economic incentives for controlling pollution incidents? An appraisal of the potential effectiveness of CERCLA's damage assessment regulations must consider two interrelated issues. One relates to the behavioral responses of polluting parties whose discharges are covered under CERCLA. The second involves the scope of incidents which are included under the Act.

CERCLA's damage assessment regulations have only recently been promulgated. Hence, any definitive evaluation of the Act's effectiveness must be postponed until experience is gained in applying the regulations. Nonetheless, the available literature and the characteristics of the regulations allow for some reasoned judgments concerning the potential effectiveness of the Act's natural resource damage assessment regulations in providing incentives for avoiding pollution.

Pollution incidents under CERCLA typically will be stochastic events. Only a few studies in the literature empirically assess firms' behavioral responses to strict liability for pollution events. Opaluch and Grigalunas[53] examined how strict liability for oil spill costs under the OCSLA affected companies' cash bonus bids for OCS oil leases. Mindful of the differences between CERCLA and the OCSLA, both in the range of pollution events covered and the scope of damages encompassed in these two Acts, the results nonetheless are suggestive. These findings indicate that firms do respond to strict liability for potential pollution damages. It was found that oil companies bid less for OCS leases when environmental risk from oil spills was greater, all else being the same. Hence, what information is available in the literature suggests that the natural resource damage assessment liability provisions of CERCLA can create incentives for avoiding pollution.

Additional insight into the potential effectiveness of CERCLA is pro-

53. Opaluch & Grigalunas, Controlling Stochastic Pollution Events with Liability Rules: Some Evidence from OCS Leasing, 15 Rand J. Econ. (1984).

vided by the literature dealing with prohibited activity and enforcement.[54] Becker's[55] seminal analysis, for example, indicates that several factors are to be considered in assessing the behavioral response of economic agents engaged in prohibited activity. These include: the probability of detection; the probability of conviction, given detection; the probability of being penalized, given conviction; and the amount of the charge levied, or in Becker's words, "the cost of punishment." These factors are briefly considered below as they relate to the potential effectiveness of CERCLA's natural resource damage assessment regulations.

Regarding the chance of detection, CERCLA[56] mandates that spills of specific hazardous substances in amounts that are equal to or greater than federally established Reportable Quantities for those substances must be reported. Penalties are available for failure to report these spills. In addition, a formal pollution reporting structure has been established through the National Response Center. The U.S. Coast Guard maintains the Pollution Incident Reporting System, which contains data for several thousand incidents which occur each year.

What is not known, of course, is the number of spills which go unreported. Nonetheless, the largest spills will be the most observable—and these are the incidents which are of most concern because they will cause the most damage. Further, it is now feasible to detect the source of an oil spill through an analysis of the unique chemical properties of oils.[57] This ability to use chemical "fingerprints" greatly enhances the prospect of identifying polluters who otherwise would escape detection. In sum, the probability of detection for incidents under CERCLA—particularly for the more serious spills—appears to be high, although certainly it is less than one.

Once detected, the probability of conviction, that is, being held liable, is very high. CERCLA carries strict and severe liability, and very few defenses are available to a polluting party.[58] Furthermore, resolution of the amount of liability is greatly facilitated through use of the type A approach. The approach is easy to use and, as noted, carries with it the benefit of a rebuttable presumption. Hence, for all but the smallest of spills, polluters can anticipate that they very likely will be liable for damages, and that when the type A approach is used, damages will be assessed without considerable delay.

54. For a good summary of this literature, carried out in the context of environmental enforcement, see Clifford Russell, Winston Harrington & William Vaughn, Enforcing Pollution Control Laws (1986).

55. Becker, Crime and Punishment: An Economic Approach, 76 J. Political Economy (1968).

56. Pub. L. No. 96-510 at §§ 102, 103, 94 Stat. 2772 (1980).

57. C. Brown, Rhode Island "Fingerprints" the Oil before It Spills, 23 Maritimes (1979).

58. Pub. L. No. 96-510 at § 107(b), 94 Stat. 2781 (1980).

A remaining issue which must be considered is the size of the damage assessment. Clearly, if the regulations consistently lead to very small measures of damages from incidents, the incentive effect of liability under the Act will be correspondingly small. To provide some perspective on this issue, the authors elsewhere have estimated damages from different size spills of a variety of substances under a wide range of environmental conditions.[59] Not surprisingly, damages from very small spills are negligible, while damages increase with the size of the spill of a given substance and with the sensitivity of the environmental conditions at the time and location of the spill. For example, a hypothetical, 100 metric ton diesel fuel spill in a Virginian Province (roughly corresponding to the Mid-Atlantic) estuary results in damages of just over $47 thousand during the summer and almost $26 thousand if it happens during the spring season spill. A similar spill in the Californian Province causes damages of almost $169 thousand if it occurs during the summer and about $373 thousand during the spring months (see Table 1). As noted earlier, if the spill is assumed to come ashore, there would be additional, intertidal losses which would have to be measured with the model.

To be sure, what one views as constituting a considerable sum is subjective, and in a particular case will depend upon the wealth of the polluter, their attitude toward risk, and other factors in addition to the size of the damage claim. Nonetheless, the prospect of paying damages for spills which in many cases easily can run into the thousands of dollars, plus cleanup and response costs, surely would be sobering for potential polluters. This is particularly evident when compared with the pre-CERCLA setting in which companies paid zero damages for many spills precisely because easy-to-use damage assessment regulations were unavailable.

