To the Graduate Council:

I am submitting herewith a dissertation written by Donna Synstelien Bueckman entitled "The Costs and Benefits of the Underground Storage Tank Corrective Action Requirements: Qualitative and Quantitative Aspects." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.

Milton Russell

Milton Russell, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

THE COSTS AND BENEFITS OF THE UNDERGROUND STORAGE TANK CORRECTIVE ACTION REQUIREMENTS: QUALITATIVE AND QUANTITATIVE ASPECTS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Donna Synstelien Bueckman

May 1992

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ACKNOWLEDGMENTS

I would like to thank my major professor Milton Russell and the other members of my committee, Matthew Murray, Robert Bohm and Gregory Reed, for their comments and assistance. In the absence of my major professor during a portion of this work, Matthew Murray's comments were invaluable and contributed significantly to my progress.

I would also like to thank the Waste Management Research and Education Institute for financial assistance in the form of a fellowship over the last two years of my doctoral work. Without this financial assistance my work would not have been possible. Yet, if environmental goals are to be reached, continued research is imperative. I applaud the efforts of the Institute to add to the body of existing knowledge of environmental concerns.

Finally, thanks go to Jan T. Knoedler for having the patience to read early versions of this work and offer valuable comments throughout its completion. As always, my husband, Randy, and my parents, Ordean and Carol Synstelien, were supportive and kept me sane throughout the process.

ABSTRACT

This research attempted to identify the costs and benefits associated with the underground storage tanks regulations mandated in 1988. The qualitative analysis of benefits was based on historical information on UST releases. Through the use of this data the range of potential impacts was identified as well as a perception of the magnitude of those impacts.

The analysis of direct costs associated with the corrective action requirements was quantitative in nature. The total costs were based on a cost simulation estimating the number of cleanups that would be expected to occur and a representative cost per cleanup. To determine the number of cleanups focus was on the total number of USTs in existence throughout the country and the percentage that would need cleanup. Data for the population of USTs was obtained from the Environmental Protection Agency. Data for the representative cost calculation was obtained from the Energy, Environment, and Resources Center at the University of Tennessee-Knoxville.

It was concluded that the costs were significant in both relative and absolute terms and that the benefits, while positive, were not of a particularly large magnitude. These findings were substantiated by concerns raised regarding the legislative process under which the legislation was passed and by possible alternatives to the regulations that were adopted.

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CHAPTER 1

COSTS AND BENEFITS OF THE UNDERGROUND STORAGE TANK CORRECTIVE ACTION REQUIREMENTS

Section 1. Introduction and Overview

Economic analysis continues to offer insight into possible means of establishing and realizing cost-effective environmental objectives. Analysis can identify the costs and benefits of various policy actions to economic agents and can illuminate a wide variety of roles that those agents can play. In this work, a specific environmental problem--releases of stored product from underground storage tanks to the environment--will be examined within a cost-benefit framework. Alternative solutions to the problem will be outlined and an economic evaluation on the actual policy approach chosen by the federal government will be conducted.

The broad findings of this dissertation assert that the costs of the corrective action requirements will approach $64.5 billion over a twenty-five year period.[1] The corrective action requirements of the UST regulations are costly in both absolute and relative terms. The value of the human health and environmental gains made from the expenditures, while positive, would not reach the cost level unless extremely high values were placed on some nonmonetized outcomes.

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[1]This total cost figure does not include other significant costs that are associated with the regulations such as transaction costs and secondary effects.

As an introduction to this study, the first chapter provides information on the broad role of economic analysis in environmental legislation. In addition, this chapter briefly describes the specific case of environmental problems caused by releases from underground storage tanks and lists the benefits of addressing the releases. The various alternative solutions will be described and contrasted with the actual legislation and regulations adopted to deal with the problem. The particular goal of this study, to measure the costs of the corrective action requirements for the underground storage tanks (USTs) and compare them to the benefits, is also outlined in greater detail.

The focus of Chapter 2 is on the benefits of reducing the releases from USTs. To assure a comprehensive analysis, the benefits examined will include both environmental and human health components; however, due to the nature of those benefits the evaluation will be primarily qualitative. Because the majority of the benefits come in the form of reduction in risks, a discussion of risk is included.

Analysis of costs dominates the remainder of the study. The general methodology of the total cost simulation and specific approaches for the three intermediate estimates are given in Chapter 3. The results of this empirical analysis are presented in Chapter 4, and analysis of these results follows in Chapter 5. The conclusions drawn from the cost-benefit analysis of USTs are given in the final chapter.

To better understand the results of the cost simulation and the process by which they were obtained, an overview of this work is presented in Figures 1, 2 and 3. Figure 1 illustrates how each of the cases herein examined is arrived at through assumption. The basic

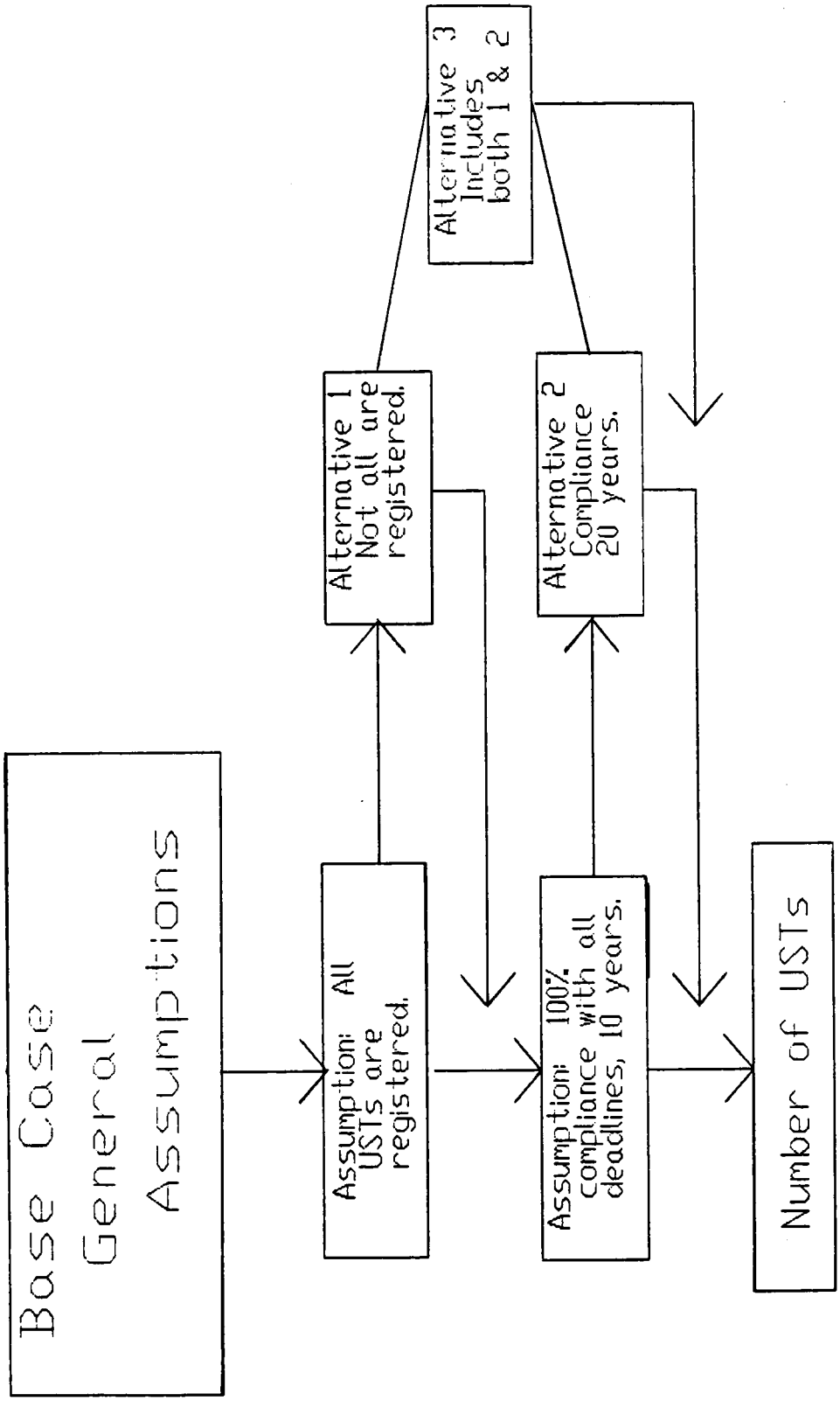


Figure 1. Basic Assumptions of the Cost Simulation

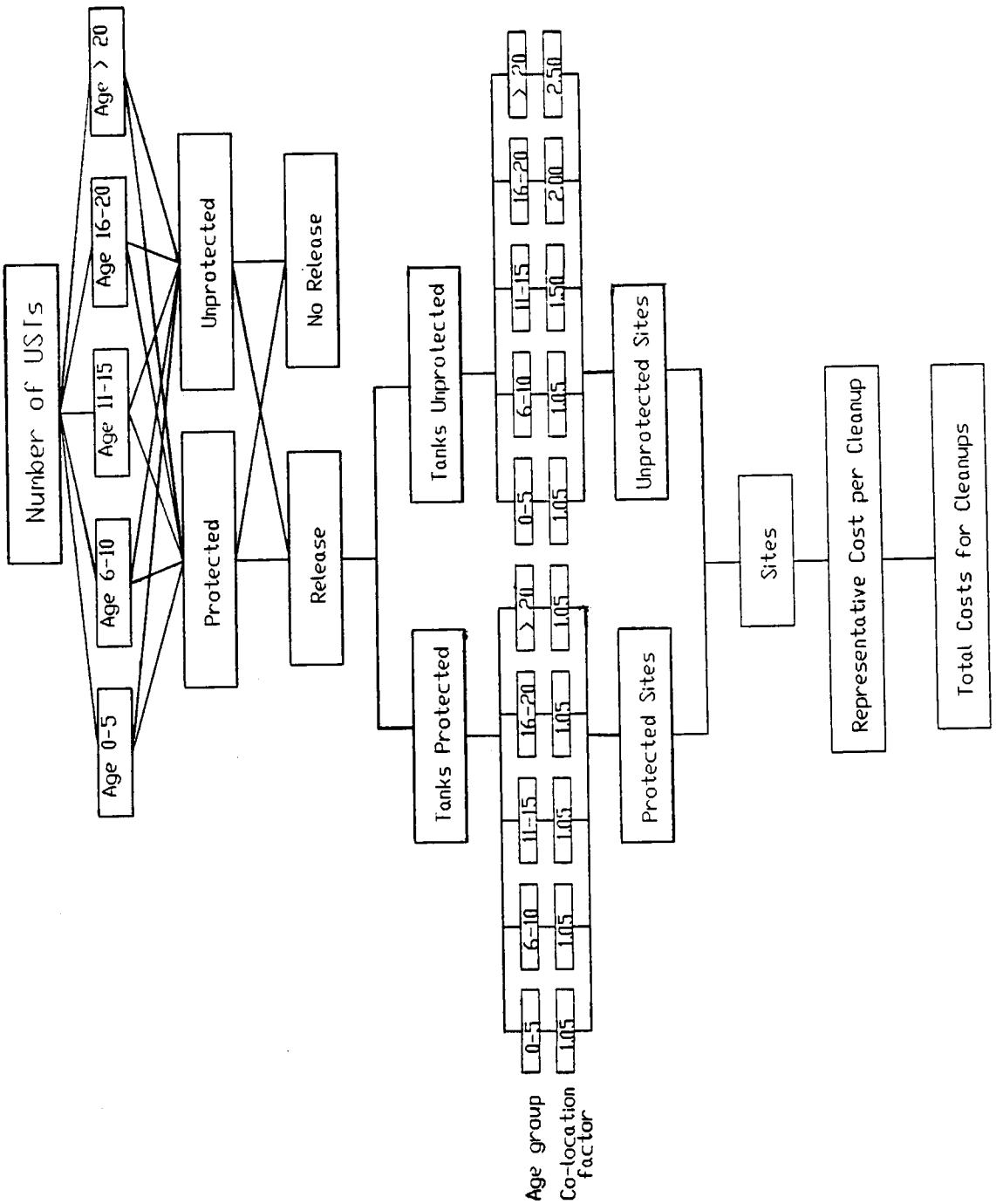


Figure 2. Cost Simulation: Part 1

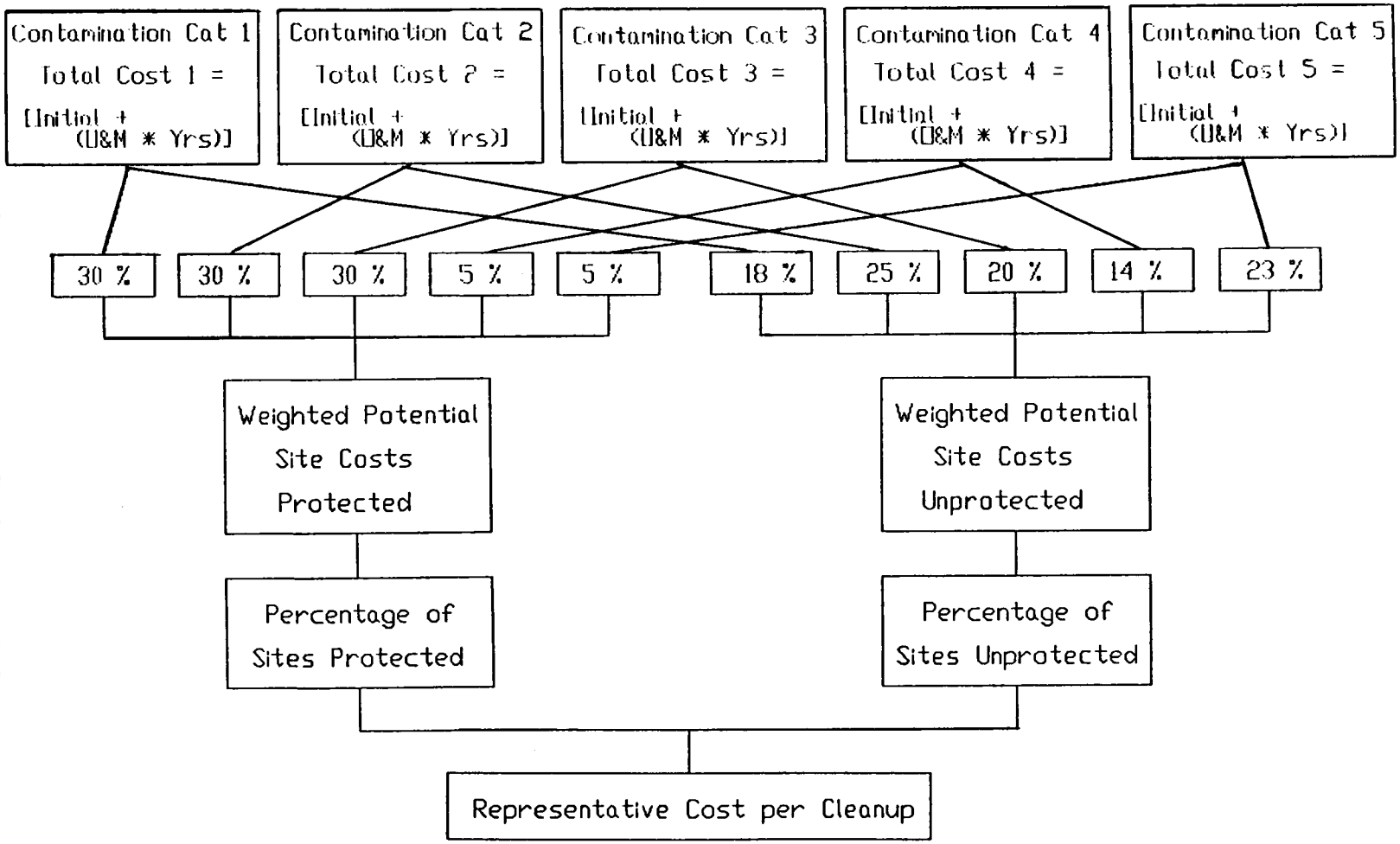


Figure 3. Cost Simulation: Part 2

assumptions of the analysis are established before the cost simulation is undertaken. (The specific assumptions will be delineated in Chapter 3.) Sensitivity analysis is performed on the two assumptions most likely to be major determinants of the final total costs. This sensitivity analysis is used to develop the three alternatives to the base case that are examined.

Once the basic assumptions of all cases have been established the number of tanks over time is examined (Figure 2). Available information on the age and level of protection against releases of the current tank population in addition to the percentage of those USTs releasing and co-location factors are used to determine the number of UST sites requiring corrective action.[2] The sites so determined are combined with a representative cost per site to calculate the total costs of UST cleanups. Recognizing that not all UST sites will be similar, the derivation of the representative cost per cleanup is illustrated in Figure 3. The available data for each of five contamination categories is weighted by the probability that a cleanup will fall in each category. The potential weighted costs for both protected and unprotected cleanup sites are weighted by the percentages of the population of USTs that are protected and unprotected, respectively. The results yield a representative cost per cleanup.

The necessary information for estimating the components of the total cleanup bill, specifically, the population of USTs, their releases and the cost of those releases, was unavailable; therefore, a cost

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[2]Typically, more than one tank contributes to an UST cleanup site necessitating the use of co-location factors in this analysis; see Chapter 3.

simulation was chosen as the means to conduct this analysis. As is typical with simulations, a large number of assumptions are required to arrive at a solution. Consequently, a pain-staking effort has been made to make all assumptions clear and explicit.

Before proceeding, two points relevant to the cost simulation and the results merit emphasis. First, the nature of this cost-benefit analysis differs from traditional cost-benefit analysis. The goal here is not to derive a cost-benefit ratio or a calculated net benefits figure; rather, the objective is to obtain an order of magnitude approximation of the benefits and costs of the underground storage tank corrective action requirements through a methodical examination of available information. Historical information offers insight into the potential benefits while a cost simulation approximates the direct costs that will be incurred as a result of the UST corrective action requirements.

Second, in this analysis neither the costs nor the benefits have been discounted to a present value figure. This study focuses on the costs and benefits of the UST corrective action requirements within a given period. For descriptive purposes only, the sums of total costs (1990 dollars) incurred from corrective action compliance from 1990 to 2015 are presented. The presentation of individual period estimates permits present value calculations, given a social discount rate. However, as this study does not focus on the allocation of resources over time, no appropriate social discount figure is employed.

Section 2. Economic Theory and Pollution

Environmental pollution is often considered to be the result of market failure. Inefficiency of the market mechanism is a result of the nature of the price signals that confront economic agents: observed prices do not necessarily reflect the marginal social costs and benefits of a good or service, but rather reveal only the private costs and benefits of the market activity. Under such circumstances, market profitability cannot be relied on to determine the social net worth of the production of a good or service, nor can we expect resources to be efficiently allocated. The full costs and benefits of all activities are not measured in market transactions; in particular, the unmeasured social costs of pollution are not accounted for and environmental degradation is the result. This suggests that a measure of economic activity such as gross national product (GNP) or GNP/capita may not necessarily reflect the quality of life for the inhabitants because all social costs may not be included in the economic measure.[3]

Environmental degradation occurs from pollution levels that exceed what modern science has estimated that the environment can absorb. This degradation is incompatible with proper maintenance of the environment as a resource, specifically the source of raw materials necessary for continued industrial and economic progress. The environment, if managed properly, can sustain raw material output, assimilate some of the by-

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[3]This, of course, begs the question of the distribution of wealth and income for the individuals of this nation, but that topic is beyond this discussion.

products of consumption and production, and support healthy and productive plant and animal life.

2.1. The Environment: A Public Good

The characteristics of the environment (e.g. air, water) enable it to be considered in the class of goods and services known as public goods. Public goods have two specific characteristics that differentiate them from other kinds of goods and services. One characteristic of a public good is nonexclusion, that is to say, it may be very difficult to exclude particular individuals from the use of the good. A second characteristic is nonrivalry or jointness of supply; in other words, one individual's consumption of a good does not necessarily preclude another from its use. These two characteristics are typically observed in the consumption of environmental goods. Due to the lack of enforceable boundaries for air, the clean air that you breathe, I breathe too; when clean air is supplied to one person, it is implicitly supplied to others as well. And, as a general rule, my hike on a trail through the forest will not diminish the value you receive from walking through the same forest.[4] These characteristics of public goods are factors that contribute to environmental contamination. Furthermore,

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[4]There are circumstances where my presence in the forest could hamper your enjoyment. If there are too many people, crowding may be a problem, and you may not be able to see the forest. Goods subject to such a phenomenon are referred to as local or congestible public goods, or sometimes club goods. Alternatively, if I leave behind reminders of my visit in the form of soft drink containers and bubble gum wrappers, I would indeed have an influence on your consumption enjoyment.

the characteristics imply that there are few means by which to market a "clean" environment.

2.2. Pollution: A Negative Externality

Environmental contamination arises when market activities cause unintended side effects. These spillovers or externalities are costs or benefits not reflected in the market transactions and accruing to third parties. The unintended side effects to the exchange are beyond the control of the third party and no compensation is made for the effect. Although these spillovers can be positive, negative externalities are responsible for much of the environmental contamination observed today, and, as such, are the focus of this discussion.[5]

Negative externalities causing degradation of the environment can be viewed as resulting from not ascribing property rights to the environment: that is, to their public good properties. No one owns the presumably abundant water resources or the air; therefore no prices are placed on their use. A firm that utilizes these resources in production, without paying the cost of using them, will have a larger output than if the firm were forced to pay compensation for the damage done to these resources as a result of its production activities.[6]

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[5]An example of a good providing a positive externality would be education. Not only does an individual gain from higher education (a higher paying job), society as a whole prospers from having a more highly educated populace that facilitates economic transactions and economic development.

[6]For a straightforward explanation of the over-exploitation of common property resources see the discussion by Robin W. Boadway and David E. Wildasin, *Public Sector Economics*, 2d ed., (Boston: Little,

2.3. An Economic Reality

The existence of externalities and public goods implies that the market-attained general equilibrium position of the provision of goods and services may not be Pareto optimal; i.e., it may be possible to improve the well-being of one person without making at least one other worse off through a reallocation of resources and reduction in pollution. A Pareto-optimal equilibrium is defined as a solution that meets the following criteria: (i) exchange efficiency, where the marginal rate of substitution between any pair of goods is equal across all consumers; (ii) production efficiency, where the marginal rate of technical substitution between any two factors of production is equated across all industries; and, (iii) the marginal rate of transformation between any two goods in production is equal to the marginal rate of substitution.[1] Yet such an efficient equilibrium solution may not be truly Pareto optimal because these efficiency solutions assume that all costs are captured in the market. Unless provisions are made to correct for environmental degradation, market equilibrium conditions may not be optimal. Given the nature of public goods and the presence of

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Brown & Company, 1984), 127-134.

[1]Robin W. Boadway and David E. Wildasin, *Public Sector Economics*, 2d ed., (Boston: Little, Brown & Company, 1984), 28-29.
In addition, formal Pareto optimality assumes no interdependencies exist such as those between factors of production.

externalities, many costs are not captured in the market. The result is excess pollution.[8]

In reality, public goods are generally not provided in the marketplace because of the nature of the goods, as noted above. In the same way, the environment is not appropriately valued when used as a receptacle of waste (essentially an input into production, for without it production could not occur or would occur to a lesser degree). Thus, the efficient equilibrium of the private market may not be optimal in the Paretian sense. By decreasing the level of pollution we may make some persons better off without making anyone else worse off; i.e., Pareto optimal improvements may be possible.

2.4. Remedies

Economic theory typically recommends that a non-optimal market equilibrium be remedied with policy instruments that change the behavior of participants using both non-market and market solutions. Non-market solutions use forces outside the marketplace to influence the market equilibrium. For example, behavior can be changed by moral suasion; publicity can be used to induce social pressure to motivate change in a

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[8]The environment does have a "healing" property of its own and can assimilate some of the waste it receives. Given the zero cost of using this means of disposal, basic economic theory of common property resources can demonstrate that these means will be overused. See: William J. Baumol and Wallace E. Oates, *Economics, Environmental Policy, and the Quality of Life* (New Jersey: Prentice-Hall Inc., 1979), 112-122; Richard Cornes and Todd Sandler, *The Theory of Externalities, Public Goods, and Club Goods* (Cambridge: Cambridge University Press, 1986), 128-131; and, Robin W. Boadway and David E. Wildasin, *Public Sector Economics*, 2d ed., (Boston: Little, Brown & Company, 1984), 127-134.

given activity. Although not considered very seriously by many economists, volunteerism has protected the environment; good examples are the recycling programs that have sprung up around the country in recent years. The use of direct control, another non-market solution, has also been used to meet environmental goals. Regulations can limit the level of pollutants allowed to be emitted, or alternatively, can mandate the use of specific technology intended to reduce the level of emissions. The government can also directly invest in programs to remediate environmental damage through research, education, and dissemination of information as well as through regenerative activities such as reforestation or water treatment plants.

Taxes and subsidies are policy instruments that rely on market solutions, i.e., price incentives, to correct for negative externalities like pollution. A tax could be placed on each unit of emissions and firms would then remit a total fee dependent on the amount of the tax and the level of emissions. Effluent charges provide incentives to reduce emissions in order to reduce costs to the firm. Subsidies could also be used to reduce emissions. A firm could be paid a premium for each unit of effluent reduced, thereby reducing the level of emissions. Transferable pollution permits are another market technique suggested by some economists. A given number of pollution permits could be sold, each allowing a specific quantity of emissions to be discharged. The aggregate level of emissions allowed would be determined by the total number of pollution permits available for purchase. These rights would be allowed to be transferred, implying that the most cost-effective pollution reductions would be made first. Firms facing high costs to

reduce emissions could purchase permits from other firms who could reduce emissions at a cost lower than the value of the tradeable permit.