In summary, the empirical literature on the behavioral response of firms to strict liability, although it is small and does not deal directly with CERCLA, suggests that firms respond to the incentives imposed by strict liability for pollution costs. Also, if one follows the classic "crime-and-punishment" paradigm of Becker, a reasonable conclusion is that the natural resource damage assessment regulations established by the DOI under CERCLA appear to create potentially effective incentives for avoiding pollution incidents.

Finally, it is important to examine the scope of incidents which can be considered under the type A regulations. The Rule allows for use of the NRDAM/CME for a spill of any of the 469 substances included in the data base. This data base includes several crude oils and refined petroleum products—together, the most common materials spilled, accounting for

59. Grigalunas (cited in note 37).

over 90 percent of all spills each year[60]—as well as hundreds of other non-petroleum substances. And since the Rule does not establish a de minimus amount for a spill, at least formally, even quite small spills of any of the substances in the data base can lead to the use of the model and, potentially, a non-zero damage amount.

Although the chemical data base is extensive, it is important to point out that the type A approach cannot be used in a variety of circumstances, several of which could be important. For example, CERCLA explicitly does not cover damages from the normal application of fertilizers and pesticides. Also, multiple-substance spills cannot be addressed as such by the model. For these incidents, the type A approach can be applied, but only one substance can be used to run the model.

Use of the type A approach also would appear to be circumscribed by the fact that the model is designed to be applied to minor spills of short duration. However, the terms "minor" and "short duration" are not quantified in the Rule. This is because what is considered minor will depend upon the specific characteristics of an incident, and not only on the amount spilled. Although using the NRDAM/CME for a multiple release or a spill which occurs over some period will result in error, the convenience and low cost of the type A approach may make its use acceptable to the trustee and the polluting party. In fact, the advantages of using the type A approach appear to be sufficiently great—and the cost of a type B approach sufficiently high—that in many cases, the type A approach may be used for spills which in some sense could be considered large.

Another restriction on the usefulness of the present model for type A assessments is that it cannot be used for non-point source pollution, nor can it be used for subsea releases (for example, underwater pipeline spills). These limitations may be addressed in future refinements of the model.

SUMMARY AND CONCLUSIONS

This paper has examined the natural resource damage assessment regulations mandated by Section 301(C) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980. These regulations are to be used for assessing damages from injury to natural resources under CERCLA and the CWA. Particular attention was given to the simplified type A natural resource damage assessment approach and to the NRDAM/CME, which is to be used for type A assessments for spills in ocean-related environments. The concept and scope of damages em-

60. Wilshire, Spills in U.S. Marine Waters, 1982-1985 (unpublished special computer run from U.S. Coast Guard Pollution Incident Reporting System data file) (1986).

bodied in CERCLA's regulations were examined, and the NRDAM/CME developed to provide an operational approach for implementing the type A regulation was reviewed.

The premise of the paper is that with the promulgation of CERCLA's natural resource damage assessment regulations, a new national environmental policy framework is provided for assessing damages. The regulations are novel and represent a major development in that they require polluting firms to compensate the public, through its trustees, for natural resource damages. Use of the damage assessment approach set out in the regulations carries the important advantage of a rebuttable presumption. Although it is not the intent of CERCLA, the provision for strict liability for damages established under the Act implements an approach which in effect is akin to a Pigouvian tax which requires firms to pay for natural resource damages resulting from pollution incidents covered under the Act. Hence, the Act introduces what could be an important, national incentives-based approach for avoiding pollution.

The question posed at the beginning of the paper remains: Will the incentives provided by CERCLA's damage assessment regulations provide an effective approach for encouraging pollution avoidance? Given the broad geographic scope of the Act, the relatively inclusive nature of the injuries considered and the wide range of incentives covered by CERCLA and the CWA, the authors are inclined to answer in the affirmative. This inclination is reinforced by the relative ease with which damages can be assessed, at least when the simplified, type A approach is used, and by the force of a rebuttable presumption given to the damage assessment regulations. Further support for the authors' optimism is provided by the literature dealing with the behavioral response by firms to strict liability, along with the literature on crime and punishment.

Counterbalancing this sanguine assessment is the recognition that despite its broad coverage, a number of categories of incidents are not encompassed by the type A approach. For example, damages to private parties are not addressed under CERCLA, so that private parties would have to bring suit under other legislation or under common law. Also, sublethal effects are not considered in the model. In addition, injuries to a variety of species could not be included in the type A approach because sufficient data for these species were unavailable. While the regulations allow for a type B approach to be used for injured species not included in the NRDAM/CME, the type B approach may be difficult and costly to use in many cases.

Finally, it must be recognized that the natural resource damage assessment regulations established under CERCLA are, of course, new. No doubt, as experience is gained with the use of the type A approach, it will be found to be more effective in some cases than in others. However, under CERCLA the regulations are to be reviewed and updated, as appropriate, every two years.[61] Hence, the opportunity exists for the CERCLA natural resource damage assessment regulations to become increasingly effective over time as new methodologies, empirical results and data become available in environmental economics and the related natural sciences.

61. Pub. L. No. 96-510 at § 301(c)(3), 94 Stat. 2806 (1980).