Other possible market-oriented corrective mechanisms for pollution include assigning either property rights to resources or liability for damages done to the relevant parties. On one hand, property rights assigned to environmental resources would force the owner of the resource to realize the full cost of resource use and, at the same time, would allow the owner to protect the resource from overuse, guaranteeing the resource for future use. It will likely be in the best interest of the owner to sustain the use of the resource and not subject it to abuse. On the other hand, assigning property rights to a party opens up the possibility of negotiation for the use of the natural resource. If one individual values the environment more than the person granted the property rights, the former can pay the latter to preserve the resources. Specifically, when property rights are assigned to the polluter, persons damaged by the pollution will seek to pay the polluter to reduce the output thereby reducing pollution. If the property rights are instead granted to those damaged by the pollution, the polluter will pay a premium to those damaged by the pollution in compensation for the amount of pollution they will tolerate. Bargaining will continue until the willingness to pay for a reduction in the damage caused by a unit of output equals the willingness to receive compensation to reduce a unit of output. If bargaining is costless, assignment of property rights to either party will result in an efficient allocation of resources. The distribution of gains from bargaining will be determined by the

assignment of property rights; yet, the efficiency of the resource allocation will be unaffected.

Assigning liability damages to correct for externalities is effectively the same as assigning property rights to the resource being damaged. Liability damages may be assigned via legally imposed compensation payments that would be paid by the polluter to those damaged by the emissions. If payments are assigned by the legal system without cost and are at the rate determined by some sort of damage function (an estimated relationship between pollution emitted and the damage it causes), an efficient solution will result. As in the property assignment case, the distribution of the gains and losses will be determined by the assignment of liability.

One key to efficient allocation of resources in assignment of either property rights or liability damages is the assumption regarding zero transaction costs. If bargaining or assignment of property rights is not costless, an efficient solution may not be achieved. If transaction costs are greater than the gains to be obtained by bargaining, no bargaining will take place.[9]

The non-optimal market equilibriums and the proposed market and non-market solutions identified above constitute the standard diagnosis and analysis of the economic approach to the problem of environmental pollution. Administrative mechanisms used to implement the elected policies differ from policy to policy. Policies can be implemented on

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[9]See Ronald Coase's, "The Problem of Social Cost," *The Journal of Law and Economics*, (October 1960), 1-44, for the original discussion of the reciprocal nature of the externality problem and potential bargaining solutions.

the local, state or national level, with enforcement included in the administrative body, or delegated to law enforcement agencies. In the case of assigning property rights, civil suits could be relied on to enforce the policy solution. If transaction costs are not prohibitive, the use of civil legal action against polluters could be an effective means of pollution control. The mere threat of such a legal suit could stimulate the desired reduction in pollutants emitted. In such a case the government would have no active role in the administration or enforcement of the program with the exception of court supervision.

2.5. Guidelines for Environmental Policy

Although there is an extensive list of policy solutions to deal with environmental contamination, it is not immediately clear how to choose among these alternatives nor how to evaluate them. Baumol and Oates have compiled a list of necessary characteristics for environmental policy that encompasses the characteristics generally recognized as essential for successful policy. Environmental policy should be: (1) dependable so that it can reliably achieve the goal of the policy; (2) permanent so that the policy works even without high visibility; (3) adaptable to economic growth so that it can accommodate both increased economic activity and population growth; (4) equitable so that gains and losses are distributed "fairly" among the parties involved; (5) economical so that the program will not waste resources in achieving its goal; and (6) politically attractive because the voting public or the legislature will likely become involved with the adoption

of the policy. In addition, the policy should: (7) provide incentives for minimizing the damage to the environment rather than encourage behavior merely sufficient to avoid reprimand; and (8) minimize the distortion to private decision-making processes by offering the broadest range of possible alternatives to the parties involved.[10]

In addition to these broad guidelines for evaluation of any policy solution, the decision must be made regarding how much of the externality--the costs of pollution--should be reduced. The questions of what is the "optimal" level of pollution and how clean is "clean" are debated in almost every environmental policy decision-making process. These questions generally focus on the assimilative capacity of the environment and the sensitivity of the ecosystems affected as well as the political and economic viability of the solutions. The good or service provided that is causing the pollution in the course of its production, e.g. electricity generation, is sometimes focused on also. If the benefits derived from the good or service are considered "necessary" by the concerned economic agents, such benefits can have an impact on the policy decision; the presence of benefits may facilitate negotiation on pollution levels that can be considered acceptable. Unfortunately, realism and rationality, two characteristics necessary to arrive at an efficient and effective solution, do not always dominate these policy-making discussions.

Having concluded that private incentives and the market may not result in prices that reflect all social costs and benefits of an

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[10]William J. Baumol and Wallace E. Oates, *Economics, Environmental Policy and the Quality of Life*, (New Jersey: Prentice-Hall, Inc., 1979), 218.

endeavor and thus may not provide an efficient allocation of resources, an alternative decision-making mechanism may be adopted. An analysis mechanism often utilized in replacing a strict profitability rule, in the accounting sense, is cost-benefit analysis. Defined generally, cost-benefit analysis measures the "net economic benefits from a change in resource allocation."[11] In such analyses, the entire economy as a whole is considered; any cost or benefit to any part of society is included. The ultimate question addressed by cost-benefit analysis is whether society as a whole will benefit from undertaking the task and the resulting redistribution of resources. Cost-benefit analysis can be used to examine the potential social net benefits from any market or non-market solution that may be proposed to correct the non-optimal market equilibrium.

Ideally, the discipline of economics, through the use of cost-benefit analysis, can assist in the determination of the level of cleanup or reduction of emissions that should take place. A marginal cost-benefit decision rule would suggest that reduction in emissions should occur until the marginal benefit obtained from a unit of pollutant reduced no longer exceeds the marginal cost of achieving the reduction, assuming of course that all social as well as all private costs and benefits are known.[12]

Thus, a useful contribution of economics to the dilemma of environmental contamination should be to bring externalities into

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[11] Boadway and Wildasin, 187.

[12] Note that the cost of pollution reduction increases dramatically as the zero pollution level is approached.

consideration in any determination of the net social benefits of undertaking a project, as presented most clearly in cost-benefit analysis. All potential impacts of a proposed policy action should be considered. Negative externalities are not always quantifiable, yet those unknown costs can be considered during the discussion of the viability of any remediation or prevention project.

Section 3. Underground Storage Tanks: A Specific Application

Environmental contamination has, over the past several decades, become a concern throughout this country, as evidenced by the establishment of the Environmental Protection Agency (EPA) and various other environmental programs that have addressed the issues of clean water, air and other environmental public goods. At the same time private organizations, such as Greenpeace and the World Wildlife Fund, have been established or have increased their activities. In the early 1980s, within the context of this concern, the publicizing of a few incidents brought public attention to the environmental contamination caused from releases from underground storage tanks (USTs).

Underground storage tanks are used for petroleum and chemical storage by a wide variety of users. Aside from retail motor fuel marketers who usually have a minimum of three tanks on the premises, USTs are also used by fleet owners, farmers, chemical manufacturers and all levels of government. The functions that an UST performs makes it almost essential to daily activity for most people in this country, both producers and consumers. Given the widespread use of USTs and the

nature of the contents held in USTs, there is a possibility of environmental contamination and hazards to human health if a release occurs. These costs to human health and the environment have not been, as a general rule, included in the decision to use USTs in production and consumption activities; thus, the market-dictated outcome of the mix of goods and services provided may not be an efficient solution.

3.1. Some Historical Evidence of Environmental Contamination from USTs

Two events in particular are responsible for these increased levels of concern about USTs. The first incident that claimed great attention was a story on the television show "60 Minutes" in December of 1983. The report recounted the saga of a small community in Rhode Island that had its drinking water supply contaminated as a result of leaks from the underground storage tanks of two nearby gasoline service stations. The major oil companies that owned the station were reluctant to take responsibility for the releases and to provide an alternate drinking water source for the affected community. It was a long and costly process for the community, both to identify the source of the contamination and to obtain compensation for damage done. The gasoline in the groundwater provides an example of the economic concept of pollution as a negative externality. Released product in the groundwater did not harm the service stations but did harm third parties not involved with the firms, thus not all of the costs of operating the station (e.g. alternate water supply) were considered in the actions of the owners.

The second event was a publicized series of incidents in California's Silicon Valley where several chemical tanks were found to be leaking, introducing a threat to the local communities. Within a three year period, leaks were reported at twenty-one plant facilities, and nearby wells and water systems were forced to close due to contamination. Again, there were negative externalities of the chemical business experienced by local communities for which no compensation occurred.

As a result of these incidents the public began to perceive a threat from the USTs both for reasons of their personal health and for the threat to the environment. It would appear that the public essentially demanded that the potential threat they faced from USTs be transferred away from them and on to the owners of USTs; such an action would cause the firms to take responsibility for the environmental costs, to "internalize" the costs. As with most public goods, the task of providing, or assuring the provision of the clean environment once again fell to the policy-makers. The actual response of the policy-makers will be covered later in this chapter.

3.2. USTs: What They Are and the Problems They May Have

An underground storage tank is defined as a tank system, including the related piping, that has at least ten percent of its volume below the ground.[13] Such tanks range in volume from a few gallons to

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[13]The definition is legislative in origin: Subtitle I, part of the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976, Public Law 98-616.

thousands of gallons and contain any of a number of chemical compounds. The basic structure of an underground storage tank can be seen in Figure 4.

Environmental contamination from an UST may originate with an aboveground or below ground release. It may result from a spill, an overfill, corrosion, or structural failure. The spill can vary in size from a few gallons to several thousand gallons, with the quantity of soil and groundwater affected measuring anywhere from a few cubic yards to tens of thousands of cubic yards. Given the potential extent of contamination per site and the potential number of sites, the resources needed to complete remediation activities may be large.

We can see from the nature of the incidents that brought the issue of leaking USTs to the attention of the public that the contamination caused by the releases from USTs does not adhere to the "rules" devised for typical environmental policy decision-making. There is no effluent discharged on a regular basis that can be taxed, nor can a subsidy or a system of pollution permits reduce UST emissions. Technology placed at the end of a discharge pipe cannot eliminate, or even effectively reduce, the contamination. All tank systems have a positive probability that they will release contents yet not all systems have the same probabilities associated with them. For example, the fiberglass reinforced plastic (FRP) tank system has a zero probability of corrosion resulting in a release given its materials of composition, but the FRP system will have a small probability of structural failure because uneven forces on the UST may cause stress beyond the limits the material will tolerate. A corrosion protected steel UST, on the other hand, is

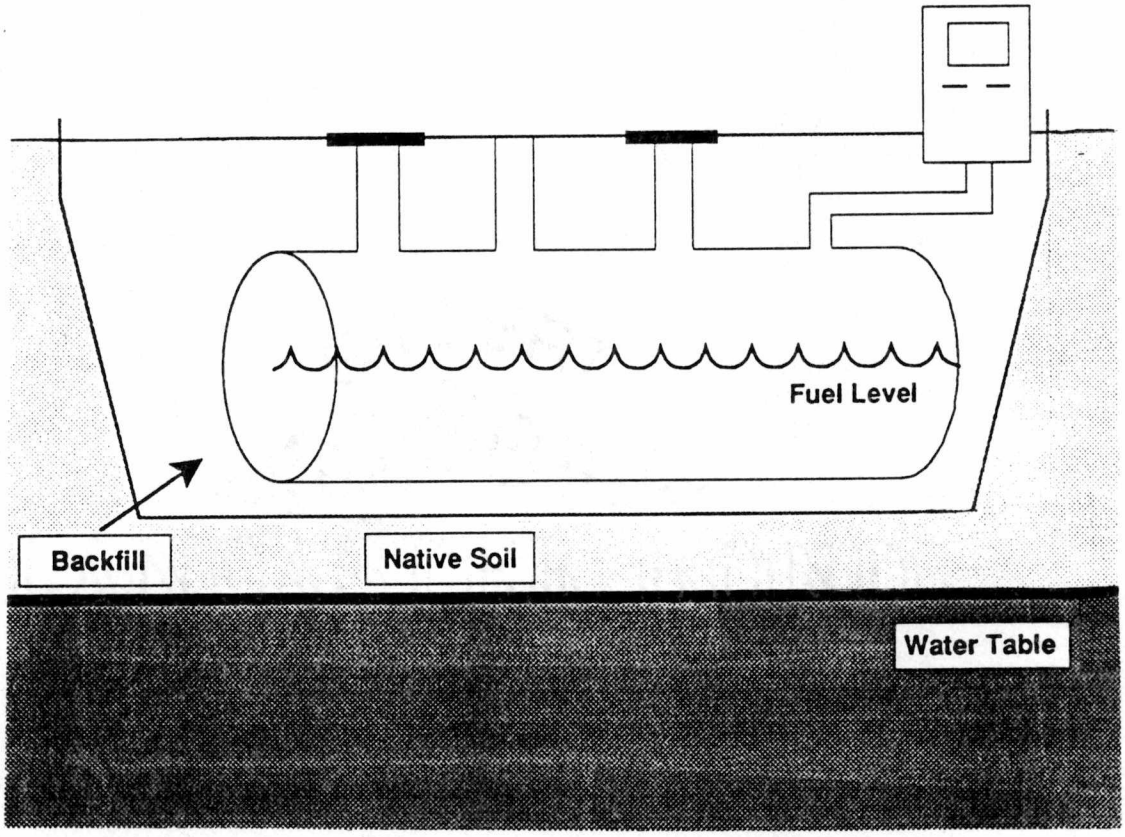


Figure 4. Diagram of An Underground Storage Tank

in the reverse situation. The steel UST has a positive probability of corrosion but it is likely to withstand slightly higher stress levels than the FRP tank.[14] Further, once a release occurs, not all tank systems have the same damage potential. Tanks are located in a wide variety of geological settings and population areas; thus, depending on the location of the UST and the volume released, specific site factors will determine the impact of the release.

As seen in the publicity that brought the UST issue to the attention of the public, there is a potential threat to human health and the environment from leaking USTs. Given the number of USTs estimated to be currently in the ground, the resulting contamination could be significant. An EPA official was recently quoted as saying that the total number of regulated and unregulated USTs may be as high as seven to fifteen million, this includes all USTs and is not restricted to Subtitle I USTs.[15]

There are at least two environmental issues to be considered here. First, all USTs have a probability of releasing product in the future, and this probability of release can be reduced thereby decreasing future threats. Second, there are a large number of USTs in the ground today

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[14]A bare steel UST has a high probability of corrosion as compared to the corrosion protected steel UST. However, even the latter will have some small probability of corrosion. The soil where an UST is located may be particularly acidic or there may be a high water table thus neutralizing the corrosion protection faster than would otherwise have occurred. Such an UST would have a higher probability of a corrosion-related release.

[15]R.D.R. Hoffman, "Stopping the Peril of Leaking Tanks," Popular Science, March 1991, 78. (Subtitle I will be defined in detail later in this chapter.)

that may be already leaking and have contamination that requires cleanup to reduce the potential present health and environmental threats.

Any solution to these potential problems should consider the differences between the two issues. In the first case there is a possibility of future contamination that can be avoided by present preventative activities. If potential costs of a future release (the negative externalities) are internalized by the owner of the UST, it will likely result in action taken on the system to reduce the possibility of a release. In the second case there are no incentive effects to be considered because there is no behavior that can avoid the contamination: the contamination has already occurred. In addition, the circumstances that led to the contamination were not necessarily malicious nor negligent; in most cases the industry code of recommended practices was followed. These factors can influence the equity considerations of any potential solutions.

This study will limit its scope to consideration of the latter problem: cleaning up contamination that has already occurred or will be found to have occurred in the process of complying with the new technical requirements.[16] The approach will be that of a cost-benefit framework. The use of cost-benefit analysis will not only assure consideration of all benefits and costs but will also help to identify the potential gainers and losers from the reallocation of resources.

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[16]The new technical standards and financial responsibility requirements are established in RCRA Subtitle I and will be covered in detail later in this chapter.

3.3. Benefits and Costs

To fully evaluate both present and future threats of releases from underground storage tanks, it is necessary to categorize the full benefits and costs of dealing with the problem. The benefits and costs will be briefly listed here. They will be explored in further detail in the following chapters.

On the one hand, with reduction of present and future releases, benefits can be derived from reduction in contamination of drinking water sources, reduction in probability of explosion or fire in adjacent structures, reduction in possible effects on wildlife in streams or ponds, and reduction in possible cancer deaths or illnesses due to exposure to UST contents. Various levels of remediation can be prescribed to meet desired reduction goals.

On the other hand, costs include the monetary charges to the owners of the USTs or to the community for the cleanup of released product to the levels specified. The level of costs will be dependent on the particular solution chosen to address the problem, which, of course, is dependent on the level of remediation sought. Indirect effects may also result in costs to the private and public sector; such effects may include changes in the structure of markets (e.g. retail motor fuel) and the availability of UST services.

The costs are estimated here on the basis of the regulations adopted in 1988 to address releases from USTs. The general assumption for estimation of the cost of remediation activities is that the costs are dependent upon the number of USTs that potentially can release their

contents, the probability that there will be a release at any given UST, and a representative cost associated with any UST cleanup. A more detailed description of the general methodology of the total cost calculation and the specific approaches utilized for each of the intermediate estimates will be presented in Chapter 3.

3.4. Alternative Solutions

Alternative solutions to this environmental problem range from taking no action to outlawing the use of underground storage tanks completely and mandating the use of substitutes. On the overall program level, the no-action option would only be possible if the collective threats to human health and the environment can be regarded as negligible. The effects that have been noted to exist may indeed be negligible, but that determination would depend solely on the basis of comparison; if the risks from UST contamination are compared to other risks such as from types of indoor air pollution, such as radon, the former may be negligible. Yet, public perception of the contamination from USTs as a significant threat to human health and the environment has presumably eliminated this option.[17]

Moral suasion could alleviate the problem if public and political pressure could be sufficiently aroused and maintained. But it would be

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[17]The question does arise as to whether or not it would have been more cost-effective to educate the public regarding the true nature of the risk, rather than attempt to eliminate all risk from UST releases. This is an especially valid argument in situations where a petroleum leak has been identified and stopped and where there is no danger of migration of the contaminant: the microorganisms in the soil will break down the contaminant naturally over time.

difficult to sustain a high enough level of pressure for the prolonged period of time necessary to effect an inspection of the entire UST population and thus would likely result in a temporary solution. Given the high costs associated with upgrading tank systems and remediating contamination and the large number of USTs and variety of owners, it is doubtful that moral suasion would be effective in any but the shortest of time frames. In addition, companies that could not afford to make changes in their physical systems would likely "lie low" until public opinion had moved on to a new topic of concern.

A strong emphasis on direct control through regulation could mandate, for example, the use of specific technologies to prevent or to clean up releases. This would directly internalize the potential cost of an UST release (possibly including all negative externalities) into the cost function of the owner of the UST. Alternatively, regulations could provide direction in dealing with USTs using language that could range from imposing stringent directives on activities to issuing suggested codes of practice. This approach could also provide a decision rule to follow for determining whether or not particular efforts need to be undertaken to prevent or clean up a release; e.g. when the cost of damage from a release is greater than the cost of the cleanup, the cleanup should be undertaken. The content of regulations will generally depend on the legislation creating the ruling and the latitude given to the implementing agency to write the rules.

Assigning property rights in this instance may prevent releases from USTs and effect appropriate cleanup activities. However, the assignment of the rights and the extent of those rights could determine

the extent of cleanup. If, for example, the owner of the UST was assigned the land and water property rights, the owner would use his own decision rule to determine if protection of the tanks or cleanup of contamination was necessary. Potential liability for off-site migration and the cost of cleanup would likely figure prominently in the owner's decision to upgrade tanks or clean up contaminated soil or water. If the contamination was not migrating and located in a relatively well-contained area, the owner may not regard cleanup necessary. Those not granted the environmental rights would obviously have the opportunity to pay the owner of the UST to reduce the probability of an UST release through such means as better equipment or leak detection procedures, or bribe the owner to clean up any contamination found on the site. Alternatively, if the non-UST-owner were assigned the land and water rights, the UST owner may be required to undertake more preventive measures and corrective action than he would otherwise have undertaken, because cost considerations will not likely be as prominent in the decision.[18]

Assignment of tort liability, a solution that has already been employed by the courts in cases of off-site contamination caused by UST releases, could prove effective in attaining preventive measures against future releases and achieving cleanup efforts on past releases. This mechanism operates in a manner similar to the case of the property rights assigned to the non-UST-owner. However, the presence of positive

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[18] It has been shown that there is a difference between what an owner is willing to pay (WTP) for a good or service and what the owner is willing to accept (WTA) for the good or service to be taken away. When that good is a "clean" environment the WTA will likely be less than the WTP.

transaction costs, as alluded to earlier, can hinder an efficient outcome using this solution. As seen in the Rhode Island case, it may also be a costly process to demonstrate the precise source of the contamination.

An extreme solution would be to eliminate the potential of any release through banning the use of USTs altogether. Such prevention of all releases would obviously be required with no regard given to costs or the availability of alternatives to USTs.

Administration of an UST program could be undertaken at a federal, state or local level. The large number of USTs will likely require that significant resources be diverted to the management of a regulatory program wherever it is established. Depending on the stringency of the program, proper administrative placement of the program could facilitate its management. If the program is designed to be flexible, working on a case-by-case basis, a local or state program might be preferable. Local officials would presumably be best able to judge local conditions and the hazard involved should a release occur. On the other hand, if the program is required to treat all USTs and owners as equal, a centralized system will likely be able to implement a program with fewer inconsistencies occurring. Ultimately, the administration of the program will depend on the solution chosen to address the problem of releases from USTs.

Financing of the program will be dependent on the scale of the program, the set-up and maintenance costs of the program, and possibly on any redistribution of resources activities that may be required to minimize equity concerns associated with the program. In general,

environmental cleanup programs can be financed by those who create the problem, those who benefit from the solution or from the general revenues of the level of government or regulating body administering the program. If all tank owners are identified as those responsible for cleanups, a tax could be levied on the owners on a per tank basis or on the basis of the throughput volume of the tank. The fund created could then be called upon to finance the cleanup of contaminated UST sites. Alternatively, a policy solution could mandate that each individual UST owner be responsible for his own cleanups. In this case some owners would incur the cleanup costs and others would not.[15]

It is apparent from the above discussion that there were many options to address the problem of UST releases. A priori, all possible options should be evaluated to determine the most appropriate action given the general goal of reducing contamination from UST releases. However, after the decision has been made, we can only evaluate that decision to determine how well it will achieve the desired goal, or alternatively, we can examine the costs relative to the benefits that will be obtained from the solution adopted. Such is the case with this present work; the costs and benefits of the UST program will be evaluated in an effort to evaluate the legislative and regulatory decisions made.

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[15]The economic burden of these differing "tax" programs will be discussed in the third and the fifth chapters when the notion of tax incidence and the secondary effects of the UST legislation are examined.

Section 4. UST Legislation and Regulations

In 1984, federal legislation was passed to address the problem of environmental contamination from UST releases. The Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 (RCRA) were signed into law containing Subtitle I. RCRA Subtitle I created a broad and comprehensive regulatory program for underground storage tanks.

Section 9003 of Subtitle I includes two major requirements for USTs and establishes the universe of tanks covered in the base case of this study.[20] First, UST systems must meet outlined technical requirements. These technical standards address tank system design, construction, installation, leak detection, recordkeeping, reporting, closure and corrective action. Second, all facilities with petroleum-containing tank systems must maintain evidence of financial responsibility for corrective action and compensation of third parties for bodily injury or property damage due to accidental releases.[21]

The underground storage tanks that are covered by these technical standards contain petroleum or substances defined as hazardous under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), except those substances regulated as hazardous waste under Subtitle C of RCRA. The financial responsibility requirements,

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[20] Public Law 98-616.

[21] The regulations promulgating the final rules to carry out these requirements were given in the Federal Register in 1988: September 23rd for the technical requirements, and October 26th for the financial requirements.

although limited to petroleum tanks at present, utilize the same UST definition.

Some USTs were specifically excluded from the regulations; several exclusions of interest include:[22]

* Farm or residential tanks of 1100 gallons or less capacity storing motor fuel for noncommercial purposes;
* Tanks storing heating oil for consumptive use on the premises where stored;
* Septic tanks;
* UST systems containing mixtures of hazardous substances;
* De minimis exclusions: 1) tanks having a capacity of less than 110 gallons; 2) those holding very low concentrations of regulated substances; 3) those that serve as emergency backup tanks, holding regulated substances for only a short period of time and that are expeditiously emptied after use.[23]

All USTs covered by Subtitle I are subject to the compliance deadlines published in the regulations with all minimum requirements expected to be met by 1998. Leak detection requirements for existing tanks are phased in over the five years from 1989 to 1993, with the

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[22]Other specific exclusions include: pipeline facilities (including gathering lines) regulated under the Natural Gas Pipeline Act of 1968, the Hazardous Liquid Pipeline Act of 1979, or State laws comparable to these Acts; surface impoundments, pits, ponds, and lagoons; storm-water or wastewater collection systems; flow-through process tanks; liquid traps or associated gathering lines directly related to oil or gas production and gathering operations; storage tanks situated on or above the floor of underground areas, such as basements and cellars; equipment and machinery that contain regulated substances for operational purposes, such as hydraulic lift tanks and electrical equipment; and, wastewater treatment tanks regulated under the Clean Water Act (CWA). Deferments included: wastewater treatment tanks not regulated under the CWA; field-constructed tanks; systems containing radioactive materials; Airport hydrant fueling systems; backup diesel tanks at nuclear facilities; and, UST systems associated with emergency generators (deferral of the release detection requirements only).

Most of the deferred USTs remain subject to the interim and corrective action requirements.

[23]*Federal Register*, vol. 53, no. 185 (23 September 1988), 37083, 37107-37114.

specific deadline contingent upon the age of the UST. Existing tanks and pipes are addressed separately in the deadlines. Pressurized piping was to have been equipped with leak detection by December 1990, while suction piping has the same deadlines as the connecting tanks themselves. Corrosion protection and spill/overfill protection must be installed before December, 1998. New tanks--those installed after December 1988--must have all detection and protection requirements fulfilled at installation.

Section 5. The Estimation of Costs and Benefits

According to the *Regulatory Impact Analysis of Technical Standards for Underground Storage Tanks*, the bulk of the costs resulting from the new regulations will be in the remediation activities which will be the focus of this present work.[24] Although the benefits of the program will be discussed in detail, the benefits will not be quantified.

Chapter 2 examines the benefits of the program as adopted in some detail. A comprehensive list of the benefits as well as the potential beneficiaries will be compiled. Chapters 3 and 4 will continue the economic analysis with an examination and quantification of the costs of the remedial action portion of the regulations. Chapter 5 will discuss the findings of the estimation and compare the benefits and costs of the regulation. Chapter 6 concludes with examination of, and speculation about, the goal of the regulations and a subjective analysis of the

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[24]Environmental Protection Agency, Office of Underground Storage Tanks, *Regulatory Impact Analysis of Technical Standards for Underground Storage Tanks*, vol. 1, (24 August 1988), 4-14.

achievement of those goals, based on the analysis in the preceding chapter.

CHAPTER 2

BENEFITS: A QUALITATIVE ANALYSIS

Section 1. Introduction

In this chapter, an economic approach to the identification of benefits will be outlined. The specific benefits that will be examined are those that can potentially be obtained from remediation of the environmental contamination caused by UST releases. All available information will be presented concerning damages that have been caused by UST releases and on the potential impacts on various media (e.g., water, air) from released product. Given that the nature of the benefits is largely in the form of reduced risks there is also a discussion of risk, its assessment, and how risk is perceived.

Section 2. An UST Release

To understand the benefits to be obtained from reducing UST releases, it must first be made clear what kind of damages can result from an UST release. An UST release can originate from either the above- or below-ground components of a tank system, and can be the result of a spill, an overfill or a leak.[1]

Subsurface releases occur from the tank or pipes located below the ground and will initially result in contamination within the excavation

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[1]Recall that an UST is defined as a tank system that has at least 10 percent of its volume underground. As Figure 4 in Chapter 1 shows, both above- and below-ground components are found in UST systems.

zone, that area immediately surrounding the tank and pipes (backfill area, Figure 4). The extent of contamination of media in the area will be determined by the rate and total volume of the release as well as site factors such as the hydrogeology of the location. The next likely level of contamination is the soil outside the excavation zone. Contamination may be restricted to the soil just outside the excavation zone, particularly if there is a considerable depth to the groundwater level. With a continuous release such as that which originates from an undetected small hole in a tank, however, contamination of the groundwater will likely occur at some point after the soil outside the excavation zone has been contaminated. Precisely when the groundwater will be affected will be determined by the groundwater level and soil factors at the site such as permeability. If the groundwater is closer to the surface, groundwater may be affected as soon as the product leaves the excavation zone.[2] Seepage into nearby structures may occur causing highly combustible fumes to be confined and possibly resulting in an explosion or other damage from fire. Again, the location of the release and site specific factors will determine whether or not such damage occurs outside the property lines.

Surface releases, i.e., releases above the ground, may cause damage through runoff into surface water and sewer systems, as well as soil and groundwater if the contaminant becomes absorbed into the ground. However, extensive damage to the soil and groundwater is less

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[2] It is possible that in certain geographic areas there may be occasions where tanks will actually rest below the water table. In such cases contamination may occur immediately upon the release of product.

likely with surface releases because the releases tend to be smaller (less than 100 gallons) and one time occurrences.[3]

2.1. Possible Effects of an UST Release: Available Information

The benefits that can be derived from reducing or eliminating releases from USTs can be best delineated through an examination of past releases. Although little information on damages caused from UST releases is available, the information that is available will provide helpful insight into the potential threats to human health, the environment, and, potentially, even to future production possibilities, as a result of the contamination.

The most comprehensive study of past UST releases was undertaken by EPA's Office of Solid Waste and was published in 1986. Contractors for the EPA examined records of past releases available through state agencies which contained site-specific information on releases reported from 1970 to 1984. A total of 12,444 incidents were reviewed in fifty states.[4] Not all of the incidents recorded in this database were

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[3]Environmental Protection Agency, Office of Underground Storage Tanks, *Summary of State Reports on Releases from Underground Storage Tanks*, (August 1986), 6-12.

[4]States in the Northeast, Mid-Atlantic and Great Lakes regions had the greatest incidence of reported releases, although all states were represented in the total number of incidents. EPA, *Summary of State Reports*, 3-4.

covered by RCRA Subtitle I; of the 12,444 incidents 10,300 incidents (or 83 percent) were covered.[5]

In the EPA analysis, a variety of media were reported as having been affected by the reported UST release incidents--soil, groundwater, surface water, air and "other" media; this latter group included such various media as pavement, sewer lines, electrical conduits and basements. Table 1 lists the percentage of incidents that affected each medium.

All 12,444 incidents in the database reported the medium or media affected by the release; however, only 17 percent (or 2,190) of the incidents reported provided additional information on the specific impacts of the release. The specific impact identifies various human health or environmental problems resulting from an UST release. Table 2 summarizes the specific impact of this sub-group of incidents as reported in the database. The greatest impacts observed were on areas where fumes collect (7 percent) and on private wells (6 percent).

Although there were a considerable number of observations, there are some shortcomings to the data collected in this study. First, the data are based on observations that do not necessarily represent a random sample of UST releases and the impacts of those releases. The incidents reported to State officials and documented in the files reviewed are more likely to have included impacts that resulted in third party complaints than those incidents not reported to officials. This

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[5]Of those 17 percent not covered, heating oil cases comprised 15 percent of the records while 2 percent were classified under other exclusions to Subtitle I, primarily under the exclusion for tanks with less than 1100 gallons in volume.

Table 1. Summary of Media Affected by UST Releases

Media	Percentage of Incidents Affecting Each Medium[1]
Soil	67 %
Groundwater	45 %
Surface Water	22 %
Air	15 %
Other[2]	12 %

[1] The percentages do not sum to 100% because most incidents reported an effect on more than one medium.

[2] Includes sewer lines, pavement, basements and electrical conduit/vault.

Source: Environmental Protection Agency, Office of Underground Storage Tanks, *Summary of State Reports on Releases from Underground Storage Tanks*, (August 1986), 8-1.

Table 2. Specific Impacts of UST Releases

Health/Environmental Impact	Number of Incidents	Percentage[1]
Private well contamination	749	6 %
Municipal water supply contamination	40	< 1 %
Human illness	100	< 1 %
Human death	2	< 1 %
Combustible fumes in confined areas	908	7 %
Fire/explosion	155	1 %
Corrosion of structures	34	< 1 %
Aquatic life impacts	103	< 1 %
Plant life/crop loss	99	< 1 %

[1]Percentage of the total incidents reported: 12,444.

Source: Environmental Protection Agency, Office of Underground Storage Tanks, *Summary of State Reports on Releases from Underground Storage Tanks*, (August 1986), 8-1, 8-4.

implies an underreporting of on-site contamination and of less seriously contaminated sites.[6] Second, the impact information reported in each file may be incomplete. Over the fourteen year period when the incidents were reported there was no specific standard reporting form used by all states, nor were those officials initially recording the UST incidents using standard reporting requirements. The officials may not even have been located in the same departments within the states; some reports may have been filed with the fire marshall's office and others with the natural resources or fish and wildlife services. For these reasons, the reported distribution of health and environmental impacts summarized in Table 2 may not be representative of the total number of UST releases.[7]

Despite the weaknesses of the information available, some conclusions can be drawn. The over 2000 incidents with reported specific impacts can be used as a basis for examining the range of potential impacts that are caused by UST releases.

2.2. Specific Potential Media Impacts

First, water supplies can be affected. Although widespread damage was found in private water supplies in the data presented, municipal

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[6]This data may also tend to overemphasize the more serious UST incidents because of the period over which records were examined. It is likely that the incidents reported in the 1970s were relatively more serious than even those that were reported later in the 1980s. In the latter decade the reporting of environmental incidents was more commonplace as was the notion of liability for environmental contamination.

[7]EPA, *Summary of State Reports*, 8-4.

water supplies can also be contaminated by UST releases. Other groundwater can be affected as well. Undesignated groundwater that may not be currently in use as a water supply source may be used for such a purpose at some later time. Surface water can also be contaminated by an UST release. Potable surface water, industrial surface water and surface water utilized for contact and non-contact recreational activities can be rendered unusable or contaminated by releases. Ideally, contaminated water can be restored through treatment processes, thus any contamination would be temporary. Unfortunately, a recent study focusing on groundwater contamination and pump and treat technologies concluded that groundwater pumping is ineffective in achieving health-based standards for aquifers. Although contamination of groundwater can be significantly reduced by treatment, drinking water standards may be unattainable and the contamination permanent.[1]

Second, human health can be negatively affected by contamination of the media with which humans have contact. Illness can result from inhalation or ingestion of released products through the air or water mediums. Given that 96-97 percent of all USTs are reported to contain petroleum products that are identifiable in low concentrations by the human senses (smell in particular), the likelihood of ingestion of contaminated water should not be high.[1] However, combustible fumes can

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[1]C.B. Doty and C.C. Travis, *The Effectiveness of Groundwater Pumping as a Restoration Technology*, (Oak Ridge National Laboratory, May 1991), 43.

[1]The *Regulatory Impact Analysis of Technical Standards for Underground Storage Tanks*, 1-5, states that 3 percent of USTs covered by Subtitle I contain chemical products. The *Summary of State Reports*, 3-3, reported the universe of USTs consisted of 4 percent chemical tanks with the remainder petroleum.

cause harm to individuals through fires or explosions. In fact, the two deaths reported in this database were associated with fire or explosion.

Third, damage can result from fires or explosions caused by combustible fumes that collect in confined places. In addition to the danger to human health, property loss can be significant if structures are damaged as a result of an explosion or fire.

Fourth, damage can occur to infrastructure such as pavement of roads and sewer lines. If an UST is located in an urban area, e.g., retail gasoline stations, there is a possibility that the infrastructure of the immediate area could be affected by an UST release if seepage of the contents occurs. If a release enters into sewer lines it may contaminate not only the lines but also any wastewater treatment systems that treat the wastes. The treatment system would require flushing to remove the contamination before it would be operational. If the contaminant were not removed the possibility of a fire or explosion would develop.

Fifth, damage can occur to aquatic life, wild life, and plant life. Ecosystems supporting a great diversity of plant and animal life may become subject to contamination if a release of UST contents occurs. In addition, crop damage can also result, causing lost income to farmers. This is likely to be a problem only where farmers own and maintain USTs for their farm equipment; urban USTs would not likely be the source of this contamination. Although unlikely, it is possible that contaminated surface or groundwater could be a threat to crops if contaminated waters are unknowingly used for irrigation purposes.

Aside from the negative effects of UST releases that were included in the state agency reports, there may be other effects that will occur from UST releases. Contamination of natural resources may preclude the use of those resources by firms other than the firm responsible for the contamination. For example, if contamination occurs in surface water that is used in the production process of a firm downstream, the contamination may cause a loss in productivity for that firm. This cost may or may not be captured in the examination of third party costs; it is not as direct an effect as a fire or an explosion and therefore may be overlooked.

There are possible long term consequences of human exposure to UST contents as well. For example, exposure to the benzene component of gasoline introduces the possibility of chronic health effects because of the carcinogenic nature of benzene. There have, to date, been no cases of cancer that can be specifically attributed to human exposure to a release of UST contents; nonetheless, this does not mean that UST releases have not contributed to cancer deaths in this country. The latency period for cancer and the synergistic nature of the disease could be reasons that explain why this phenomena has not been observed. Alternatively, as mentioned above, the taste and odor thresholds will tend to keep these numbers lower than would be observed without the sensory threshold limits.[10] There could, however, be psychic costs

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[10]The *Regulatory Impact Analysis of Technical Standards for Underground Storage Tanks*, 5-9, estimated that the number of cancer cases over 30 years without regulatory action would be 98.5 incremental cases assuming that the sensory threshold did not limit exposure. If taste and odor thresholds were assumed to hold, the number of cases fell to 25.4, which is approximately one-fourth the initial number of cases.

associated with the potential risk to human health that have not been observed in the state cases.

Despite this extensive list of potential problems, the actual magnitude of the damage that can be caused by the release of contents from an UST is unknown. There is a wide array of possible effects on a variety of media and systems, and little is known about the probability that any particular impact will occur (or alternatively, the risk of that impact).[11] Given that the nature of these benefits is largely in the form of a risk that is reduced, a short discussion of risk is necessary to properly understand these benefits.

Section 3. Risk

Risk and the communication of risk have received increasing attention in recent years. Discussion ranges from the assessment of risk to its communication and management. Risk is defined as the probability of occurrence of some specific event. This contrasts with the notion of uncertainty where the probability of the event is unknown.[12] In environmental discussions, the event that is suspected to occur with a given probability is usually a human health effect.

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[11]Risk, essentially the probability of an event, will be defined and discussed below.

[12]The classic work on risk and uncertainty, *Risk, Uncertainty and Profit*, was first published in 1921 by Frank H. Knight, (repr., New York: Harper & Row, 1965).

3.1. Risk Assessment

A formal risk assessment estimates the relationship between exposure to a substance and the incidence of some disease (e.g. cancer), and thus is based on scientific data.[13] Although risk assessment is grounded in scientific observation, the process is not without controversy. An increasing ability to detect ever smaller amounts of pollutants can change "clean" water at one point in time to contaminated water a decade later. Problems that were supposedly solved become problems once again. In addition, there may or may not be thresholds below which exposure is safe or, alternatively, a no-effect level of exposure may not exist. Finally, in human health risk assessments there remain questions regarding the extrapolation of dose-response relationships from animals to humans, and further, from high dose to low dose effects.

Despite the problems inherent in risk assessment, a formal risk assessment is the first step in the process of managing and communicating risk effectively. The more accurately the scientific community can define threats from pollutants, the more the process of dealing with the threats can be based on accurate assumptions of risk.

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[13] It should be noted that this science is far from exact and this is particularly true in the area of carcinogenesis. As William D. Ruckelshaus, former Administrator of EPA put it, "Science is only orderly after the fact; in process, and especially at the advancing edge of some field, it is chaotic and fiercely controversial....And even if we could somehow get a group of scientists to endorse a consensus position, it would be, in the first place, only tentative and subject to revision with the arrival of new discoveries; and in the second place, it may be entirely wrong." ["Risk, Science, and Democracy," *Issues in Science and Technology* 1, no. 3 (Spring 1985): 24.]

This formal view of risk, however, does not necessarily reflect the way risk is viewed by the layperson.

3.2. The "Reality" of Risk and the Risk From USTs

Integrating risk assessment and benefits analysis may be difficult due to the broader concept of views of risk held by the public rather than more restricted, and likely more accurate, views of risk held by experts. The formal concept of risk and its characterization does not necessarily reflect the public view of risk. On the one hand, experts tend to evaluate risk in terms of estimates of annual fatalities. Lay people, on the other hand, define risk not only by fatal consequences but also by other perceived characteristics such as voluntariness of exposure, familiarity, control, catastrophic potential, equity (of both risks and benefits), and level of knowledge.[14]

This difference in perception in the context of USTs is well illustrated by a study published by EPA in 1987 that conducted an overall assessment of environmental problems, including an evaluation of risks from storage tank[15] releases.[16] The study evaluated risks ranging from radon to global warming; in all, thirty-one separately defined divisions were identified in the entire group of environmental concerns. Each of these segments were ranked on the basis of risks of

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[14]Paul Slovic, "Perception of Risk," *Science* 236, 17 April 1987, 283.

[15]Includes tanks above, on and under the ground.

[16]Environmental Protection Agency, *Unfinished Business: A Comparative Assessment of Environmental Problems*, February 1987.

cancer, risks of non-cancer health effects, risks of ecological effects and risks of welfare effects (property). Risks resulting from releases from storage tanks were considered to rank relatively low in all areas: cancer risks were assessed at less than one annually; non-cancer health risks were considered to be small given the sensory thresholds of the contaminants; ecological effects and welfare effects were both considered to be low and of local impact. Yet despite these considerations, the public was regarded as ranking this as a moderate[11] risk, not as low a risk as the experts had selected. The public's rich perception of risk, in addition to contributing to a possible misplaced emphasis of public policy, can have an impact on some of the methods of estimating the willingness to pay of the consumers for the benefits obtained from remediating UST releases.

Section 4. An Economic View of Benefits

In economic analysis, a benefit to a consumer is roughly defined as the satisfaction, or utility, received from the consumption of a good or service. The degree of benefit or the level of satisfaction is typically determined by measuring a consumer's willingness to pay (WTP) for the good or service because actual utility levels are unobservable. Summing the WTP of all consumers yields a measure of aggregate WTP that captures the total benefits for a proposed good or service. Using this framework, the value of changes in the produced output of goods and services can also be evaluated; benefits that are derived from changes

[11]Three rankings for risk were offered: high, moderate and low.

in output, assuming the subsequent consumption of the goods and services by the consumer, can be examined. Further, a reallocation of resources in order to produce an alternative mix of goods and services can be evaluated by examining the change in aggregate WTP from one output mix to another. An increase in aggregate WTP would signify an increase in benefits, while a decrease would indicate a reduction in benefits. Thus, through an examination of WTP it is possible to evaluate the benefit of changes in a good or service.[11]

Ideally, the benefits described above that can be obtained from reducing the damage caused by UST releases can be measured by WTP as well. However, given the nature of the benefits of UST contamination prevention and remediation, methods of evaluation providing alternatives to price signals from market activities must be relied on to determine such value.

4.1. Possible Measurements of UST Damages Avoided

In terms of risk reduction, the potential benefits listed above may not be observed directly in market situations; however, economic analysis provides some methods by which these benefits can be measured indirectly. While extensive analysis has not been undertaken in this

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[11]An economic concept closely related to willingness to pay that does include cost is that of consumer's surplus. Consumer's surplus is the difference between what an individual is willing to pay for a good or service and that amount the person is required to pay. Although this concept is often used in economic evaluations of changes in the allocation of resources, the changes being evaluated here involve externalities and the reduction of risks, none of which are measured in markets in any formal sense.

study, such means are available. The goal of these indirect methods continues to be the measurement of the willingness to pay of the consumer for intangible goods such as clean air or water.

Indirect market models are a means that can be used to estimate the benefits of a given policy. These particular models focus on the existence of an assumed association between a non-marketed good and a marketed good. For example, hedonic models may use property value to evaluate environmental quality by assuming that the environmental amenities, such as clean air and water, are attributes of the site and therefore are included in the value of the property.

Using hedonic modeling methods, it may be possible in the case of underground storage tank releases to examine the property value of pieces of property before and after the discovery of a release. A number of observations of such properties may provide evidence on probable property value loss when an UST release occurs. One problem with this approach would be the diversity of sites that can occur and the financial arrangements that may or may not be made prior to the release that would assure restoration of the property. These arrangements could be reflected in property value as well. Another possible evaluation could be done on the basis of property values of UST locations and similar properties without tanks located on them. Anecdotal evidence suggests that property values are beginning to reflect liability concerns of the property. Some owners are asked to clear properties, not only of contamination that may be present, but also of any liability for the contamination that may occur, and to do so prior to any property transaction. In the purchase of land, potential

buyers are often more concerned with what is under the ground than what is on top.

Contingent valuation surveys have also been used to value goods or services that are not priced in a market. These are surveys conducted to ask individuals to "value" particular goods or services, often asking what the person would pay to acquire the good or service and what they would accept to give up use of the good or service. In the case of USTs, there are a variety of media (e.g. soil, groundwater) that can be contaminated at any one UST site, and the specific media affected will vary from site to site. Contingent valuation surveys used to value those contaminated natural resources would need to be conducted so as to extract the value of the resources on a media by media basis. The total value of avoiding the contamination found at an UST site would be a combination of the determined media values. To evaluate the possible media affected as the result of an individual UST release, site specific information on, for example, the hydrogeology of the area may allow a reasonable estimate to be derived. However, the estimate for any individual site would be of questionable usefulness in an effort to estimate the value of all natural resources contaminated by all UST releases. With historical data such as is reported in Table 1, it may be possible to use contingent valuation surveys along with the historical data to evaluate the overall impact of UST releases on the environment.

Damage functions have been used as another means to evaluate benefits. These functions attempt to measure the physical effects of environmental degradation that are associated with specific patterns of

pollutant exposure. Damage functions operate under the premise that there is a technical relationship between environmental pollutants and environmental degradation. Thus, estimating physical degradation can result in a measure of total damages. In the UST case there are many different environments that USTs operate in and it is unlikely that it would be feasible to try to establish a universal "damage" function. While a relationship may be roughly established between the source of the release, the amount of the release, and the damage resulting, a host of specific factors would need to be included to determine the full extent of contamination from any single release. Factors such as the permeability of the soil, the depth of the water table, hydrogeology of the area, proximity to drinking water sources, presence of nearby structures or infrastructure as well as seasonal concerns (such as temperature and rainfall) would require consideration. Some of this information is currently available and predictions of the damage caused by an UST release may be possible for the impact of a single release in some areas of the country. However, it is not feasible to use this approach to determine a composite damage function that could predict the damage caused by all UST releases in a given period of time because of the diverse nature of the releases and the lack of information on specific factors determining the extent of damage caused by releases.

Recreational areas have been valued by estimating travel costs for populations visiting the areas. The analyst estimates willingness to pay by making inferences that those costs incurred to travel to the recreational area are the least cost the visitor is willing to incur to visit the area. Specifically, the analysis identifies particular areas

at given distances from the natural resource, the population of those areas visiting the resource as a percentage of the population of that area, and an estimated cost per visit to the resource. With this information a willingness-to-pay curve can be estimated; the relationship that exists between the cost per trip and the visits as a percentage of the population. The area under such an estimated curve would approximate the total direct social benefits of the natural resource.[19] Such values could be used as a proxy for some of the natural resources that may be damaged as a result of an UST release. Some natural resources affected by UST releases could be valued by this method; however, most existing studies have valued resources considered to be natural treasures, such as the Grand Canyon. Travel cost may not be an appropriate proxy for streams or ecosystems located in urban areas where such costs would be low for customary users.

Two values have been identified as being particularly difficult to quantify although perhaps some form of contingent valuation could be used to obtain the values. First, the "options value" is derived by assuming there is a willingness to pay on the part of those who do not anticipate using a particular natural resource in the near future but are aware that they may, at some time in the extended future, desire to use the resource. There may be options value to be included in the consideration of costs of UST contamination. Recall that groundwater not currently used for a drinking water source may be used at a later date. If this option to use the water in the future has value it should

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[19]E.J. Mishan, *Cost-Benefit Analysis: An Informal Introduction*, 4th ed. (London: Unwin Hyman Ltd., 1988), 318-321.

be considered in the enumeration of benefits. Second, there may be an "existence value" attached to an area or resource, even though a resource will not be used by a particular individual. A positive willingness to pay for preservation of the area arises because people are interested in preserving the value so that the resource is available to the entire nation or even to humankind in general.[20] In the UST case there may be some individuals who would be willing to pay to avoid damage to some ecosystems with which they might never come in contact.

Valuation of human life, making allowances for loss of life or limb, has also been done through economic analysis. Given that instances of both illness and loss of life have been documented as resulting from UST releases this value should be included in the potential benefits from reducing releases as well. Several methods have been used to value human life. One method values the loss of life by the "economic" worth of the person's life: the discounted present value of the individual's expected future earnings. Another method is one of calculating the discounted present value of the losses accruing to others over time as a result of the individual's death. A third method involves calculating the loss to society from the loss of potential earnings, or rather, spending, to society as a whole. A fourth and unrelated tactic for valuing life uses the insurance principle. This method uses the premium that a person pays along with the probability of death as a result of engaging in a particular activity to calculate the value a person places on his or her life.[21] Finally, the value of

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[20]Mishan, 322-323.

[21]Mishan, 330-332.

human life has been estimated by the value an individual places on risk avoided, or alternatively, the compensation that must be paid to that person for exposure to a particular risk.

The above methods do represent possible ways that the benefits from reducing UST releases and remediating contamination can be valued. However, this valuation assumes that the reduction in the probability of damage, i.e., the damage that can be avoided, is known.

Section 5. Conclusion

The analysis of benefits associated with a reallocation of resources yields a measure of utility to be gained (or lost) from the change. Benefits can be observed through changes in market values and through changes in non-market values (intrinsic) values for the individual affected by the reallocation. In the specific case of UST releases, gains can be obtained through the remediation of contaminated resources. Most of the benefits to be obtained through UST remediation efforts are difficult to quantify because market prices are not available. However, as has been demonstrated in this chapter, a qualitative assessment of the benefits allows the analyst to grasp the potential range from which benefits can arise. Table 3 summarizes the benefits and possible means to value those benefits that can be derived from the cleanup of UST releases.

As can be seen from Table 3, no individual source of information or approach for gathering information would result in a comprehensive measure of benefits. Therefore, a qualitative approach will have to

Table 3. Summary of Evaluation Methods

Potential Damages Avoided	Degree[1]	Means to Value Damages Avoided[2]
A. General Impacts		
Soil contamination	H	Possibly ecosystem values[3]: contingent valuation; travel cost
Groundwater contamination	M	Value of the aquifer; contingent valuation; alternative uses
Surface water contamination	L	Contingent valuation; travel cost[4]
Air contamination	L	Hedonic valuation[5]; contingent valuation
Other[6]	L	
B. Specific Impacts		
Water supply contamination	L	Cost of substitutes (alternate water supply); contingent valuation
Human health effects	L	Historical evidence/data; contingent valuation
Combustible fumes, fires, explosions	L	Historical evidence/data; insurance[7]
Plant life[8]	L	Travel cost; contingent valuation
Aquatic life	L	Travel cost; contingent valuation[9]

[1] Relative likelihood of an UST release resulting in the impact: high, medium or low. The degree of impact is determined by the percentages reported in Tables 1 and 2; H = greater than 50 percent, M = 25 to 50 percent, L = 0 to 25 percent.

[2] These methods attempt to value the opportunity cost of the media that are affected by UST releases.

[3] Although there may be some value at looking at ecosystem values, these methods do not necessarily value the soil below the surface of the ground where the majority of contaminated soil would be.

[4] The value of recreation areas could be a source of information.

[5] Some hedonic studies evaluating property value differences in areas with differing air quality have been undertaken and may be a source of information.

[6] Includes sewer lines, pavement, basements and electrical conduit/vault.

[7] It is possible that some insurance information may be of value in determining the value of losses from these sources.

[8] It may be difficult to determine the value of plant life as it is so broadly defined. There may be some proxy that could be identified such as the value of grazing land if the plant loss is comparable or perhaps the value of crops if the plant life lost is of some harvestable value. The methods listed would likely to be able to evaluate only the general aesthetics of plant life in the context of a larger setting (i.e. wilderness area, city park).

[9] Value of recreational fishing areas may be helpful in this determination. However, the value of the experience of the recreational fisherman may be not only the fish that he catches but also the natural surroundings he enjoys as well.

suffice in the examination of these benefits. In a more narrow investigation, and more likely a regional-based investigation, of UST activities any of the above approaches could provide ample data for more definitive results.[22]

[22]However, as is usually the case, the more specific the results the more difficult it is to generalize those results beyond the context of the circumstances from which they were gathered.

CHAPTER 3

ESTIMATION OF COSTS

Section 1. Introduction

Having obtained a better understanding of the potential benefits that may be derived from the cleanup of UST contaminated sites, we now turn to the cost side of the analysis. This chapter will discuss the costs of the various resources that will be needed to clean up releases of contents from USTs.

The full extent of costs of an UST release may not be reflected in the observed market prices for remediation resources; the full cost likely encompasses more than the cost of physical resources that are required for remediation activities. A full cost measure could include environmental degradation that is not remedied by cleanup procedures as well as any psychic costs to residents. Residents may perceive that their health and welfare are at risk from the environmental contamination.[1]

A comprehensive measure of the full cost of UST remediation activities would incorporate all of these costs, including those very difficult or impossible to quantify. Yet, an approximate measure of costs will allow an identification of the order of magnitude of the

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[1] It is interesting to note that, in general, Americans perceive that they face more risk in the present than they did in the past, and that the future will involve greater risks than today. This contradicts the views of professional risk assessors who believe that risks have generally decreased. [Paul Slovic, "Perception of Risk," *Science* 236, (17 April 1987): 280.]

costs. This information can be used to estimate the scarce resources that must be diverted from other uses toward UST remediation activities if such activities are to occur. The focus of this chapter will be those costs that are associated with physical remediation activities that are measurable.

Specifically, this analysis will use a cost simulation to estimate the direct costs of corrective action for all UST releases occurring over the twenty-five year period from 1990 to 2014. The total cost is assumed to be a general function of the number of USTs that are in existence, the percentage that will experience releases and the costs associated with any release. The model assumes the current UST statutes form the basis for actions taken with regard to USTs. In addition, the analysis includes the examination of alternative assumptions influencing these estimates.

Section 2. An Illustration of Costs

The cost simulation, as mentioned above, will focus on the more readily quantifiable costs--the costs specifically associated with remediation activities. An example will introduce the elements of these costs to those readers unfamiliar with UST cleanup activities.[1] After the example, the general and specific methodologies for this analysis will be presented.

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[1]This example was obtained from the EPA Computerized On-Line Information System (COLIS) listing historical information on cleanup operations at a limited number of UST sites. The specific case outlined here is incident number 122.

During November and December of 1988, approximately 5,000 gallons of gasoline leaked from an UST located at a gasoline service station in Vermont. Four unprotected tanks were located at this facility--one of which leaked. The station was located in a residential/commercial district along a busy state highway. The leak was initially detected by smell and was confirmed by inventory records and an external leak detector.

The soil at the site was permeable at a rate of 6-20 inches/hour with the predominant soil materials being sand and gravel. This permeability allowed the released product to travel quickly throughout a widespread area. The groundwater flows toward the southeast from the site with a depth to the groundwater of about 12 feet. The aquifer impacted ranged from 10 to 15 feet, but was non-potable.

Immediate corrective action was taken at the site and adjacent buildings. Three homes and a church rectory were evacuated due to gasoline vapor contamination and the potential danger of explosion or fire. The power to the buildings was also shut off. In addition to the homes, two businesses, a church and a post office were also affected. Soil ventilation systems were installed to decrease the effect of vapor migration. At the site, the leaking tank was emptied and the other tanks were tested for leaks.

As takes place at any site, this site was studied to determine the characteristics and extent of the contamination. Twenty-five groundwater monitoring wells were installed ranging in depth from 15 to 20 feet. Ten soil borings were taken within that same depth range. In

addition, soil gas analysis was conducted and a hydrogeologic study was performed.

Long-term corrective action included the treatment of groundwater in addition to the soil ventilation. The groundwater was treated using two twelve foot air stripping towers and one 500 gallon activated carbon tank. This system operated for eight months pumping 85 gallons per minute recovering free product and treating dissolved hydrocarbons. Less than 100 gallons of free product was recovered. The ventilation systems were expected to be in operation until all vapors had been removed.[3]

The total cost of this cleanup was $525,000, broken down as follows:

	CAPITAL COST	O & M*	TOTAL
Site Assessment			$ 25,000
Immediate Corrective Action	$ 30,000	$ 20,000	$ 50,000
Long-Term Corrective Action, Soils - includes indoor air	$ 30,000	$ 170,000	$ 200,000
Long-Term Corrective Action, Groundwater	$ 30,000	$ 170,000	$ 200,000
Free-Product Removal	$ 25,000	$ 25,000	$ 50,000
TOTAL			$ 525,000

* = Operation and Maintenance Costs.

The capital costs typically represent the initial cost of equipment necessary for corrective action activities such as bulldozers

[3]At the time the report was submitted to the COLIS system, the vapor ventilation system had been operational for seventeen months and was still on line.

or monitoring systems. Operations and maintenance can include the power for operating and the labor for maintaining a pump and treat system. The first stage, site assessment, includes the engineering and design phase of the operation.

The costs of this particular incident are slightly higher than the typical UST site primarily because of the permeability of the soil and the ability of the contaminant to move fast and far, carrying the contamination off site. Although this is only one illustration, it shows that there need not be an overwhelmingly large spill to precipitate significant cleanup costs. It also demonstrates that the location of the site is a large determinant of the cost of cleanup activities. If there had been no buildings located near this site, the soil ventilation would not have been as critical. Yet, if the aquifer that was contaminated by the released product had been used as a water supply resource the costs would have been significantly higher. An alternate water supply and restoration of the aquifer to drinking water standards would have involved significant cleanup effort.

In this particular case the costs of the cleanup were divided among the parties involved. The site owner was responsible for $10,000, the state petroleum cleanup fund paid approximately $80,000 and the site owner's insurance company, which according to the owner's policy covered up to one million in costs, paid the remainder of the costs.[4]

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[4]This is not an uncommon financial arrangement. The owner is responsible for a specific deductible amount agreed upon in the insurance policy. To assist with coverage of the deductible (or for those uninsured owners), many states have set up trust funds that allow payment (or reimbursement) for some cleanup costs. The distribution of costs among the parties will depend on the insurance agreement and the particular state fund requirements. It is interesting to note that the

Section 3. General Methodology

The cleanup costs associated with releases from underground storage tanks are assumed to be a function of three intermediate estimates (equation below): the number of USTs, the percentage of those USTs requiring cleanups, and the representative cleanup cost per site, with an assumption made regarding the number of tanks co-located on any one site. The estimates have been approximated over a twenty-five year period in five year increments beginning with 1990. This period was chosen based on the deadlines in the current regulations, but assumes some flexibility in the actual completion time.

$$\text{Total Cleanup Costs} = f(N, R, C)$$

where,
N = Number of USTs
R = Percentage of USTs with Releases
C = Cost per Cleanup

3.1. The Intermediate Estimates

The intermediate estimates of the cost simulation are determined using differing methodologies. The specific methodologies will be outlined individually after this brief introduction to the general approaches used for the estimations.

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financial source of state trust funds is often a tax on each registered tank which raises equity questions with regard to the a priori question of who should pay, and the de facto observation of who is paying for the UST cleanups. The financial assurance and trust funds issues may be the focus of further research in the area of UST regulation, however, it is beyond the focus of this present work to examine these issues.

The first calculation to be made is regarding the total number of USTs in existence, over time. The number of USTs is determined as a function of several factors in any one period: marketing strategies and technological changes in the tank industry, replacement and upgrade strategies by firms, and secular growth or decline in the industries utilizing USTs. A general supply and demand framework will be developed to examine the number of USTs in existence.

The second calculation necessary is the percentage of USTs that have had, or will have, product releases associated with them and require cleanup.[5] This percentage is determined as a function of specific tank and pipe characteristics (e.g., protected or unprotected, age, material compatibility, pressurized or suction pumping); installation, maintenance and operational procedures (e.g., fill material, compliance with leak detection requirements); and replacement and upgrade schedules used by firms and enforcement agencies. For this process the USTs are classified by age and by the presence or absence of protection, because both of these factors are significant in predicting the likelihood of a release.[6] The number of cleanups occurring is determined by assigning probabilities of releases to the different classifications of tanks. Because very little empirical evidence is

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[5]No cleanups that occurred prior to 1990 will be included in this estimate; only sites with cleanups occurring from 1990 through 2014 are estimated. Thus, prior spending on remediation activities is not measured.

[6]Not all types of releases are explained by these characteristics; spills and overfills are not affected by the age or the composition of the tanks but rather by operator error. Although protective measures have been adopted in the new technical standards, some spills and overfills will continue to occur.

available on the probability of releases from different tank groups, weights for releases have been developed based on the available insights from published tank release information and from known characteristics of the UST population. The basic assumption is that older tanks are assumed to be more likely to release, as are tanks not protected from corrosion, spills or overfills. These probabilities are assumed not to change over the period examined: i.e., the probability that a protected tank of a given age will release is assumed to be the same in the year 1990 as it is in 2010.

The third and final calculation determines a representative cost of corrective action for a particular release. This cost of cleanup is a function of the extent of contamination, determined by the amount of product released, the hydrogeology of the area, soil characteristics, and other disturbance factors such as the potential for drinking water contamination and location factors of the specific site. The representative cost of cleanup estimate is calculated on a per site basis with an assumption made as to the number of tanks creating any one cleanup site. This cost is based on the direct cost of cleanup of a site; peripheral costs such as third party liability or indirect costs such as psychic costs are not included.

These intermediate estimations and the final calculation of the total cost of cleanup for the period are done for a base case using the UST program as defined in 1990 by RCRA Subtitle I; and then assumptions of the base case that address compliance are changed for alternative scenarios. It should be noted that program changes are currently under

consideration by EPA; however, this analysis does not take these changes into consideration.

3.2. Base Case and Alternative Scenarios

The base case scenario assumes full compliance, both now and in the future, with all UST regulations. Under this assumption, all tanks covered by the regulations are currently registered as required by the regulations; all upgrading or replacement of tank systems will be done within the schedule mandated; and all contamination found in the soil or groundwater in the process of upgrading or replacing systems will be remediated. These are restrictive assumptions that may not reflect reality. It is more likely that not all regulated USTs are registered as required, and that compliance schedules will be delayed due to the resources required for corrective action. Although the remediation resources required at any one UST site may not be large, the potentially large number of sites needing cleanup may cause a shortage of remediation resources in the short run.[1]

For these reasons, the simulation includes three alternative cases that relax the full compliance assumptions to give a more realistic measure of costs. Alternative 1 allows for a greater universe of tanks than represented by current registration data, while Alternative 2

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[1]Such shortages could be regional in nature because of the lack of mobility of some of the remediation resources (i.e., sluggishness in the market). However, it is not inconceivable that there would be an absolute greater demand for the resources than are able to be supplied in the short run (lag time in the production of the remediation resources, e.g., education of a cleanup contractor).

lengthens the time for full compliance from approximately ten to twenty years. The third alternative combines the first two alternatives in perhaps the most realistic case. The lengthened compliance time implies that spills will not be detected as quickly and thus the cleanup costs are likely to be greater. The increased costs can be either the result of more product escaping into the environment or of the fact that the product that was released has the opportunity to migrate further.

The three alternatives examined constitute a sensitivity analysis of two of the basic assumptions of the base case, the results of which illustrate an array of possibilities for the current UST population and potential changes within the population over time. Note that these differing scenarios are not based on changes wrought by policy change but, rather, on different compilations of the data and differences due to behavioral uncertainties and potential outcomes of the present program. The definition of the leaking UST problem and current regulatory cleanup requirements are not in question; thus policy choices do not play an active role in the base case and alternatives.

The base case of the total cost estimate represents a plausible lower bound with respect to the number of USTs requiring remediation and the representative cleanup cost per site, while the percentage of releases determined is in the nature of a most probable or "best" estimate.[1] Given these characteristics of the estimates, the true total cost of corrective action can be expected to lie above the base

[1]The true percentage of releases may lie above or below the derived estimate.

case, and is probably closest to the highest estimate--Alternative 3.[1] However, it is possible that any of the cases could occur; the outcomes must not be considered to bound a range of outcomes in any statistical sense.

Section 4. Data Sources

The primary source of information for the number of tanks in existence and their characteristics is a database obtained from the EPA. The database contains information from an annual survey of USTs conducted by the Office of Underground Storage Tanks (OUST) which collects information from each state on registered tanks, including some characteristics of those tanks.

Probabilities of releases from USTs for various categories of tanks are obtained from a variety of published sources, particularly studies on the causes of releases from USTs.

Cost information used in the estimation of the representative cost of cleanup was obtained from the Energy, Environment and Resources Center (EERC) at the University of Tennessee. The database acquired contains recent survey responses on the cost of UST cleanups by major oil companies, engineering consultants, insurance companies and state UST programs. The database as well as other published materials provide the necessary information for the specific cost assumptions used in the estimation.

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[1] It is true that the uncertainty of the percent releasing and of the cost per remediation action conceivably could result in the total costs being overestimated.

4.1. Discussion of Data

4.1.1. EPA Estimates

According to EPA, approximately 1.75 million tanks regulated under RCRA Subtitle I are currently registered with state UST programs. The latest report from EPA on the number of tanks registered in this country, with individual state totals, is given in Table 4. These estimates are based on a survey of all the states and territories; each reports to the EPA on the number of tanks registered within their boundaries. The most recent survey with available results was completed in 1989. The states completed the questionnaires from June to October of 1989, with the majority of responses completed in June. The national estimates were compiled in December of 1989.

To verify the numbers of tanks reported in the EPA database, all states reporting 50,000 tanks or more were surveyed by phone. The updated numbers for those states and a few other states whose totals were obtained through special contacts are reported in Table 5. The number of tanks verified was only the aggregate number of tanks found in the state and not a detailed listing by age or composition. The majority of the states contacted reported no change or only a slight increase from the total in the EPA annual survey report. Some of the figures reported were a "best estimate" of the individual in the state regulatory agency because exact updates were unavailable. In addition, two states went through definition changes that dramatically changed the

Table 4. Number of USTs by State/Territory (1989)

STATE	USTS	STATE	USTS	STATE	USTS
Alabama	33647	Kentucky	31726	Ohio	70538
Alaska	4954	Louisiana	30718	Oklahoma	25448
Amer.Samoa	50	Maine	24345	Oregon	20979
Arizona	19062	Marianas	70	Pennsylvania	89490
Arkansas	16202	Maryland	29360	Puerto Rico	5902
California	148311	Massachusetts	30482	Rhode Island	6381
Colorado	21816	Michigan	68330	South Carolina	31937
Connecticut	29915	Minnesota	34798	South Dakota	6914
Delaware	5395	Mississippi	23993	Tennessee	38220
D.C.	1935	Missouri	26453	Texas	128424
Florida	74525	Montana	18405	Utah	11057
Georgia	39036	Nebraska	16130	Vermont	4815
Guam	583	Nevada	6363	Virgin Islands	259
Hawaii	4703	New Hampshire	9811	Virginia	60541
Idaho	9387	New Jersey	34004	Washington	30909
Illinois	59646	New Mexico	12370	West Virginia	16290
Indiana	41058	New York	83306	Wisconsin	76728
Iowa	24563	North Carolina	79129	Wyoming	8196
Kansas	18409	North Dakota	6822		
		TOTAL	1752840		

Note: Several states reported 1988 numbers: Arkansas, Florida, Louisiana, Missouri, New Jersey and Texas. The total number of tanks given here differs from the reported full database. Louisiana (30718) and American Samoa (50) were not included in the final total, nor was Ohio updated to 1989 figures (Ohio; 70538, down 4421 from the 1988 report).

Source: Totals are recorded from Material of Construction/Age of UST in Years Matrix compiled by EPA's Office of Underground Storage Tanks from the 1989 Annual Survey of Underground Storage Tanks. December 1989.

Table 5. Updated State UST Totals
From Selected States

STATE	USTS	PERCENT CHANGE
California	148311	0.0
Florida	74525	0.0
Illinois	60000	0.6
Michigan	69398	1.6
Minnesota	36453	4.8
New York	91882	10.3
North Carolina	65889	-16.7
Ohio	70538	0.0
Oklahoma	28000	10.0
Pennsylvania	89490	0.0
Tennessee	41174	7.7
Texas	132304	3.0
Virginia	61760	2.0
Wisconsin	58000	-24.4

Note: California, Pennsylvania, Ohio and Florida totals received were identical to the reported 1989 survey results; estimates were given by Illinois, Oklahoma and Wisconsin; and decreases in North Carolina and Wisconsin were due to definitional changes in the tanks registered.

estimates from those stated in the last EPA report. Given the minor and rather inconclusive nature of the observed differences between the individual state contact-reported numbers and the numbers that the EPA published, the figures obtained from the 1989 Annual Survey of Underground Storage Tanks will be used in the base case for this analysis.

The OUST database reports the number of USTs in a given tank age group or tank volume group according to several characteristics. Reported characteristics include: the material of construction, contents, the existence of corrosion protection, piping, and ownership. Given the importance of construction materials and the presence or absence of protective measures in determining whether any action is taken on an UST, two matrices constructed by EPA will be used extensively in this estimation: the "Material of Construction by Age" ("Construction") Matrix and the "Corrosion Protection by Age" ("Protection") Matrix. Each contains information relevant to the action taken on USTs and is, for the most part, available on a state-by-state basis. The information in the ownership and piping materials matrices would have been useful in this study, but was too incomplete to be of significant value.[10] Other information correlated by volume was not used because no relationship appears to exist between tank volume and the size of a product release.[11] A small hole is as likely to occur in a small tank as in a similarly constructed large tank; and the size of

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[10]Many states did not report the ownership and piping materials information.

[11]EPA, *Summary of State Reports on Releases from Underground Storage Tanks*, 5-9.

the hole will largely determine the size of the release. In addition, the volume of the tanks will have no influence on releases caused by spill or overfills, or from releases originating from piping.[12]

4.1.2. Limitations of the EPA Data

Definition problems are a source of uncertainty in the estimate of the number of tanks covered under the UST regulations. Not all states have defined the population of tanks they will regulate in the same fashion as the federal government: some states regulate more stringently, some observe the same delimitations, and some, in the interim, regulate less stringently than the federal government. For example, New York is one of several states that includes home heating fuel tanks in their state UST regulations.[13]

The amount and detail of data to collect on the USTs are also left to each state to determine, thus introducing potential for great differences in the information available from various states. Several states have extensive data collection and management systems, while other states have just begun the process of establishing their UST

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[12]The size of a piping release is more determined by the use of pressurized or suction pumping than any other factor. Pressurized piping can essentially force the contained product out a hole in the piping. Suction pumping, which is based on gravity for product pumping, is far less likely to be involved in a major UST release.

[13]According to CRM Associates (the EPA contractors conducting the UST survey) the 1990 Annual Survey of Underground Storage Tanks has attempted to correct for definitional differences among states. The survey will distinguish between those tanks falling under federal regulations and those covered by the state definitions. The 1990 Survey will also clarify other tank classifications as well, including ownership of the tank. This survey is not yet available.

programs. About half of the states use the "Revelation" database management system (UST-DBM) developed by EPA contractors for use by individual states. For those using the UST-DBM system the annual survey of USTs is extracted directly from the system; and those states have very little difficulty in generating the numbers requested by EPA. Other states who do not yet have an extensive information system required to control the data and to generate the report to OUST identifying the number of tanks in the categorical breakdowns requested will have difficulty in reporting the numbers.[14]

Another potential problem with these data may be caused by the data entry done by each state. As mentioned, not all states have fully staffed and functional UST programs, thus state program officials may find it difficult to keep their databases current. In the annual OUST survey each state estimates the percentage of data entry that has been completed. Estimates reported range from 10 percent to 100 percent completion. It was initially assumed that these figures could be used to generate a more accurate total of the current number of tanks; i.e., if 50 percent of the data had been entered, the tank numbers could be doubled to reflect the actual number of tanks in existence. However, according to the EPA contractors who conduct the annual survey, the

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[14]The EPA contractors who serve as technical support for the OUST tank survey of the states, CRM Associates, report that as of 8/13/90 there were twenty-three states on the UST database management system. These are: Alaska, Arizona, Arkansas, California, Colorado, Delaware, Hawaii, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Montana, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, South Dakota, Tennessee, Utah, Virginia, and Wyoming. At that time, six states were in the process of converting their systems to the UST-DBM system and were to be completed within the next six months: Georgia, Idaho, Kentucky, Minnesota, New Jersey and West Virginia.

reported figure is a very subjective estimate of the data entry completed. The estimate of completion may also be misleading because states may interpret the raw data yet to be entered into the system differently. One state official reported several thousand forms to be entered into the system; yet, most of those were corrections to tank registrations already on file. In addition to the difficulty in interpreting the percentage completion, many states did not provide this figure. For these reasons, the percentage of completion figures are not used to adjust the data.

Despite the weaknesses of the EPA database, it remains the best available source of the estimated UST population and is used as a basis for this study for two of the three intermediate estimates. Trade associations in both the UST and the motor fuel industry were consulted to determine the existence of an alternative detailed estimate of the universe. The EPA database was the only source recommended. After investigating other published estimates (Table 6), it was determined that only rough estimates of the population are available elsewhere.[15]

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[15]No other sources have been identified to have reached estimates in a demonstrably superior fashion. These other estimates did not have the total number of USTs identified on a state-by-state basis, nor were specific tank characteristics of the population provided.

The 1990 survey (results yet to be released) will try to differentiate the tanks federally regulated versus those regulated under state definitions and address several of the concerns about the EPA database. The survey will also attempt to further define the owners of the USTs.

Table 6. Published Estimates of the Universe of USTs

	SOURCE					
	DOE	RIA Technical Standards (1)	EPA Database	RIA Financial Responsibility	Federal Register Proposed Rule	UMFST Survey
Total USTs	2,345,000	1.7 million	1,736,628 (2)	1,626,187	1,381,000	796,000 (3)
Total Facilities		"over 500,000"	276,213 (4)		512,000	326,000 (5)
Retail Marketers	800,000	676,000	942,816	791,300	676,000	
Nonretail/ Industry	625,000 (7)	651,000	(6)	642,070	472,000	

(1) Categories defined are more appropriately defined by contents than by owners. Aside from those tanks listed 330,000 store used oil, and 54,000 store chemicals.
(2) Number reported for tank records processed.
(3) A range of 503,000 to 1,090,000 was given.
(4) Number of facilities reported with both readable and unreadable records for the entire database.
(5) Farms: 79,000.
(6) Private and corporate retail and nonretail marketers are reported together.
(7) Assumes fleets would account for over 300,000 tanks; given one UST per 30 vehicles in a fleet.

Table 6. Continued

	SOURCE					
	DOE	RIA Technical Standards (1)	EPA Database	RIA Financial Responsibility	Federal Register Proposed Rule	UMFST Survey
Military	20,000				49,000	
Government			136,393	147,000	98,000	
Federal			26,253	85,000		
State			110,140	(8)		
Local			(9)	62,000		
Agriculture	900,000 (10)		45,817	86,000	158,000	
Material	150,000 protected; >90% of steel tanks - no protection	84% bare steel 16% protected	70% - no corrosion protection		80% - unprotected steel	11% - fiberglass reinforced plastic

(8) Federal and State governments are reported together.
(9) Local and State governments are reported together.
(10) Assumes 50% of all farms are equipped with tanks; includes tanks less than 1100 gallons.

Sources: *DOE* - Department of Energy. "Technical and Economic Data Development Concerning the LUST Program," U.S. Dept. of Energy, Office of Environmental Analysis, February 1987; *RIA Technical Standards* - "Regulatory Impact Analysis of Technical Standards for Underground Storage Tanks," U.S. EPA/OUST, August 24, 1988; *EPA Database* - Information collected in the Annual Survey of Underground Storage Tanks; *RIA Financial Responsibility* - Regulatory Impact Analysis for Financial Responsibility Requirements for Petroleum Underground Storage Tanks, U.S. EPA/OUST, October 1988; *Federal Register: Proposed Rule* - Federal Register, 40 CFR Part 280 and 281, Underground Storage Tanks, Proposed Rules. Volume 52, Number 74, April 17, 1987, pp. 12662-12864; *UMFST Survey* - "Underground Motor Fuel Storage Tanks: A National Survey," U.S. EPA/OPTS, May 1986.

4.1.3. Compliance

Although reporting and registering USTs has been required since 1986, the number of tanks that has actually been counted is not a meaningful estimate of the total universe of USTs. For example, the Pennsylvania Department of the Environment recently gave an estimate of 15 percent to 30 percent as the percentage of the total number of tanks in the state actually registered.[16] New York financed a study to determine the extent of compliance in the state by tank owners; the results of the study showed a 65 percent compliance rate.[17] Although these estimates differ in the percentage of tanks registered, the numbers provide evidence that there is significant noncompliance with the UST regulations among tank owners and operators. When state officials were asked informally to make an estimate of the percentage of tanks registered in the state, those individuals who did venture to guess reported anywhere from 40 percent to 80 percent compliance. One state official reported that construction crews and concerned citizens were daily reporting findings of "ghost tanks"--abandoned tanks about which nothing was known--that have yet to be counted; the official would not offer an estimate as to the number of those tanks yet to be discovered.

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[16] *Environment Reporter* 20, no. 51 (20 April 1990): 1983.

[17] New York State Department of Environmental Conservation, "Petroleum Bulk Storage: Comprehensive Compliance Plan and Compliance Survey" (14 November 1988), 1.

4.1.4. EERC Survey Estimates for Cleanup Costs

The 1990 survey conducted by investigators at EERC collected information from a cross-section of groups involved in UST cleanups. Responses to the survey came from three principal groups: engineering consultants, major oil companies, and state UST programs.[11] The database includes more than 75,000 sites representing a wide geographical area and various levels of cleanup complexity. The data set was designed primarily for estimating an average UST cleanup cost estimate.[11]

The database contains information on UST cleanups initiated or in progress between 1985 to 1990. Information was collected on characteristics of both the tank systems and the owners of those systems. The database focuses on five categories of cleanup, and each category represents increasingly higher levels of contamination, from environmental assessment only, to simple soil contamination, complex soil contamination, floating free product on groundwater, or at the extreme, the dissolved phase of groundwater contamination. These

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[11] Information was also requested from pollution liability insurance companies and EPA regional offices. A total of 217 surveys were mailed to the following: 120 engineering consultants, 20 oil companies, 55 state and territorial UST programs, 10 EPA regions, and 12 insurance companies. A total of 84 completed surveys and 15 other responses (ineligible or scantily complete) were received for a response rate of approximately 50 percent.

[11] D.S. Bueckman, S. Kumar and M. Russell, *Underground Storage Tanks: Resources Required for Corrective Action*, (University of Tennessee-Knoxville: Energy, Environment and Resources Center, December 1991), 60-70.

categories are defined below in a detailed discussion of the representative cost per cleanup estimation.

The database information suggests that the typical UST site is owned by a retail motor fuel marketer. The tank is likely to be composed of carbon steel and to contain a petroleum product. Release of contents is probably due to corrosion, spill or overfill. The average number of tanks per site is 3.3.

The cost data collected is assumed to represent both small and large sites with a variety of cleanup technologies. The database includes sites that range from less than ten to a million cubic yards of soil that have been remediated and from one hundred to one hundred million gallons of water remediated. Primary technologies used for the remediation of soil contamination were excavation and off-site disposal, soil venting, and on-site aeration. Remediation technologies used for free product and groundwater contamination were primarily pump and treat systems utilizing air stripping and/or carbon adsorption.

4.1.5. Limitations of the EERC Database

The EERC database combines the survey responses of several different groups of respondents. This may cause some misconceptions about what the data actually represents; however, statistical tests did not show the various groups' responses to be significantly different from each other in any of the cost categories examined.[20]

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[20]Bueckman, Kumar and Russell, *Underground Storage Tanks: Resources Required for Corrective Action*, Appendix B-3.

A large number of the survey responses, and those reporting the highest average costs per cleanup, were obtained from engineering consultants who are affiliated with hazardous waste cleanup. Although most sites reported in the database are petroleum sites, consultants who routinely deal with hazardous cleanups may experience higher costs in some areas than a consultant who works specifically with the remediation of petroleum UST releases. For example, fixed costs allocated across all cleanups performed by the firm that are special precautions necessary for hazardous cleanups only may cause an upward bias of the cost figures.

Section 5. The Number of USTs

Section 5.1. Methodology

The number of USTs in existence at any point in time is a result of the supply and demand for USTs, as determined by the buyers and sellers of the tank systems. The UST systems are essentially capital equipment and the demand and supply of USTs is contingent upon factors affecting capital equipment purchases such as the expectations of general economic conditions. Specifically, the supply function of an individual supplier of USTs can be generalized as being determined by:

$$S_{USTS} = f(E_E, R, T, P_S, P_{USTS}, P_I)$$

where,

E_E	=	Expectations of growth for the industry
R	=	Regulations affecting product characteristics
T	=	Technology and production capabilities
P_S	=	Price of substitutes

P_{USTs} = Price of USTs
P_I = Price of inputs to production (labor, raw materials)

In this analysis it is assumed that the regulations have been changed and the response of the seller of USTs to the change in regulations has already taken place. Technology and production capabilities are assumed to be constant over the period examined as well as are the prices of substitutes and the prices of inputs to production. The seller of USTs expects growth in the industry to remain high for a decade or two to meet enhanced replacement demands and then begin to taper off to a slower growth rate that reflects the general growth of the economy. A positive relationship is assumed to hold between the price of USTs and the supply of USTs thus the market supply curve for USTs slopes upward and to the right. Given the nature of the supply function, there are no anticipated shocks that will shift the supply curve for USTs causing a change in the UST equilibrium.

Sellers of USTs may differ in firm size, in the type of USTs they sell (particularly by volume and construction, e.g. steel), and by area or region of operations. Despite these differences, the individual supply curve as outlined above is representative of the typical seller of USTs. Therefore, the single firm supply function can be horizontally summed over all sellers of USTs to yield the market supply function.

By contrast, the demand for USTs is more difficult to generalize because the consumers of USTs consist of more than one type of user. Recall that USTs are utilized by both public and private, large and small entities. The demand for USTs generated by each of these types of

firms will be different. In general, the demand for USTs for a single buyer can be considered a function of many factors. Specifically,

$$D_{USTS} = f(P_{USTS}, P_S, P_R, U, E_E, K_\varphi, R, T, M)$$

where,

P_{USTS}	=	Price of USTs
P_S	=	Price of substitutes
P_R	=	Price of related goods and services
U	=	Nature of tank use (necessity/convenience)
E_E	=	Expectations of general economic activity
K_φ	=	Present state of the capital stock
R	=	Regulations
T	=	Tank technology
M	=	Marketing strategies of sellers

Like the supply side, this analysis assumes that technology is constant and that all regulatory changes have been made; for example, it is assumed there are no changes in fire protection codes. The costs of substitutes such as aboveground storage tanks is also assumed not to change. Management strategies are assumed not to change within each estimable time period. Expectations of future economic activity are assumed to reflect the general growth of the economy.[21] The present operational state of the USTs is assumed to be determined by the composition and age information provided by the EPA data and thus is included in the analysis in a systematic fashion across all owners.[22] A negative relationship is assumed to hold between the price of USTs and the demand for USTs thus, the market demand curve for USTs slopes

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[21]Such expectations could incorporate regional differences; some areas may be experiencing sluggish growth while other areas may be experiencing more active growth.

[22]Note that all USTs are assumed to have a twenty to twenty-five year life span.

downward to the right. However, differences in the nature of UST use segments this market. Each segment represents a different type of user with corresponding differences in elasticity of demand.

Aside from the increased cost of purchasing an UST system, the costs related to operating the system (i.e. P_R, the price of related goods and services) have increased dramatically as well with the onset of the UST regulations. Costs have increased due to several requirements placed on UST owners: tank tightness testing, demonstrable financial responsibility, required tank protection measures, etc. The financial responsibility requirements have proven to be a particular burden, with many owners unable to afford the upgrades necessary to obtain insurance or even to afford the insurance itself.[23] EPA estimated that costs increased by approximately $7,500 per tank for the component replacements and upgrades, with annual system testing costs adding close to $2,700 per tank to that total. Additional costs for the attainment of financial assurance were estimated at $1,152 per UST.[24] Thus, the total additional costs amounted to just over $11,300 for each

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[23]Studies have been done on the availability and affordability of insurance for UST owners. See: Petroleum Marketers Association of America, "Petroleum Marketers Association of America Underground Storage Tank Insurance Survey" (1 February 1990); Petroleum Marketers Association of America, National Association of Convenience Stores, and the Society of Independent Gasoline Marketers of America, "Joint Survey of Gasoline Marketer Financial Responsibility" (13 February 1990); Department of Budget and Fiscal Planning, *The Report of the Governor's Task Force on Underground Storage Tanks* (State of Maryland, January 1990).

[24]Environmental Protection Agency, Office of Underground Storage Tanks, *Regulatory Impact Analysis of Technical Standards for Underground Storage Tanks*, 4-4 through 4-8; *Regulatory Impact Analysis for Financial Responsibility Requirements for Petroleum Underground Storage Tanks* (October 1988): 4-13. All per tank costs reported in these documents were discounted at 3 percent.

UST.[25] Within the framework defined above, these costs would constitute an increase in the price of related goods and services. This increase would be expected to cause a decrease in overall demand for USTs.[26]

Finally, the nature of tank use differs with type of ownership. As was previously noted, the owners of USTs are a diverse group; they include retail motor fuel marketers, fleet owners, farmers, construction companies, delivery services, school districts and police and fire departments (municipalities). Although all of these owners demand USTs, some of these owners will use the UST as an integral part of the production of their good or service while others will use the UST in the production process in a peripheral support role. Within this framework, the owners, their tank use, and incentives, largely determine the number of USTs that will be demanded. These factors will be addressed in the following section.

This analysis looks at the supply and demand for USTs; however, it could be argued that what should be examined in this analysis is not the number of USTs but the demand and supply of UST services.[27] With such

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[25]The system testing costs and the financial insurance costs would be incurred annually for every year the UST is in operation or until it is properly `closed' according to regulations.

[26]If the UST owner can shift the costs forward to consumers or backward to labor or other inputs, the owner will not bear the full burden of the increased costs. However, precisely how these costs will affect retail fuel consumers is uncertain.

[27]It could be argued that the consumer who buys gasoline at the pump has a demand for UST services, however, this analysis differentiates between the demand for gasoline and the demand for UST services. The demand for UST services is created by the firm using the UST as an input into the production of another good or service (i.e. retail fuel). For example, gasoline is the product sold by the retail

a perspective the interesting side of the discussion becomes the supply side. Demand for UST services would remain relatively stable or fall slightly as substitute services are used (e.g. aboveground storage tanks). However, on the supply side the providers of UST services have been affected by the UST regulations that have resulted in significant cost increases for UST operations. The cost increases, both through the cost of technical upgrades and the cost of contamination cleanup, would be likely to force those owners with less secure financial situations out of the market, effectively increasing the monopolistic power of those remaining providers.

Such a perspective provides an interesting, but logical, observation to be made. The UST services that are necessary for the operations of many different types of firms in many different industries may be more efficiently provided by firms specializing in the provision and maintenance of UST operations than by the owners of the firms and industries relying on USTs in the provision of other goods and services. For example, a firm providing UST services could be contracted with to install and maintain UST systems as well as accept liability for any releases while extracting a user fee from the owner of the firm requesting the services. Specifically, a service station owner could enter a contractual agreement for the provision of inventory holding services with another party who would actually own and maintain the USTs. Economies of scale could be achieved in the areas of maintenance,

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motor fuel marketer; the consumer demands the fuel and the marketer, to meet the demand of the consumer, demands the UST services that provide the gasoline for sale. The demand for fuel or for UST services should not be confused with the demand for USTs as discussed previously.

monitoring for releases and soil and groundwater testing procedures. The firm providing the service would have an incentive to properly maintain the system in addition to reducing releases. It is likely that resources would be devoted to decreasing the probability of a release from any source (e.g. spill, overfill, leak).

From both theoretical and practical perspectives, such a business relationship could exist; however, several problems would have to be overcome for successful provision of UST services by such an industry. Most noticeably a moral hazard issue would arise if all liability were to be assumed by the UST provider. Given that the provider of the service is not the user of the service and liability remains with the former, the latter has no incentive to observe those practices best suited to maintain the integrity of the UST system. This would be particularly difficult if the UST provider were liable for lost revenues if the system is unable to perform in a satisfactory manner. This moral hazard issue would need to be resolved for such a relationship to be successful. Difficulty may also arise in the determination of ownership; UST systems are comprised of many components and who would own exactly which parts of the system may become a point of contention. Hypothetically, pumps owned by the retail motor fuel marketer are used to extract stored product from out of the tank which is owned by the provider of UST services. The pump is an integral part of the operation of the UST system; thus, controversy may arise over where one owner's rights begin and another's end. Another difficulty may arise from the fact that USTs are non-mobile capital. They are typically located under pavement or concrete making removal of the system upon termination of

the agreement costly and time-consuming. On the one hand, should the UST provider default on the arrangement, the party purchasing the services has no readily available alternative for the UST services (particularly in the case of the retail motor fuel marketer). On the other hand, if the purchaser of the services were to terminate the agreement, the UST provider would be unable to market those services at another location until a major excavation of the equipment could be undertaken.

Despite these difficulties, it appears that the potential does exist for a private market solution for the provision of UST services. Further examination of this potential is the topic of continuing research and is not a part of the current analysis.

5.2. The Nature of Tank Use by Owners

As discussed earlier, the nature of the tank use will largely determine the incentives of the owner to continue to utilize his own UST or to look elsewhere for the services. For the retail motor fuel marketer, the tanks are probably an essential ingredient to the service provided given current tank technology. The product for sale is held in underground storage tanks, and there are few alternatives to the use of tanks for this storage. Retail motor fuel marketers are typically located in concentrated population areas that are regulated by fire codes; these codes often preclude fuels from being stored above

ground.[28] Substitutes for USTs for these firms will be difficult if not impossible to find. On this basis we would expect the demand for USTs by retail motor fuel marketers to be relatively less elastic than for most other UST owners.

According to EPA, the single largest group of owners and operators of registered USTs subject to Subtitle I are the retail motor fuel marketers. The retail motor fuel marketers are estimated to own one-third to one-half of the current tank population. Approximately 39 percent of the tanks covered by the UST regulations are used for retail motor fuel sales, 38 percent are for storing petroleum products for other uses, and 20 percent are for storing used oil. Only about 3 percent of the regulated USTs are used for storing chemicals.[29]

The retail marketing sector of the universe of UST owners and operators is generally defined as service stations and convenience stores that sell motor fuels. Since 1972 the number of service stations operating in this country has decreased substantially, while the number of convenience stores that sell gasoline has slowly risen over the same period (Figure 5). The net result of the two changes in these retailers is a slight downward trend in the availability of motor fuel retail outlets. It should be noted that motor fuel marketers remaining open have extended their hours of operation and have increased their volume of business.

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[28] Aboveground tanks are being introduced that do meet fire code requirements and may be a viable alternative to underground storage in the future.

[29] EPA, *Regulatory Impact Analysis of Technical Standards for Underground Storage Tanks*, 1-5.

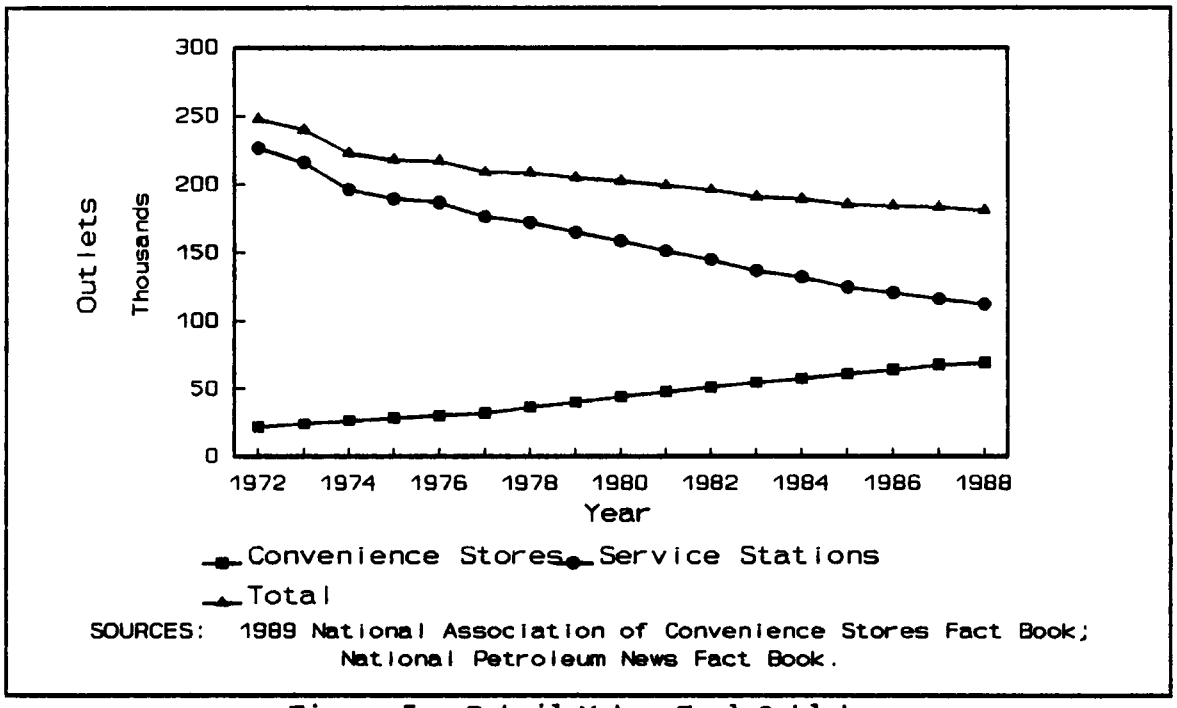


Figure 5. Retail Motor Fuel Outlets

Given the downward trend in retail motor fuel outlets, the present outlook for the industry does not indicate increases in the number of retailers in the near future. There have been no significant stimuli to the market to warrant a reverse in the trend; in fact, uncertainty in the petroleum industry has only risen in the recent past. In addition, it has been reported that the convenience store portion of the marketers may also, for a variety of reasons, have reached a slower growth stage, suggesting relatively little new growth in this portion of the industry.[30]

Other owners of USTs may have a tank more as a matter of convenience than of necessity. Delivery services or municipalities, for example, do not necessarily require outright ownership of their own UST, but can obtain the services that an UST provides through other means.

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[30]Steel Tank Institute, "Tank Talk" 5, no. 10 (October 1990): 1.

In general, less is known about the non-retail motor fuel tank owners and their past activities and present motivations. These owners are a diverse group and are not easily characterized, either by industrial sector or by regulatory impact. Given the increased costs of related services of owning and operating an UST, it is assumed that any firm investing in an UST will examine the costs and benefits of all storage alternatives and may investigate the possibility of obtaining UST services elsewhere. As the costs of owning and operating an UST have increased, the availability of alternatives to UST use will likely also increase. Aboveground tanks are being introduced that do meet fire code requirements and thus may be a viable alternative to underground storage in the future. Given the costs of owning an UST and the increasing availability of alternatives, it is assumed that there will be no significant growth in the demand for USTs by this diverse group of owners. In fact, the less intense tank use on the part of these owners may allow these owners to more easily substitute away from owning USTs in favor of contracting for fuel services.

No significant growth in the demand for USTs is assumed to be evident among retail motor fuel marketers or other groups of UST owners. In addition, other factors suggest that there will be a downward shift in the demand for USTs;[31] thus the equilibrium number of USTs bought and sold would be expected to fall. This conclusion, which indicates

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[31]These factors include the price of related goods and services, and the demographics of the current tank population (almost half of the tank population is over fifteen years old and over thirty-six percent are over twenty years old). Another factor which could potentially influence the downward trend is potential liability concerns, particularly any that may be mandated.

not only no new growth but also a decline in the number of new tanks introduced into each period, forms the basis of the reasoning for the estimated decrease in the number of USTs in existence over time.

5.3. Other Observations on UST Closures

Not all of the decisions on tank closures are yet to be made. Some tank closures were actually made prior to the 1988 UST legislation because most major retail motor fuel marketers were already aware of the underground storage tank leak issue. As early as 1984, the American Petroleum Institute (API) surveyed its member companies to obtain accurate data on the number, type and ages of the tanks held by those companies. The respondents were primarily major and semi-major oil companies, and all reported having leak detection programs already in place, with 83 percent of them having formal replacement and upgrade programs. These programs universally emphasized the replacement of bare steel tanks with protected substitutes. API estimated, based on the survey responses, that the companies had invested a total of over $650,000,000 since 1975, with expenditures increasing on an annual basis at a rate of approximately twelve percent. These outlays had been used to update about 34 percent of the tanks. Unfortunately, no information was collected on the number of tanks that had been permanently closed rather than upgraded or replaced. The projected time table for the upgrading of remaining unprotected tanks was approximately seven to nine years, which suggests that the tank upgrades for these marketers will be

completed by 1993.[32] It should, however, be noted that this optimistic schedule may be somewhat overstated, given the statements by some major companies. These companies indicated that only 20 percent of their tanks, rather than the 60 percent as scheduled, had actually been upgraded by 1986.[33]

Few estimates are available on the number of firms using USTs that may close as a result of the increased protection measures that must be undertaken on tanks; yet the estimates that are available suggest there will be a significant number of closings. The regulatory impact analysis conducted by the EPA on the proposed technical standards estimated the number of closings of both large and small retail motor fuel marketers. These EPA estimates report the percentage of retail motor fuel outlets expected to be driven out of business by the increased costs resulting from the required technical upgrades and corrective action. The analysis showed that the cumulative percentage rate of outlets closing (i.e., closings above and beyond the expected natural rate of exits from the industry) would be as follows:[34]

Firm Size	Year 5	Year 10	Year 15
Large	19%	32%	28%
Small	29%	43%	41%

[32] American Petroleum Institute, "Underground Storage System Survey of the API General Committee of Marketing" (December 1984).

[33] Environmental Protection Agency, Office of Underground Storage Tanks, "State/Local/Industry Practices" (October 1986): 10.

[34] EPA, *Regulatory Impact Analysis of Technical Standards for Underground Storage Tanks*, 7-9 through 7-12. These figures assume no additional increase in revenues will be received by the firms in this time period.

In the first five years, 4 percent of the small firms would exit the industry above the natural number of exits due to the upgrade requirements alone. The corrective action requirements on the other hand will affect both the large and small firms with 19 percent and 25 percent of the firms exiting, respectively, above the natural exits.[35] These results support the contention that the greatest impact on the retail motor fuel marketer population will be seen in the first ten years under the regulations when all compliance deadlines for tank owners have been passed.

A recent study by the Petroleum Marketers Association of America (PMAA) examined this same issue, with similar results. The PMAA surveyed its members to determine the likely attrition rate of its marketers as a result of the new regulations. This study estimated that 26,500 stations would close--half of the stations nationwide whose marketers are represented by PMAA--with the financial responsibility requirements being the primary cause these exits. The report also estimated that almost half, 47 percent, of the non-retail commercial tanks these marketers supplied were expected to close over the same time period.[36]

Because the focus of the present work is on the costs of remediation of UST releases, it is not the number of firms closing that

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[35]After five years under the regulations 4 percent of the small firms will exit due to upgrade requirements and 25 percent will exit as a result of corrective action requirements. This yields the 29 percent listed in the table.

[36]Petroleum Marketers Association of America, "PMAA Survey Results: The Impact of Federal Underground Petroleum Storage Tank Regulations on the Nation's Service Station Population" (January 1989).

is the significant issue, rather, it is the number of USTs closing that is of concern. The percentage rates of UST closures may or may not be directly comparable to firm closure rates, depending on the relationship assumed between firms and the number of USTs they own or operate. If the UST closure rate equals the firm closure rate, the assumption is made that the number of USTs per firm will be the same for those owners who close their tanks as for those owners who do not close their tanks--which may not be the case. Owners who rely on their USTs as a matter of convenience or utilize their USTs only on an occasional basis, first, may own fewer tanks, and second, as discussed earlier, may be more likely to close their tanks, opting to obtain their UST services elsewhere. Those owners who rely heavily on their USTs in the production of a good or service may have more USTs and be less inclined to look for a substitute for their UST services. Thus, the percentage of USTs closing may be less than the percentage of firms closing as a result of the regulations. An interesting result may occur if these observations are correct; as firm closings occur, the average number of tanks per site for remaining UST owners may increase.

5.4. Estimation Procedure

The EPA database of registered USTs--results of the 1989 Annual Survey of Underground Storage Tanks--serves as the basis for the first estimation: the number of USTs in existence over time. The Construction Matrix sets the initial conditions that establish the current ages of the tanks thereby allowing the use of algorithmic

iterations to age the tanks over time. Figure 6 shows the breakdown of age categories used in this process.

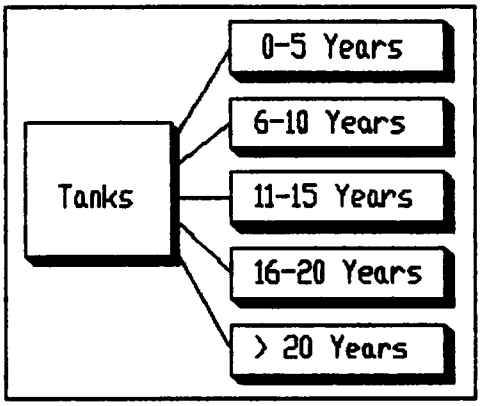


Figure 6. Age Categories for USTs

The simulated estimation begins with the year 1990, (t=0), and all Table 4 values (1988-1989) are attributed to 1990 for the analysis. The estimation is done in five year increments over a twenty-five year period.

As illustrated in Figure 7, at t=0 the total number of tanks in each age group is taken from the database and subdivided into two groups: protected or unprotected tanks. A protected tank is a tank assumed to be in compliance with all four of the protection requirements mandated by EPA: corrosion protection, leak detection, spill protection and overfill protection. The initial characterization for protection is determined by the Protection Matrix, also given in the EPA database. Those tanks listed in the Protection Matrix as protected (cathodic protection, interior lining, FRP and other[31]) and those listed as unprotected (none and unknown) are calculated as a percentage of the

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[31]Acceptable means of protecting USTs from corrosion are outlined in the *Federal Register*, 37125-37129. Cathodic protection prevents corrosion of a steel system by making the surface the cathode of an electrochemical cell by using such means as galvanic anodes or impressed current. Interior lining is an option for existing UST systems (those installed before 12/22/88) to successfully upgrade an UST system. The interior of the tank is coated with a corrosion resistant material. The fiberglass-reinforced plastic (FRP) UST is a system constructed of a material that is resistant to corrosion without steel or other metal support in the construction. Both interior lining and cathodic protection must be monitored or inspected periodically to assure the integrity of the protection.

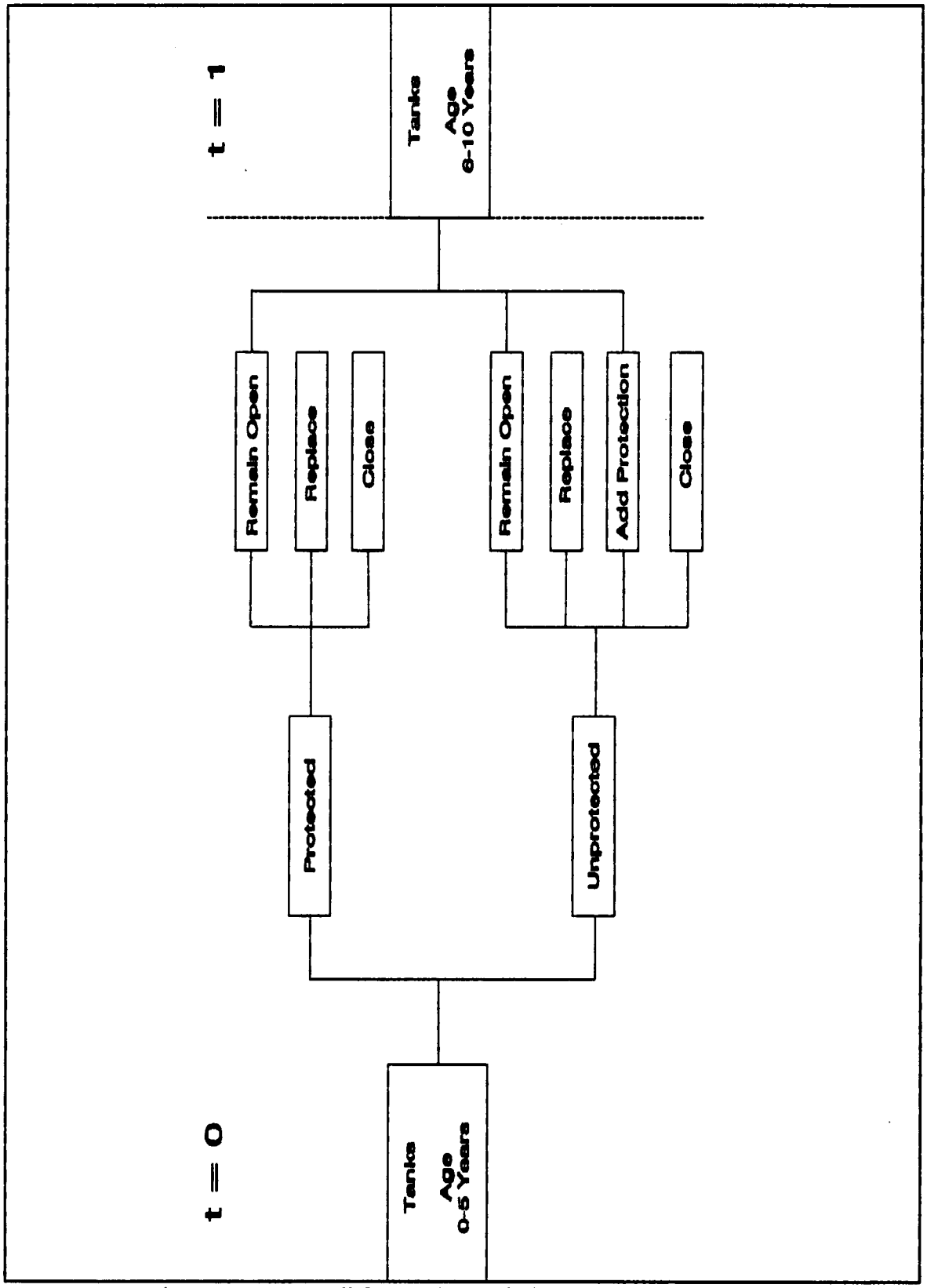


Figure 7. Possible Tank Activity Over One Period

total number of tanks covered in that matrix. The results represent the percentage of protected tanks and the percentage of unprotected tanks in the given age group. Although the entire universe of tanks represented by the Construction Matrix is not covered in the Protection Matrix, there is no reason to believe that a systematic bias exists in those tanks whose protection was not reported. Seven states and three territories did not report any values in the Protection Matrix but did report values in the Construction Matrix.

These corrosion protection percentages serve as proxies for all types of protection and are extrapolated to the full universe of tanks as reflected in the Construction Matrix. Thus, all tanks are considered to be either protected or unprotected. States whose values for the protection matrix were missing were assigned the mean percentage values of those states reporting.

After the tanks are divided into categories of protected and unprotected, the action on the tanks is considered. Protected tanks will either remain open (active or inactive), will close according to formal closure procedures, or may be replaced in the period under examination. An additional option is available to owners of unprotected tanks: they can add protection to the tank, redefining it into the protected category. The option to remain open for the unprotected USTs is only available during the time allowed for compliance because all tanks must be in compliance by regulated deadlines. (Recall that the base case scenario assumes that all deadlines for compliance are met.) After tank action is determined, the tanks can then be advanced to the next age category and regrouped into protected and unprotected tanks.

Although only one age group of tanks is illustrated (Figure 7), all age categories with the exception of the last go through the same processes.[31] The group of tanks older than twenty years or of unknown age is subject to the assumption that the USTs have a twenty to twenty-five year life span. Thus, the tanks reaching age twenty will have closed by age twenty-five. Tanks of unknown age are treated as being greater than twenty years old.

The new tanks in the 0-5 year age group in any one time period are determined by the replacement of USTs that occurs in the previous time period. Replacement in this context refers to a tank that is installed to replace the services of an UST being removed. A replacement need not occur at the same site where a removal occurs. For example, a service station may close its doors on one corner while two blocks away a new station opens; however, the UST services have been "replaced." Given the state of the retail motor fuel industry and the anticipated decline in the use of tanks in other industries, as discussed earlier, there is no increase anticipated in the demand for tank use. Thus, only the USTs replacing previous services during a time period are considered the new tanks (0-5 years) in the next period.

5.5. Illustration: Movement of USTs Through Time

To help understand the movement of the entire system, a specific example and Figure 8 diagramming the activity of all age groups over time is given here. At t=0, 15.8 percent of all USTs registered are in

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[31]All specific parameters of this model are given in the Appendix.

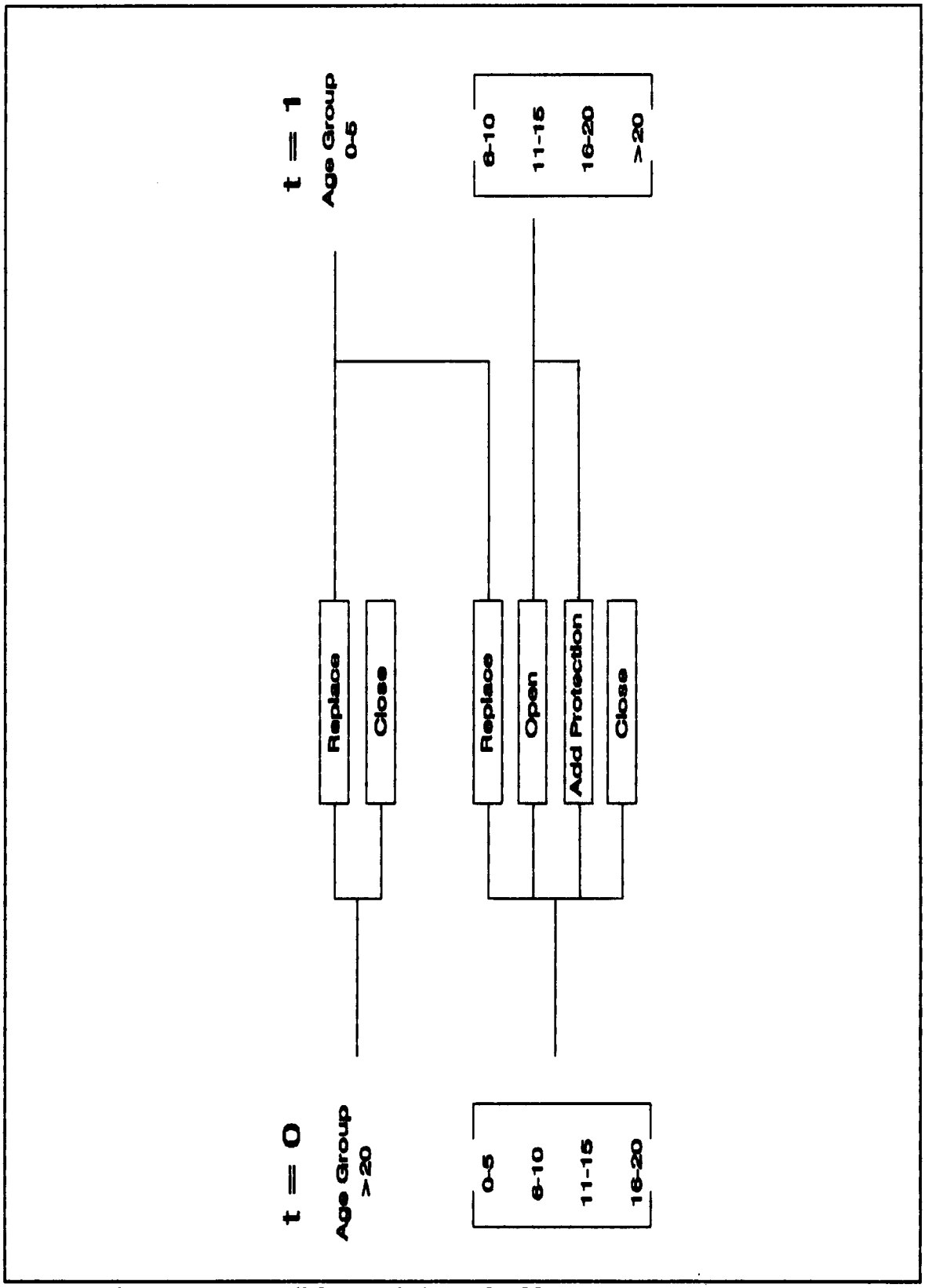


Figure 8. Possible Activity of All Age Groups Over Time

the 11-15 year age group (approximately 277,000). Of those USTs, only 27.8 percent (approximately 77,000) are protected and the remaining 72.2 percent are unprotected. During the first time period the majority of the protected USTs (95 percent or about 73,000) are assumed to remain open; a small number will have their services replaced (2.5 percent) or will be closed (2.5 percent). For the reasons outlined earlier, these percentages assume a slight decline in the use of tanks; therefore, not all USTs closing will have their services replaced.

Of the unprotected USTs, a little more than half--60 percent--are assumed to remain open at the end of the first time period in the base case scenario. Compliance is likely to be costly and many owners will seek to delay it as long as possible. Even with half of the mandated compliance time passed, the number of USTs updated is expected to be less than half. Thus, it is assumed that about 120,000 USTs will remain open and unprotected after five years. The remaining 40 percent of the unprotected USTs will close (10 percent), be replaced (15 percent), or will have protection added (15 percent).

Some UST owners will decide that the additional costs of upgrading or replacement are not feasible given their present revenues and expenditures. Without sufficient revenue, an owner may choose to close the tank rather than pay the costs involved with obtaining protection for the USTs and meeting the other regulatory requirements to keep the UST operational.[39] Owners who decide to maintain their USTs have the

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[39]The formal closure process also involves costs. To obtain a "closed" status, an UST must be removed from the ground or filled with an inert substance and it must be demonstrated that no contamination was caused by the system.

option either to replace the USTs or to have protection added to their existing system. Adding protection to the UST will allow the owner to benefit from the remaining 10-15 years available from the life of the existing UST and is also likely to involve fewer costs. However, assuming the UST is not considered to be "new" after upgrading, this solution is temporary in that the problem will be revisited in another 10 years as the UST nears the end of its life span. Although the costs involved with total system replacement may be higher than that of upgrading, the issue of underground storage should not have to be seriously addressed for 20-25 years, assuming good monitoring and maintenance of the system. Owners who have the financial capability are likely to replace their systems to avoid revisiting the problem in the shorter time.

This same illustration can be used to understand the other age groups and the percentages assumed to reflect the actions of the owners. The precise values of the parameters (all percentages) assumed and used in this estimation are listed in the Appendix and the results of the estimation are presented in Chapter 4.

Section 6. The Percentage of USTs Releasing

Estimating the percentage of USTs regulated under RCRA-Subtitle I that have had, or will have, product releases associated with them, and as a consequence, will require investigation and cleanup, is based on a variety of factors. A number of private and public organizations have speculated on the percentage of USTs releasing, with a few private

estimates ranging from 0 percent to 3 percent, and a few as high as 50 percent; most of the estimates fall somewhere between 8 percent and 20 percent.[40] However, the majority of sources also recognize that the actual percentage of UST releases is unknown.[41]

There is much less data on the percentage of UST with releases than on the total number of USTs or on the costs of UST cleanups. Most studies of UST releases examine a specific set of releases, surveying the causes of the releases and the extent of release detection, with some evaluation of the extent of contamination. Few studies have linked the releasing USTs to the total population of USTs in terms of a release rate. When percentages are given, they are not disaggregated to the level of detail according to which the preceding population of USTs are compiled--by protection and age group. For these reasons, the current estimation assigns various release factors to groups of USTs with common characteristics and weights these factors with known characteristics of the UST population. The weighted factors are applied to the UST population to determine the number of tanks with releases.

A key assumption made in the determination of this intermediate estimate should be noted: a suspected release will be investigated, and a release, if it occurs, is assumed to be found and subsequently cleaned up. In the process of complying with the UST regulations any sites where evidence of a release is found will be investigated for contamination. During this environmental assessment stage,

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[40] *Federal Register*, 37088.

[41] For example, see Environmental Protection Agency, Office Of Underground Storage Tanks, *Summary of State Reports on Releases from Underground Storage Tanks* (October 1986): 2-1.

contamination will either be confirmed or it will be determined that no further action is necessary at the site. Sites undergoing such an initial environmental assessment for contamination are considered to have a release associated with them for the purposes of this analysis.[42]

6.1. Causes of UST Releases

Recall that a release can occur from a spill, an overfill or a leak and may be found above or below the ground. Aboveground releases occur from spills or overfills that take place at the time of filling of the tanks and are generally caused by operator error. Below-ground releases may occur from the tank, the piping or from non-operational components of the system that release in overfill conditions, e.g. tank bung hole, manholes, fill and vent pipes, vapor recovery lines, and manifold piping. Pressurized piping has been identified by one source as the most important and most frequent cause of UST releases.[43] Possible causes of below ground releases include loose fittings, corrosion and structural failure.

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[42]Although remedial action is not required at all sites investigated, this is accounted for in the third estimate, the representative cost per site, which includes a percentage of sites that undergo an initial assessment where no further action is required. See the discussion of the cleanup categories in this chapter.

[43]Environmental Protection Agency, Office of Underground Storage Tanks, "Causes of Release from UST Systems" (30 September 1987), 4.

6.2. UST Release Rates

Historically, tank tightness tests have been an obvious means of estimating the percentage of USTs that are leaking product into the environment. Tank testing companies record the number of USTs found to be leaking as a percentage of all those tanks tested. These testing results are reported to indicate that about 5 percent to 7 percent of all USTs actually leak when tested.[44] If understood and utilized properly, the test results can offer insight into the actual leak behavior of USTs.

When analyzing results of tank tightness tests, care needs to be given to interpretation of the results. A system defined as non-tight under test conditions is not necessarily one that is releasing; it can be found to be non-tight with a potential for releasing, yet have had no release occur. For example, a system with loose fittings among the non-operational components may release contents in overfill conditions that may or may not have been experienced by the system.

According to an EPA report, one tank testing company's data revealed that 5 percent of the tanks are leaking, 10 percent of the USTs have leaking product delivery lines, and 15 percent of the systems have non-operational components that are not tight in overfill conditions. Those tanks found to be leaking were all constructed of bare steel and almost all (96 percent) were identified as over ten years old.[45]

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[44]EPA, "Causes of Release from UST Systems," 6.

[45]EPA, "Causes of Release from UST Systems," 4.

Although the tank testing data are useful in the defining of release factors, such testing is not a comprehensive measure of UST release rates. The testing does not encompass the accidental spills and overfills that are known to be a major source of releases. Testing may also not identify very slow releases that may result in a significant degree of contamination over a long period. In addition, the data available have been collected from firms that have been employed to test specific tanks and not necessarily to conduct testing of a random sample of the UST population. Therefore, the tanks tested, and thus the testing information, may not be representative of the total UST population. For these reasons the tank testing data will be used only to corroborate the release percentages used in calculating the total cost estimate, but will not be used directly in the cost simulation.

6.3. Estimation of USTs with Releases

The percentage of USTs with releases is estimated by applying weighted release factors to the UST population, with these weights chosen through the use of informed judgement. These results are used to calculate the total number of estimated releases as a percentage of the total UST population, thus determining an overall release rate. This estimation is based on the release factors assigned to the UST population, which are in turn based on the age and protection status of the USTs. Although information on tank volume is also available, it was

not used because tank size has been confirmed to have no bearing on the probability of release.[46]

All USTs were assigned a probability of release dependent upon both the age of the system and the level of protection.[47] Each age group in both the protected and unprotected categories was assigned a probability of releasing, with the smallest probability assigned to protected USTs less than ten years old and the greatest probability of releasing assigned to the unprotected USTs greater than twenty years old or of unknown age. Release rates were assigned to the age groups in an effort to maintain the anticipated relative relationships between the protected and unprotected groups, as well as among the different age groups. Figure 9 illustrates the probabilities of releasing assigned to both the protected and the unprotected tanks by age group. These probabilities are assumed to be constant in all time periods for the base case and all alternative scenarios.

These assigned probabilities represent a cumulative probability of a release, based on factors that have both constant and increasing probabilities of release. In other words, the probability of a spill or overfill will be fairly constant over time because both spills and overfills are generally considered to be dependent on operator error and are not judged to be time dependent. Operator error can be decreased by educating the operator and introducing incentives for more careful

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[46]Environmental Protection Agency, Office of Solid Waste, *Summary of County/City Reports on Releases from Underground Storage Tanks* (20 February 1987): 1-2.

[47]The basis of the assigned probability was informed judgement using the tank testing information and causes of release information. Both age and tank protection have been shown to affect release rates.

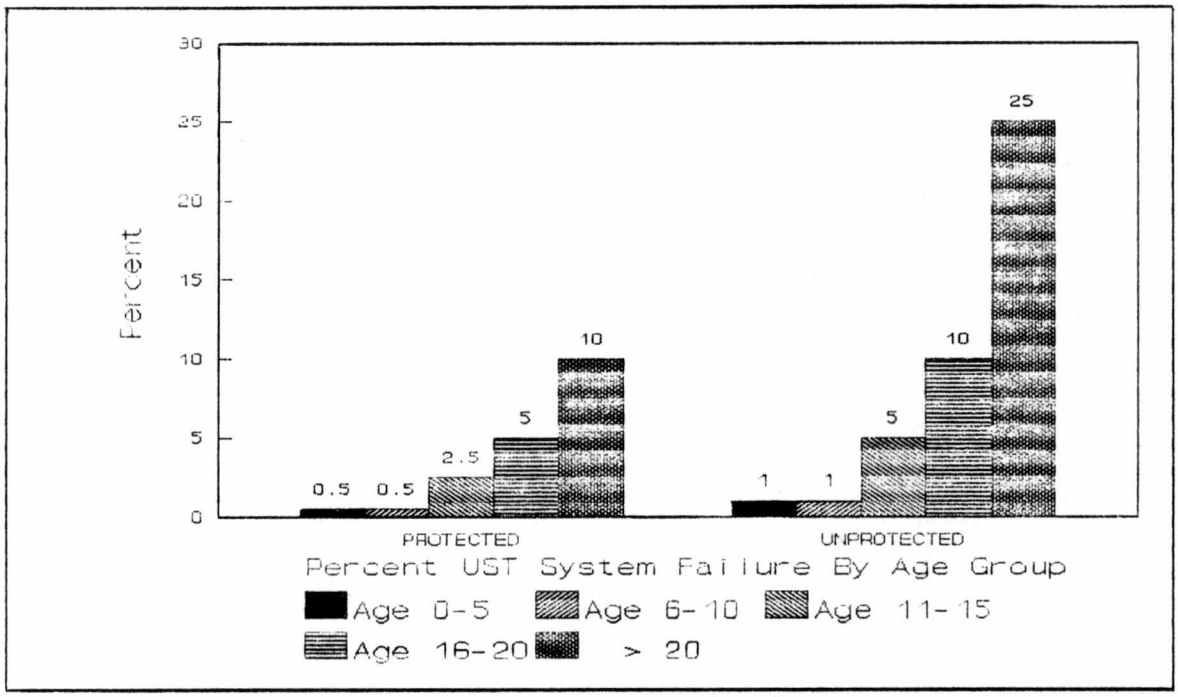


Figure 9. Percent Releasing Protected vs. Unprotected

behavior. Such changes would be exogenous to our system and unrelated to the factors considered here. In any event, for the unprotected USTs, and to a lesser extent the protected USTs, there remains a positive probability that a spill or overfill may occur. Some evidence suggests that spills and overfills are the second most common cause of a release from an UST system.[48] For that reason and for the purposes of this estimation, the probability of release attributed to spills and overfills is assumed to be constant over time.[49]

Releases attributed to corrosion are dependent on time; corrosion by definition is a chemical reaction occurring gradually. Corrosion may be either external or internal and can cause a hole in the tank or pipes. Most of the corrosion documented as contributing to the UST release problem is external (70 percent to 80 percent), with USTs failing due to corrosion having an average age of failure of between ten and twenty years.[50] To address the corrosion problem, the UST regulations and new UST designs have incorporated protection against external corrosion. The regulations allow three methods for upgrading existing USTs against corrosion: interior lining, cathodic protection, or a combination of cathodic protection and interior lining. New systems constructed to resist corrosion may be composed of fiberglass-reinforced plastic (FRP), coated and cathodically protected steel, or steel-fiberglass-reinforced plastic composite.

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[48]EPA, "Causes of Release from UST Systems," 4.

[49]The distinction has been made between the systems that are protected and those that are not; the latter are more likely to have a spill or overfill occur.

[50]EPA, "Causes of Release from UST Systems," 7.

The internal corrosion of steel tanks, while a concern of UST regulators, has not been specifically addressed by the technical requirements of the UST regulations. Coated and cathodically protected steel is protected against external corrosion, yet still has a potential for internal corrosion. Some concern has been raised that this type of corrosion may, in the future, become a primary cause of UST failure. The EPA has concluded, however, that the use of striker plates below the fill and gauge fittings where internal corrosion primarily breaks through will prevent internal corrosion from becoming a significant problem.[51] Striker plates are now standard in construction of new steel tanks and are required under the consensus codes. Those USTs with interior lining or of FRP construction have, to date, demonstrated no significant risk of internal corrosion. For such systems it is possible that this corrosion may still play a role in UST failure in the future, but presumably at a greatly reduced rate.

Structural failure may be the result of poor installation techniques and workmanship, or of accidents and natural events, such as a frost heave. This failure may occur in the tank or in the piping of the system. Some failure by this mode can be avoided by training installers with proper techniques. Piping and FRP USTs, in particular, require careful installation to avoid releases. Unequal forces or stress on a system may cause a rupture or result in leakage from pipe fittings. For example, improper anchoring of an UST at its installation may cause the tank to "float" when the groundwater rises resulting in

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[51] *Federal Register*, 37128.

unequal pressures on the tank. These unequal forces can lead to structural failure and release of product.

After each age group has been assigned a probability of release, the probability is weighted by the percentage of USTs found in that age group.[52] For example, in the first time period the probability that a protected tank 0-5 years old will release, 0.5 percent, is weighted by the percentage of tanks found in the protected, 0-5 years of age category, 9.4 percent. The result is a weighted release factor that is then applied to the total number of tanks as a whole to determine the number of tanks in that age group, 0-5 years, that are releasing. All age groups are weighted in a similar way and then multiplied by the total number of USTs in that period. The number of USTs with releases from all age groups in one time period is summed, and the overall percentage of tanks releasing is determined by dividing the total universe of tanks by the total number of tanks releasing.

This scenario is repeated for each time period. The assigned probability of release is reweighted by the new demographic distribution of the population of USTs, and new weighted release factors result. In each period the number of tanks with releases is summed and the overall percentage of USTs releasing is calculated. This results in a total release rate over time for each set of assumptions. These results will be reported in Chapter 4.

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[52]The UST population was disaggregated into age groups for the estimate of the number of USTs and those groups are used here.

Section 7. The Representative Cost of a Cleanup

As we have seen from our discussion of benefits in Chapter 2, the product released from an UST can migrate into nearby soil, groundwater, or surface water, and may affect current or future drinking water supplies as well as recreational, agricultural, and business activities. A release can also cause the accumulation of combustible fumes in confined areas such as in basements. The amount and type of material released, subsurface physical properties and the time that elapses before action is taken will largely determine the extent of contamination of the environment. The extent of contamination, in turn, will be the primary determinant of the cost of a cleanup.

Once a release has occurred and has been identified, both short and long term solutions are required to control the release and to remediate the soil, groundwater, or surface water. These efforts will endeavor to reduce or eradicate the hazards posed to human health or to the environment from the contamination. The total cost of such actions over the course of a cleanup depend on the extent of contamination, type of technology used, cleanup criteria, and other site-specific factors. The type of technology used varies depending on applicability and availability as well as the relative cost of possible options. The cleanup criteria depends on the sensitivity of nearby receptors (i.e., wells, groundwater, surface streams, structures, etc.) and the stringency of state and local regulations.

The costs encompass a wide range of services from engineering design and construction to capital equipment purchases as well as the

operation and maintenance costs (O&M) of the equipment. Specific remediation activities might include drilling wells, excavating soil, digging trenches, or installing groundwater pump and treat systems and monitoring systems. Costs accrue from the first day of action taken on the site and can continue to accumulate even after remediation activities have been completed if post-closure monitoring is necessary. Because of the complex nature of these cleanups, costs can range from a few hundred to a several million dollars and can occur over a period of a few days to several years.

The representative cost of a cleanup is estimated based only on the direct costs of corrective action required to remediate a site. Other peripheral costs such as third party damages, litigation, tank replacement, regulatory agency costs, and property or business losses have not been included. Moreover, the cost results do not allow for productivity gains or technological improvements in the remediation industry.

7.1. Estimation Approach

The database obtained from the EERC provides a basis upon which to estimate the representative cleanup costs. This intermediate estimate has four stages. First, the release is categorized into one of five categories representing contamination levels. Second, the representative cost of a cleanup in each category is estimated. Third, the probability that a cleanup will fall into each category for both the protected and the unprotected USTs is examined and associated estimates

are presented. Finally, the calculation of the composite cost of a cleanup is completed. The following sections explain these steps in detail for the estimation of one time period.

7.1.1. Release Categorization

As outlined in the benefits chapter, cleanups can be generally grouped into one of five contamination categories where each group represents an increasingly higher degree of contamination and a correspondingly higher level of treatment. These stages of contamination are not mutually exclusive nor are they regarded as strictly progressive. These categories were selected based on their simplicity in dealing with the wide variety of sites that exist so as to identify similarities in cleanup sites by the nature of the extent of contamination. These categories help divide the range of cleanup costs into a loose hierarchy based on the types of technologies, problems, and corrective actions associated with each category.[53]

The simplest stage of cleanup involvement, environmental assessment with no further action necessary, exists when the release under investigation is determined to pose no significant threat to human health or to the environment. The need for investigation may have been the result of a false alarm or an extremely small spill or overfill of the tank. Although in some cases monitoring may be necessary, soil and

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[53]These categories are the basis of the EERC cost data and are utilized for this estimation.

groundwater tests indicate that no other specific remediation activity is required.

The second stage of contamination is simple soil contamination. In this stage the contamination is primarily confined to the tank excavation zone (backfill area). Although groundwater and further soil testing and monitoring may be required, no threat to groundwater is found to exist. With this extent of contamination the tank may have to be removed and some contaminated soil may have to be excavated and treated or disposed of properly.

The third stage of contamination is complex soil contamination. Here, contamination has been confirmed to have migrated outside the tank excavation zone and may even have reached the foundations of nearby buildings or underground structures. The contaminant has not, however, entered the groundwater to any significant degree. Contamination could be found in the form of vapor, free product, or adsorbed soil particles. With this extent of contamination extensive soil treatment and/or excavation of the soil may be required.

The presence of product in the groundwater in the undissolved state is considered to be the free product stage--the fourth stage of contamination. Product may be found to be flowing into groundwater or surface water through seepage or soil pathways. To intercept the release or recover the free product, recovery wells or downstream trenches may have to be constructed to intercept the flow. Some soil contamination is also likely to be evident and to require cleanup.

The final stage of contamination is the dissolved phase of the released product in groundwater. Released product has reached the

groundwater and some portion of the contaminant has been dissolved. In addition to the cleanup activities associated with the remediation of contaminated soil and free product removal, aboveground water treatment will likely be necessary for restoration of the groundwater.

After a release occurs, it is assumed to result in a contaminated site that can be categorized into one of the above five categories. A site is considered to be in a particular category or group if a substantial share of the cleanup effort and cost involving the remediation is associated with that category. A site in the third stage, for example, may have some free product or dissolved phase contamination associated with it, but the primary focus of the cleanup is on remediating complex soil contamination. Each site can only be assigned to one of the cleanup categories.

Cleanup technologies, while not specifically addressed in the categorization of the sites, are implicitly assumed in each of the cleanup categories and are reflected in the cost figures. Technologies used for remediation of soil contamination were primarily a mix of excavation and off-site disposal, soil venting, and on-site aeration. Free product and groundwater contamination were primarily remediated with a combination of pump and treat systems utilizing air stripping and/or carbon adsorption technologies. Thus, the estimated costs are assumed to reflect these types of technologies.[54]

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[54]The database reflects cleanups with a wide range of quantities of soil and water remediated. The quantities of soil reported to correspond to the cost figures ranged from 4 cubic yards to 1,000,000 cubic yards; the quantities of water remediated ranged from 100 gallons to 100,000,000 gallons. Thus, these ranges as well as the types of technologies used to remediate them are assumed to be reflected in the database cost figures.

7.1.2. Representative Cost of Cleanup in Each Contamination Category

The representative cost of a cleanup corresponding to each contamination category is based on the EERC data. Survey responses included information on the average initial cost associated with a cleanup in each category as well as average operation and maintenance costs and the length of time over which the O&M costs are usually incurred. Given that this information was provided for each contamination category, the total costs associated with each category can be calculated for the survey responses using the following formula:

$$TCOSTS_i = (Initial\ Cost_i) + [(O\&M\ Cost_i) * (Years\ of\ O\&M_i)] \quad (1)$$

where,

TCOSTS i = Total Cost for Category i

for every,

i = 1 to 5

This results in a distribution of total costs for each contamination category. The question is how to use these calculated total cost figures for each category to determine a representative cost of UST cleanups.

Given that the respondents of the survey were asked to report their average cost of cleanup, we must assume that the reported figures reflect a greater range of costs in a representative way. To allow each average cost reported to have an equal representation in the current calculation of the total cost of UST cleanups, the arithmetic mean of

each contamination category distribution is assumed to represent the costs of each category.[55]

These contamination category costs will be used over the entire estimation period (25 years). Inflation or deflation will not be considered to occur in these calculations, nor will productivity and technology be allowed to change. The present value of the stream of costs and of benefits could be calculated but was not in this analysis. As used in the present work, the estimated total cost is compared with the benefits in the time period in which they will occur, and is not compared to any other alternative expenditures today.

7.1.3. Probability of Occurrence of Each Contamination Category

As discussed above, all cleanups can be classified into one of five contamination categories. However, it is also necessary to identify the distribution of sites among these categories to determine the representative total cost of cleanup. Given the differences between the protected and unprotected USTs, separate probability schedules have been developed for each group.

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[55]Examination of the distributions of these total cost figures reveals that the distributions are skewed to the right as would be expected given the nature of cleanup costs. There are UST cleanups where costs have reached, and will reach, into the millions of dollars before all contamination can be remediated if significant groundwater contamination is found. As a result of the shape of the distribution both the median and the geometric mean (log normal) were considered as possible alternatives to the arithmetic mean. However, these methods of statistical representation either disregard or de-emphasize the extreme values of the distribution. The total cost of UST cleanups will in fact be dominated by the few high cost cleanups rather than the more frequent lower cost cleanups.

The EERC database reflects sites that contain primarily unprotected carbon steel USTs, thus, the distribution percentages in each contamination category by the survey respondents are attributed to the unprotected USTs.[56] The percentages are shown in Figure 10.

Protected USTs, given the leak detection requirements, are likely to have releases corresponding to the first two and perhaps three categories of contamination. A leak is likely to be detected immediately upon, or shortly after, a release. Such prompt discovery followed by timely response can considerably limit the extent of contamination for protected USTs as compared to unprotected USTs.

For the distribution of the percentages of protected USTs two hypothetical probability distributions will be used. As mentioned previously, the leak detection requirements that are being incorporated into new tank systems should make discovery of leaks faster, allowing for a more timely response to the release. Therefore, two alternate assumptions are used in this estimation. Scenario A will assume that a release has an equal probability of resulting in a Category 1, 2, or 3 site with the remainder of the probability divided between the last two categories. The probability for the first three categories will be thirty percent and for the last two categories will be five percent each (Figure 11).[57] Scenario B will assume that the greatest number of

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[56]As can be determined from Table 6 earlier in this chapter, most sources estimate that seventy to ninety percent of the current UST population are unprotected and the vast majority of those are unprotected carbon steel.

[57]Even with mandated leak detection systems there will be releases that occur. Albeit the releases will be reduced in number, but they will occur. This is because some of the leak detection equipment does not observe a release until after it has occurred, e.g., groundwater

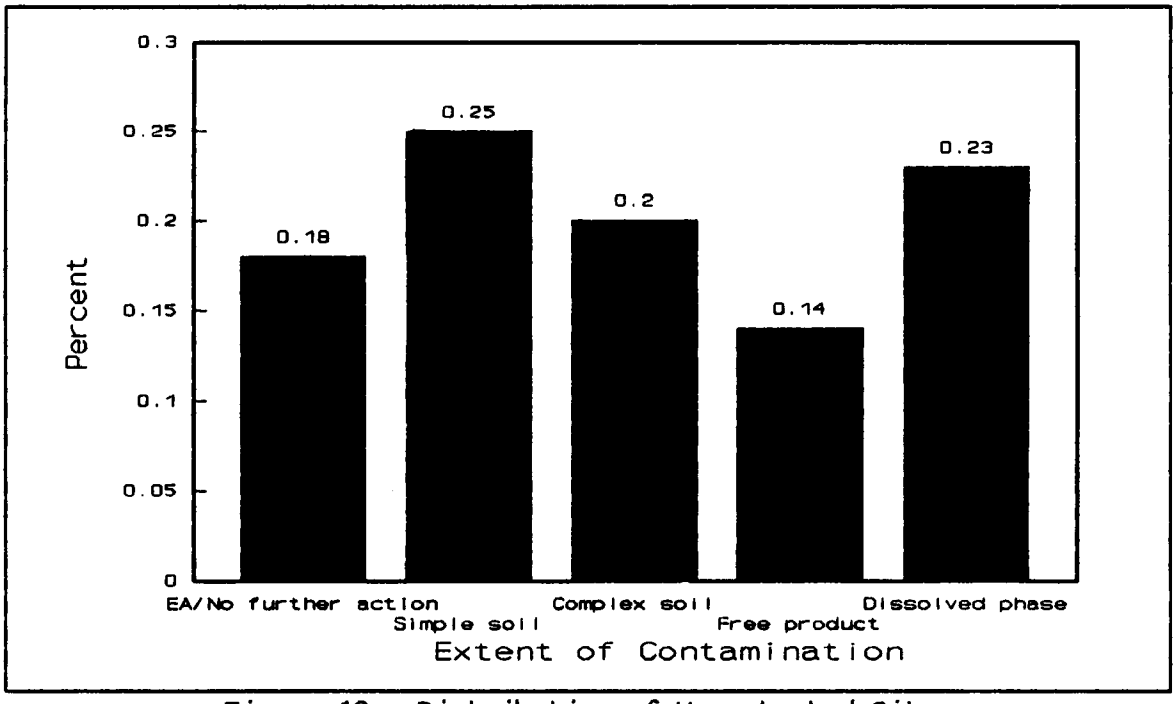


Figure 10. Distribution of Unprotected Sites Among Contamination Categories

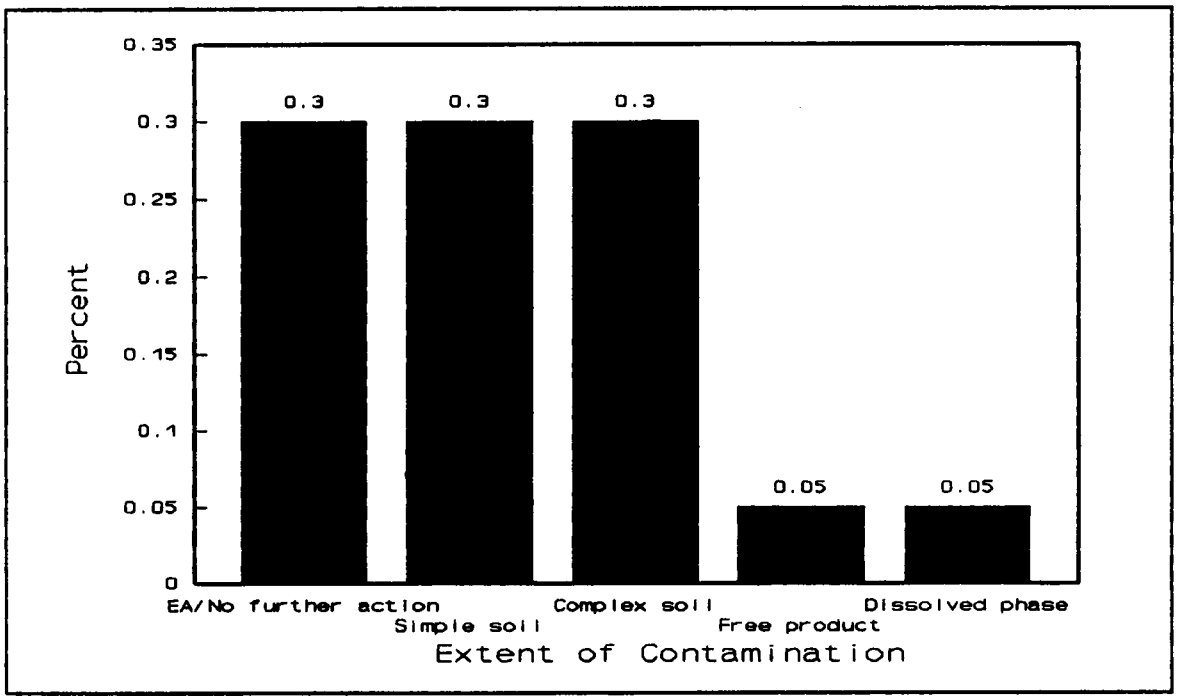


Figure 11. Distribution of Protected Sites Among Contamination Categories: Scenario A.

releases, upon investigation, will require an environmental assessment only, with no further action necessary (Category 1). It will also assume that release detection will be so effective that the majority of releases will cause an immediate response with virtually no loss of product. The percentage of releases thereafter will decrease dramatically with each contamination category producing a distribution of percentages convex to the origin. The assumptions are: half of the releases fall into Category 1, thirty percent to Category 2, ten percent into Category 3 and five percent each into the remaining two categories (Figure 12). The distribution of the last two categories does not change between the two scenarios; instead, the focus is on the distribution of the majority of sites among the first three categories.

7.1.4. Calculation of the Composite Cost of Cleanup

The percentages of releases attributed to protected and unprotected USTs for each contamination category are used to ascertain the total costs for a protected cleanup and for an unprotected cleanup. In other words, the cost figures for each contamination category (TCOSTS i) that have been derived from Equation (1) are weighted by the distribution of protected sites and then for unprotected sites. For each category that means,

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monitoring. In addition, the detection systems are subject to error. The UST regulations allow any leak detection method that will detect a 0.2 gallon per hour leak rate with a probability of detection of 0.95 and a probability of false alarm of 0.05 within thirty days. Thus, there is still a possibility of a release occurring and going undetected for a time.

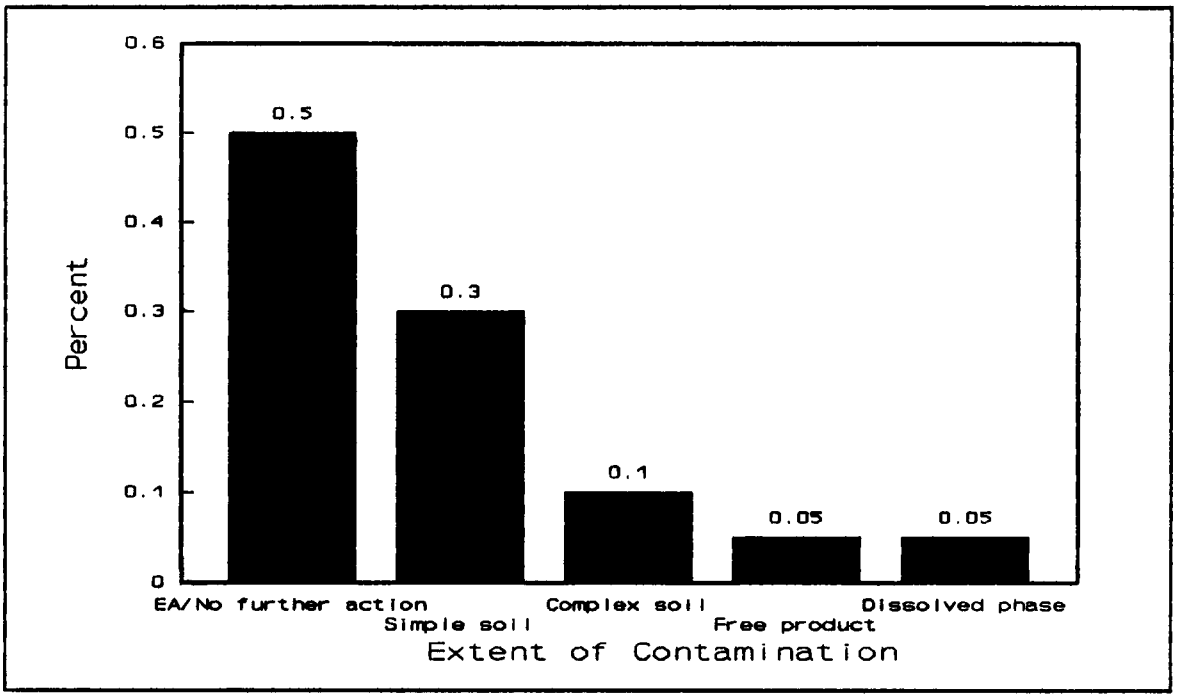


Figure 12. Distribution of Protected Sites Among Contamination Categories: Scenario B.

$$\text{Potential Cost}_i = (\text{TCOSTS}_i) * \Pr(\text{CAT}_i) \quad (2)$$

where,

TCOSTS_i = Total Costs for Category i
$\Pr(\text{CAT}_i)$ = Probability of a Cleanup in Category i

The sum of the potential costs for each category represents the potential total costs for each unprotected or protected site. The potential total site costs obtained for the protected and unprotected sites are then weighted by the percentage of sites that are protected and unprotected, respectively, for each period. These weighted values are then summed for the total representative cost of cleanup. Specifically,

$$\text{Representative Cost of Cleanup} = [(\text{Site cost}^{u} * \%\text{UNP}) + (\text{Site cost}^{p} * \%\text{PRO})] \quad (3)$$

Site cost^{u} = Potential total unprotected site cost
Site cost^{p} = Potential total protected site cost
%UNP = Percentage of cleanups with unprotected sources
%PRO = Percentage of cleanups with protected sources

where,
%UNP + %PRO = 1

These calculations are repeated for each time period in each of the cases examined to yield an estimate of the costs of remediating those sites that have been determined to need cleanup.

Note that the contamination categories have been weighted by the percentage of protected and unprotected cleanup sites. However, system age and protection information is not readily available on a site basis; rather, the protection information is recorded on an individual UST basis thus creating a units problem. Not all USTs that release create independent sites--two or more USTs may create one cleanup site. This

is particularly true with corrosion through the conductivity of soil. Corrosion may begin with one tank but, through the soil and its ability to conduct current through moisture, more than the original leaking UST may be the cause of the release. There is also a probability for common failure of USTs on a site; for example, a piece of heavy equipment that exceeds the load-carrying capacity of the USTs may drive over the top of the tanks, causing the simultaneous failure of all USTs. Although the probability is small, it is nonetheless present.

To address these issues, conversion factors have been created to determine the number of UST sites based on the estimated number of individual USTs that have releases. It is necessary to treat the protected and the unprotected USTs separately because of characteristics that promote or do not promote concurrent failure.

For protected USTs simultaneous releases due to corrosion will not likely occur; however, a small probability for common failure does exist as a result of outside stresses. This probability should not change as the tanks age, with proper care and maintenance. If there were no cases of common failure the probability that one UST caused one cleanup site would be one hundred percent, i.e., one UST per one cleanup. However, because of the small probability of common failure the ratio of USTs per each cleanup must be slightly higher, reflecting that probability. For the purposes of this simulation the ratios will be 1.05 USTs per one cleanup, thereby allowing a five percent probability of common failure.

The situation is more complex when determining the conversion factors from the number of unprotected USTs with leaks to the number of

unprotected cleanup sites. Unprotected USTs, in addition to possible common failure, can experience simultaneous corrosion; this corrosion probability will increase as the unprotected UST ages. Using the age groups that were used to estimate the number of USTs that are in existence, five conversion factors must be determined. Given that corrosion has not been determined to become a significant problem until the age of ten years, the first two age groups (0-5, 6-10) can be attributed with the same factors as the protected USTs where common failure is possible. Thus, the conversion factor for each of these two age groups is 1.05. At the opposite extreme we can determine a logical conversion rate for the oldest age group of USTs (over 20) and then interpolate for the two middle factor values. Obviously the oldest unprotected USTs are the most likely to have simultaneous corrosion and a possible weakening of the tanks, making common failure more likely as well. There are on average three to four USTs on any one storage site, and it is possible for all to fail. The probability that all tanks would fail is remote, but it is entirely probable that more than two tanks will fail. For the purpose of this analysis it will be assumed that on average 2.5 unprotected USTs cause one cleanup if the USTs are older than twenty years of age.

Having established reasonable estimates for the lower two and the upper age groups, a simple assumption is used to determine the conversion factors for the remaining middle groups. Thus, for age groups 10-15 and 16-20, the difference between the first two and the last age groups will be considered approximately equal, i.e., an increase of 0.5 for each group. Thus, the five conversion factors for

the unprotected UST age groups will be, respectively, 1.05, 1.05, 1.5, 2.0 and 2.5, by increasing age group. These conversion factors will be used to convert the number of releasing USTs (determined by the previous intermediate estimate, i.e. the percentage of USTs releasing) in each age group to yield the total of protected and unprotected sites that can be summed for each period and subsequently converted to percentages and used in Equation (3).

7.2. Summary, Computation of Cleanup Costs

The previous sections have, in a straightforward manner, outlined the factors used to estimate the representative cost of cleanup for one period. This process will be undertaken for each time period and for each scenario evaluated. The results of this estimation with all time periods and scenarios is presented in Chapter 4.

Section 8. Conclusion

The simulation used to estimate the cost of UST cleanups for this study--including intermediate estimates for the number of USTs, the percentage of USTs that have releases associated with them, and the representative cost of a cleanup--have been presented along with the relevant assumptions for these estimations. The analysis has been completed for the years 1990 through 2014, and the results will be presented in the following chapter. Using the intermediate estimates,

the total cost of cleanup for all UST sites for each of the cases examined will be evaluated and presented as well.

CHAPTER 4

PRESENTATION OF RESULTS

Section 1. Introduction

In this chapter the results of the simulated estimations using the various assumptions described in the preceding chapter will be presented. After presentation of the three sets of intermediate estimates for the number of USTs, the percent of USTs releasing, and the representative cost per cleanup, the final section combines these estimates to calculate the total costs for UST cleanups over the twenty-five year period 1990-2014. The results herein are provided in tabular format.

Section 2. The Estimated Number of USTs

The number of USTs in existence over time was estimated for the base case and three alternative cases under different assumptions as outlined in Chapter 3 for each specific case. Table 7 below reports the estimated number of USTs for all four cases. Although the base case assumptions were outlined in the previous chapter, the major assumptions are reiterated below to make comparison of the results more convenient. The alternative cases relax these compliance assumptions; these cases are summarized briefly later in this section.

Major Base Case Assumptions:

1) All USTs are registered in compliance with registration requirements.
2) All UST owners will comply with the regulated time frame for upgrades and replacements.
3) USTs have a life span ranging from twenty to twenty-five years.
4) The substance of the regulations will not change over the estimation period.

Table 7. Estimated Number of USTs

YEAR	BASE CASE	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
1990-1994	1,752,800	2,696,700	1,752,800	2,696,700
1995-1999	1,448,000	2,227,700	1,575,800	2,424,200
2000-2004	1,330,900	2,047,600	1,421,900	2,187,500
2005-2009	1,308,100	2,012,400	1,359,600	2,091,700
2010-2014	1,283,900	1,975,200	1,294,000	1,995,700

2.1. Base Case

The base case results for the first intermediate estimate reveal the approximate total number of USTs judged to be in existence between 1990 and 2014. The total number of USTs decreases rapidly over the first decade, from 1.75 million to 1.33 million, reflecting the large number of systems initially unprotected and requiring attention before the 1998 deadlines.[1] After the compliance dates for the regulations

[1] *Federal Register*, 37099.

have passed, the population becomes fairly stable at approximately 1.3 million.

The distribution of the ages of the tanks over time for the base case is illustrated in Figure 13 below. As of 1990, a large number of the existing tanks are either older than twenty years or of unknown age. Under the assumptions of perfect compliance and expected tank life of twenty-five years, this large group of tanks--approximately 635,000--must be replaced within the first decade to remain operational. Replacement of this large group of old tanks will bring a large group of new tanks into the system (in the 0-5 year old category); as these systems age, this group will continue to be the largest group in subsequent periods as well. Both the magnitude of the tanks in this large group, all with the same life span of use, and the requirements for continual compliance, suggest that a cyclical pattern will occur over time with regard to the number of tanks requiring replacement and remedial action. Based on the assumptions of the nature of tank use and the owners' actions regarding their tanks, this cycle will dampen over time, eventually resulting in a more even distribution of the tanks across age groups.[2] However, in the foreseeable future, this cyclical pattern may cause periodic bottlenecks in those industries related to USTs and UST cleanup activities if it is not anticipated.

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[2]See the tables in the Appendix outlining the assumed percentages for those USTs being closed, remaining open, having protection added, or being replaced, for each case estimated.

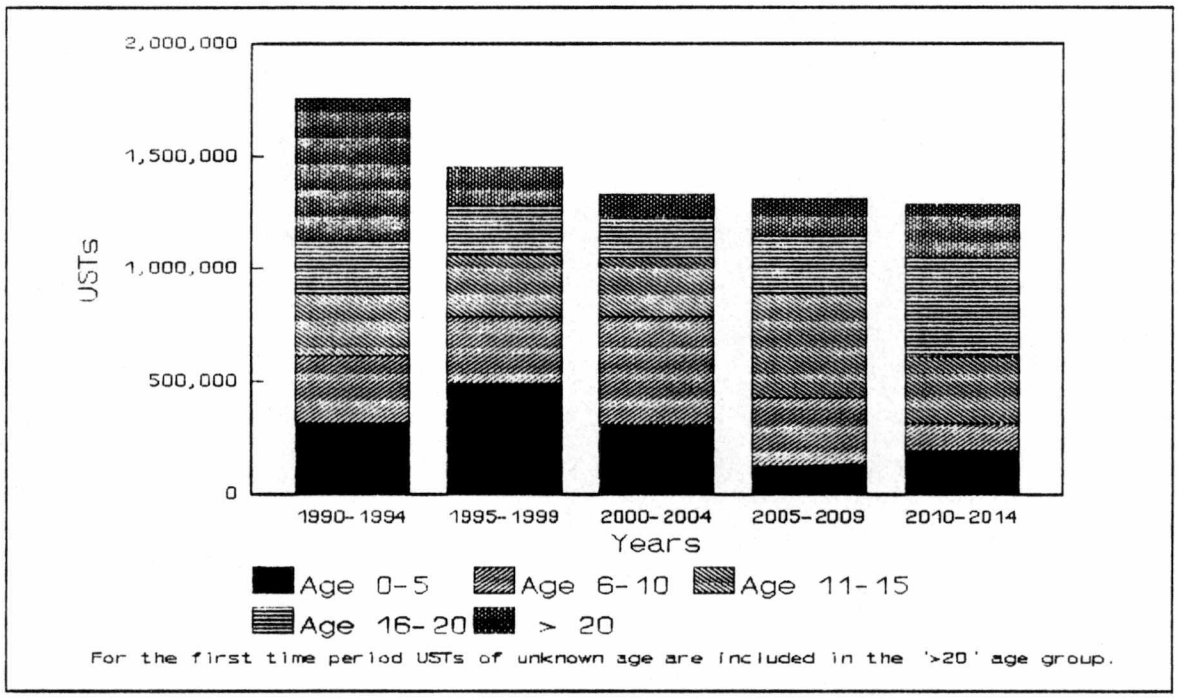


Figure 13. Age Distribution of USTs, Base Case

2.2. Alternative Cases

The alternative scenarios examined relax the major assumptions of the base case. The results that derive from these alternative scenarios offer insight into more plausible outcomes regarding the total number of USTs in existence over time, given present uncertainties.

The first alternative case changes the first major assumption of the base case, which considers all USTs in existence to be registered as required. As discussed earlier, it is well known that not all owners and operators of USTs are in full compliance with the UST registration requirements. Thus, Alternative 1 relies on the more realistic assumption that not all USTs that should be registered have actually been reported to the relevant implementing agencies. Recall that this analysis assumes that only 65 percent of the regulated tanks are actually registered; a linear transformation of the initial conditions is used to proportionally increase the number of USTs in each age group, maintaining the relationships projected in the initial conditions of the base case. With the linear transformation, the actual universe of tanks in this scenario is assumed to be approximately 2.7 million rather than the 1.75 million used in the base case. Table 7 above also reports the results of this estimation for the years 1990 to 2014.

As with the Base Case, Alternative 1 also uses the assumption that a large number of USTs are older than 20 years and are already in need of replacement and possible remediation activities. Again, a large replacement of tanks in a short time is likely to cause a cyclical

pattern of replacement; in this case, the effect will be more pronounced than in the base case due to the larger number of USTs.

The second alternative to the base case changes the assumption regarding the expected time frame required for the remediation activities. Given the large numbers of tanks that must be upgraded, replaced or closed, the number of tanks that will need remedial action is likely to be substantial. The demand for corrective action resources and services such as mobile incinerators and pump and treat systems will be great, and it is quite probable that there will be significant bottlenecks in the supply of these remediation resources. Further, many owners, despite possible penalties, will resist action because of its expense. This response may, in part, be due to the fact that enforcement of the regulation will also be imperfect. Thus, the time period for the tanks to meet the protection requirements is assumed to be twenty years, as opposed to the ten years as assumed in the base case.

The results of the estimation of the second alternative are also presented in Table 7 above. The longer time period required for remedial action, upgrades and replacements produces a more gradual decline in the number of USTs over time as compared to the base case. It takes almost a decade for the number of USTs to be reduced from 1.7 to 1.4 million whereas in the base case it took only five years. There also is no evidence of the replacement cycle observed in the base case that could cause recurrent bottlenecks to occur over time (Figure 14).

The third alternative combines the first and second alternatives in what is probably the most realistic of all the cases considered. It

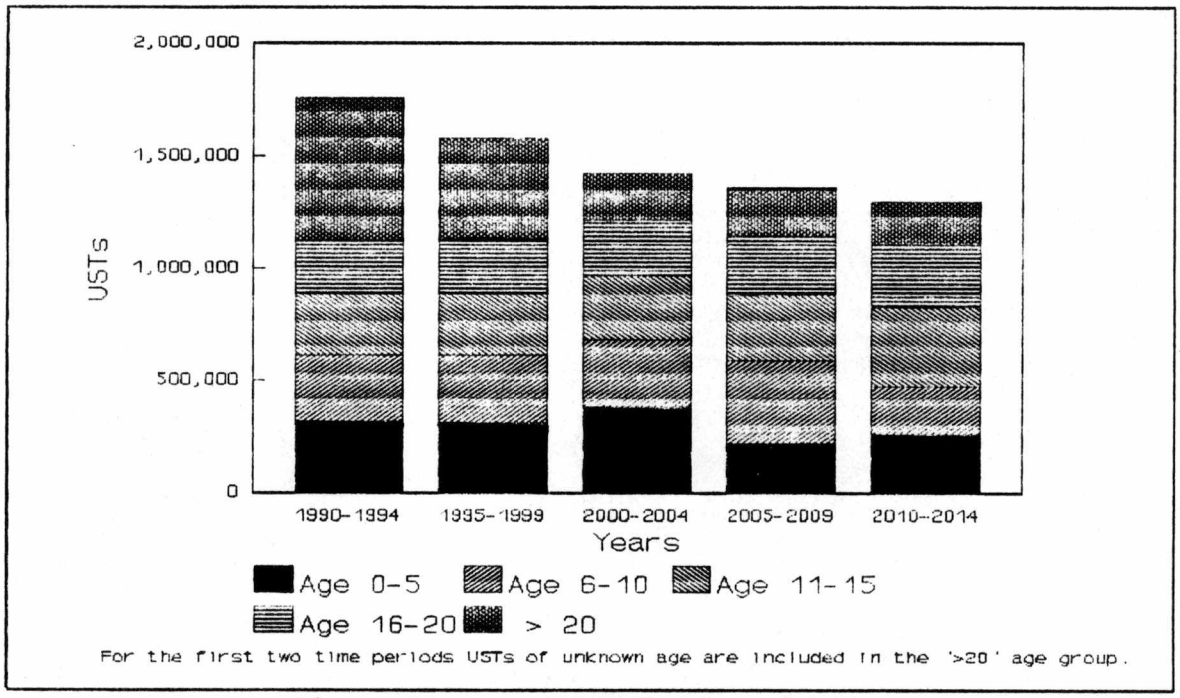


Figure 14. Age Distribution of USTs, Alternative 2

is likely that the universe of USTs is larger than the number currently registered with the States and reported in the EPA database. If that is the case, it is even more probable that not all corrective action at UST sites will occur within the next decade. The results of the estimation of the third alternative to the base case are also given in Table 7 above. The universe of USTs is assumed to be approximately 2.7 million in 1990 and to decline slowly reaching about 2 million by 2014. As with Alternative 2, the longer compliance time allows the USTs to be replaced at a more consistent rate over time, thus there is little evidence of replacement cycle activity.

2.3. Summary of Number of USTs Estimation

The overall rate of UST closure for the twenty-five year period in the base case and in each of the alternatives exceeded 26 percent. Given the assumption of timely compliance with the regulations in the base case and the first alternative case, almost 25 percent of these closures will occur during the first decade.[3] The closures for the USTs in Alternatives 2 and 3 occur more gradually over time, as would be expected, given the assumptions of the lengthened compliance time frame; accordingly, less than 20 percent of the closures are experienced in the first decade. However, over the entire estimation period, in all scenarios, approximately the same cumulative percentage of USTs will be closed. At the same time, examination of the estimates for any of these

[3]The closure rate is unaffected by a proportional increase in the number of tanks across all age groups as was done for Alternative 1.

four cases reveals that the number of USTs is at present very large and is likely to remain significant even with the large number of closures resulting from the regulations.

Note that two of the basic assumptions listed at the beginning of this chapter were not allowed to change in this analysis. The assumption of tank age is based on the estimated life span given by the manufacturers of tank systems. Should changes in tank technology or production occur this number could increase. Such a change would affect how long an UST was in service and push back replacement schedules but would not be likely to have a significant impact on the number of USTs in service. Alternatively, additional changes in regulations could affect the number of USTs in existence. If regulations are tightened, further dictating the activities of UST ownership and management with corresponding additional costs, demand for USTs could fall further and more dramatically than that estimated here.[4]

Section 3. The Estimated Percentage of UST Releases

The results of the second intermediate estimation for the percentage of USTs that have releases are not changed between the base case and the first alternative, nor are they changed between the second and third alternatives. The increased numbers of USTs for Alternatives 1 and 3 (increased over the Base Case and Alternative 2, respectively) were categorized according to age group through a linear transformation,

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[4]Changes in any of the other factors that determine the supply or demand for USTs that have been held constant for this analysis, as introduced in Chapter 3, could also affect the outcomes reported here.

i.e., by proportionally increasing the USTs in all age groups. Each age group was increased in number by the same percentage; thus the relative distribution of USTs among the age groups did not change. With no change in the age distribution of USTs, the weighted release factor does not change; thus, the estimate is unaffected by an increase in the number of USTs in Alternatives 1 and 3.

3.1. Base Case and Alternative 1

The estimates for the percentages of USTs releasing over time in the base case and the first alternative case are reported in Table 8 below. The large decrease from 10 percent to 2 percent during the first decade reflects the more stringent compliance assumptions of these two cases. Between 1990 and 1999, as both the unprotected and the oldest USTs are replaced, the percent of USTs releasing falls dramatically.

Table 8. Estimates of the Percent of Releasing USTs

YEAR	BASE CASE & ALTERNATIVE 1	ALTERNATIVES 2 & 3
1990-1994	10.0%	10.0%
1995-1999	4.4%	8.6%
2000-2004	2.2%	4.8%
2005-2009	3.3%	4.5%
2010-2014	4.3%	3.4%

An interesting result in this estimation is that the percent of USTs releasing actually increased slightly toward the end of the second decade. As noted in the estimate of the number of USTs in Section 2

above, a large group of tanks will be replaced in a short time in both the base case and the first alternative. What becomes evident, therefore, in the third and fourth time periods in the base case, is the aging of that large group of replacement tanks. As these new USTs age, the probability of releasing increases and a cyclical pattern in the percent releasing is observed.

3.2. Alternatives 2 and 3

In the second and third alternative cases, the unprotected USTs remain operational in their unprotected conditions for a longer period of time, being either removed, or replaced more slowly due to the longer time to reach full compliance. The leaking tanks are identified less quickly and releasing may continue over a longer period. Given that the percent releasing is derived from the number of protected versus unprotected USTs, the overall release rate of the USTs will decline more slowly if one assumes that the unprotected USTs will remain in the ground longer (Table 8 above).

The percentage of releasing USTs is used to compute the absolute number of USTs releasing, which in turn is converted to the absolute number of cleanup sites that are created by releasing USTs.[5] The number of sites estimated for the base case and each of the alternatives is reported in Table 9 below. The Base Case and Alternative 1 results indicated the cyclical pattern described above for the replacement of USTs, while Alternatives 2 and 3 demonstrate a more gradual tapering off

[5]See the co-location of USTs discussion in Chapter 3.

of sites created. Note that, even assuming full compliance with all UST regulations as is done in the later periods, there remains a positive number of sites caused by UST releases. The extent of contamination of these sites is mitigated over time, however; this is reflected in a reduction in the estimated representative cost of a cleanup over time.

Table 9. Estimated Number of UST Cleanup Sites

YEAR	BASE CASE	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
1990-1994	87,380	134,430	87,380	134,430
1995-1999	39,200	60,300	67,580	103,970
2000-2004	28,390	43,670	43,300	66,620
2005-2009	41,030	63,110	43,610	67,080
2010-2014	51,980	79,970	42,100	65,240

Section 4. The Estimated Representative Cost per Cleanup

The average cost associated with each contamination category--obtained from the EERC survey data--is reported in Table 10 below. To determine the representative cost of a cleanup, these costs are weighted by the percentage of sites that are assumed to be included in each category.

As described in Chapter 3, two scenarios were considered: in Scenario A, USTs in the first three categories would be equally responsible for 90 percent of all releases, and in Scenario B, half of all releases would, upon examination, require no further action while 30 percent of the releases would fall into the second category (simple soil

Table 10. Costs for Each Contamination Category

EXTENT OF CONTAMINATION	MEAN
TCost Category 1 Environmental Assessment, No Further Action	$ 15,207
TCost Category 2 Simple Soil	$ 35,468
TCost Category 3 Complex Soil	$ 111,589
TCost Category 4 Groundwater, Free Product	$ 340,109
TCost Category 5 Groundwater, Dissolved Phase	$ 503,385

contamination). The estimates for all cases are reported in Tables 11 and 12 below for Scenarios A and B, respectively. The estimates for Scenario B are lower than for A as would be expected, given the probabilities of occurrence assigned to the contamination categories for each scenario. All results are reported below; however, in the remainder of this work the results of Scenario A will be those generally referred to.[6] Recall that these costs represent the actual costs that will be incurred during each period, essentially being built in each period.[7]

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[6]Current regulations do allow groundwater monitoring as a means of monitoring for leaks; thus, the contamination has already gone beyond the excavation zone before the release is detected. For the present, Scenario A is likely to be more accurate. However, detection systems may tend in the future to veer away from groundwater monitoring as a means of detection for that very reason.

[7]No calculation of present value has been done nor were the pecuniary benefits of delayed cleanups considered. It is possible for there to be benefits obtained from the delay of a cleanup. For the UST

Table 11. Estimated Site Cleanup Costs for All Cases, Scenario A

YEAR	BASE CASE AND ALTERNATIVE 1	ALTERNATIVES 2 AND 3
1990-1994	$ 174,600	$ 174,600
1995-1999	$ 148,040	$ 171,870
2000-2004	$ 90,850	$ 139,350
2005-2009	$ 90,850	$ 119,240
2010-2014	$ 90,850	$ 90,850

Table 12. Estimated Site Cleanup Costs for All Cases, Scenario B

YEAR	BASE CASE AND ALTERNATIVE 1	ALTERNATIVES 2 AND 3
1990-1994	$ 170,490	$ 170,490
1995-1999	$ 139,120	$ 167,230
2000-2004	$ 71,580	$ 128,860
2005-2009	$ 71,580	$ 105,110
2010-2014	$ 71,580	$ 71,580

As noted these are merely representative costs of an UST cleanup and should not be used to estimate the cost of any single cleanup. The exact cost that will be required for a specific cleanup will depend on the extent of contamination at the site and other site-related factors. In general, as the extent of contamination increases the cost of cleanup increases as well.

Section 5. The Total Costs of UST Cleanups

The results presented in the preceding three sections will now be brought together to calculate the total cost of UST cleanups. The estimates of total cost of UST cleanups are presented in Tables 13 through 16 for all cases examined.

The most likely situation to occur, given the assumptions of the four cases evaluated, is Alternative 3, where it is assumed that the universe of USTs is larger than presently identified and that the UST deadlines will not be perfectly met. In this case, the estimates yield approximately $64.5 billion dollars or $60.6 billion depending on the assumption of the future distribution of UST sites among the five contamination categories. Even the base case results, with less realistic assumptions, estimated the costs of cleanup to be $32 billion.

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owner who has to sponsor the cleanup a delay means that he does not have to spend money now but later instead. In addition, if there has not been a continuous leak it gives natural bioremediation processes the opportunity to decrease the severity of the contamination, albeit at a slow rate.

Table 13. Total Cost of Cleanup, Estimates for the Base Case
(in millions)

YEAR	ESTIMATED COSTS	
	SCENARIO A	SCENARIO B
1990-1994	$ 15,256	$ 14,897
1995-1999	$ 5,803	$ 5,453
2000-2004	$ 2,579	$ 2,032
2005-2009	$ 3,727	$ 2,937
2010-2014	$ 4,723	$ 3,721
Total[1]	$ 32,088	$ 29,039

[1] Subject to rounding errors.

Table 14. Total Cost of Cleanup, Estimates for Alternative 1
(in millions)

YEAR	ESTIMATED COSTS	
	SCENARIO A	SCENARIO B
1990-1994	$ 23,471	$ 22,918
1995-1999	$ 8,927	$ 8,389
2000-2004	$ 3,967	$ 3,126
2005-2009	$ 5,734	$ 4,518
2010-2014	$ 7,266	$ 5,724
Total[1]	$ 49,366	$ 44,675

[1] Subject to rounding errors.

Table 15. Total Cost of Cleanup, Estimates for Alternative 2
(in millions)

YEAR	ESTIMATED COSTS	
	SCENARIO A	SCENARIO B
1990-1994	$ 15,256	$ 14,897
1995-1999	$ 11,615	$ 11,304
2000-2004	$ 6,034	$ 5,580
2005-2009	$ 5,200	$ 4,583
2010-2014	$ 3,825	$ 3,013
Total*	$ 41,930	$ 39,377

*Subject to rounding errors.

Table 16. Total Cost of Cleanup, Estimates for Alternative 3
(in millions)

YEAR	ESTIMATED COSTS	
	SCENARIO A	SCENARIO B
1990-1994	$ 23,471	$ 22,918
1995-1999	$ 17,869	$ 17,390
2000-2004	$ 9,284	$ 8,584
2005-2009	$ 7,999	$ 7,051
2010-2014	$ 5,927	$ 4,670
Total*	$ 64,551	$ 60,614

*Subject to rounding errors.

Section 6. Conclusion

The number of USTs that exists today is estimated to be 2.7 million; with approximately 10 percent presently giving rise to releases, about 134,000 sites will require remediation from 1990 to 1994. The cost of site remediation, along with the remaining cleanups that are estimated to occur between 1990 and 2014, will be approximately $64.5 billion. Even with the restrictive assumptions of the base case this cost will be approximately $32 billion.

Recall that the costs that have been considered in this estimation process are those costs that can be more easily identified and quantified. It should be noted that there are many indirect costs not included in these calculated estimates of total costs, as was mentioned throughout the preceding chapters. These include transactions costs, third party liability costs, psychic costs, and certain environmental costs.[1] In addition, some secondary effects on the economy that might cause additional costs to be incurred--business closings and the restructuring of industries--have also not been included in these cost calculations. These concerns will be discussed in the next chapter, in the context of an extensive analysis of these results and the consideration of the costs and benefits of the UST regulations.

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[1]There may be environmental costs associated with remediation activities such as hazards imposed by the landfill disposal of contaminated soils or the volatilization of organic compounds in air stripping processes or soil aeration.

CHAPTER 5

DISCUSSION OF RESULTS

Section 1. Introduction

This chapter examines the potential benefits and costs associated with the remediation requirements resulting from the UST regulations. The discussion is largely qualitative, drawing on some quantitative measures where possible. First, an overview of the various benefits and costs that have been discussed in this study will be presented. Next the benefits and costs will be compared. Finally, the net benefits of the UST regulations will be evaluated.

A key aspect of this discussion is not only to ascertain the correct magnitude of the costs and benefits of the UST requirements, but also to raise some pertinent questions. Several scenarios will be developed in this chapter as a means of exploring different possibilities for examining the overall impact of the UST regulations within a comparative "cost-benefit" framework.

Section 2. An Overview of Benefits

As described in Chapter 2, the observed benefits resulting from the UST regulations come not so much as gains, but rather in the form of damages avoided. Records of past UST releases indicate that the most noteworthy damage has been found to occur in private and municipal water supplies; structures; human health (including both illness and death);

and aquatic and plant life. Although it should be acknowledged that each of these specific effects has been reported, it should also be noted that most of these serious impacts were reported as occurring in less than one percent of over 12,000 UST incidents.[1]

Section 3. An Overview of Costs

As a result of the corrective action requirements of the UST program, UST owners will be upgrading their tank systems to regulatory standards and, in the process, will also be forced to clean up any extant contamination, regardless of whether the contamination poses a threat to human health and to the environment.[2] This cleanup task alone is likely to cost $64.5 billion dollars;[3] this cost does not include many other costs that are less easily quantified--transaction costs, third party liability costs, some environmental costs, and psychic costs to various groups involved in the transaction. Secondary

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[1]The incidents were recorded by state officials from 1970 to 1984. Those specific impacts that occurred in one percent or more of the incidents included: private well contamination, 6 percent; combustible fumes in confined areas, 7 percent; and, fire/explosion, 1 percent (See Table 2, Chapter 2). All of the specific impacts were observed in less than ten percent of the total number of incidents. Note that these were the incidents significant enough to be reported to authorities.

[2]No provision was made in the legislative mandate for the consideration of costs in cleanup activities. Yet, it is possible that in some cases there will be no migration of the product and no other use for the area for the time it takes for natural bioremediation of the contamination. The EPA chose to interpret the legislation conservatively such that any contamination that is found must be cleaned up regardless of the cost or potential threat to human health and the environment.

[3]See the results of Alternative 3 presented in Chapter 4.

effects are also not included in this estimate; these could include changes in the markets and industries utilizing USTs. For example, in the retail motor fuel market increased costs could cause some outlets to be closed resulting in employment impacts and possibly even increased consumer costs for obtaining fuel in the form of increased search time and travel time.[4]

Section 4. An Indirect Comparison of Costs and Benefits

Let us examine the cleanup costs and benefits, in terms of damages avoided, for the first period, 1990 to 1995. For purposes of illustration, let us assume that the number of USTs covered under RCRA Subtitle I in existence today is 2.7 million, that bottlenecks in resources required for cleanup services do occur, and that regulation enforcement is imperfect (i.e., that the assumptions of Alternative 3 assumptions do in fact hold). Assuming that approximately 10 percent of these USTs are releasing (depending upon age and existing protection levels) the total number of sites created from the releases of UST contents will be about 134,400.[5] Of these sites some will require no specific cleanup action beyond that required in the tank excavation zone, while others will require extensive cleanup. Because most USTs currently in existence are assumed to be unprotected, in this example it

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[4]See, D. Bueckman, S. Kumar, M. Russell, "Environmental Legislation and Market Structure: The Case of the Underground Storage Tanks Legislation and the Retail Motor Fuel Industry," Paper presented at the Southwestern Social Science Association, Sixty-Ninth Annual Meeting, San Antonio, Texas, March 1991.

[5]See Table 3, Chapter 4.

is assumed that 57 percent of the sites involve a substantial release of UST contents that causes contamination beyond the excavation zone, therefore falling into contamination categories three, four or five (complex soil contamination, free product, and dissolved phase, respectively).[6] Thus, approximately 76,620 sites--or incidents of contamination--will result.

For the purposes of illustration, let us further assume that the specific impacts reported in Chapter 2, the records of damage from UST incidents provided by State officials, can be used to estimate a worst case scenario[7] for the extent of damage as a result of UST releases.[8] Recall that the incidents reported are more likely to have included impacts that resulted in third party complaints than those incidents not reported to officials. This implies an underreporting of on-site contamination and particularly of the less seriously contaminated sites. Thus, the more seriously contaminated sites are likely to be overrepresented in the data obtained from the survey of state information. This overrepresentation of serious impacts among the

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[6]The 57 percent represents a sum of the probabilities of releases from unprotected USTs that result in complex soil contamination, free product in the groundwater, and dissolved phase groundwater contamination. See Chapter 3.

[7]It should be noted that the incidents reported to the authorities were more likely to have been more serious cases of UST contamination observed from UST releases, causing a selection bias in the data collected from the State reports. As a result, it is likely that the percent of serious impacts from UST releases over the period examined has been overstated, and this suggests that the results obtained from this exercise can be considered as a plausible upper bound for the physical impacts resulting from UST releases.

[8]EPA, *Summary of State Reports on Releases from Underground Storage Tanks*, 8-1.

12,000 sites makes this a useful source of data for a worst case scenario. In other words, an extrapolation of the UST risks represented by these 12,000 to all UST sites can be representative of the upper bound for statistical risks that will be faced at UST sites across the country. There is no reason to believe that these more serious cases are not representative of the serious cases that would occur during a later time period. With such an extrapolation, an estimate of the impact of the UST sites on communities around the country will be determined; the resulting estimate of the threat to the population from releasing USTs (based on releases occurring over a five year period) is given in Table 17. These estimates suggest that twelve lives will be lost and over 600 people will become ill over the five year period as a result of UST releases. Recall that the benefits from the UST regulations occur in the form of damages avoided, thus, these results represent the potential benefits of the regulations.[9] Note that these are <u>potential</u> benefits, all of the above benefits could be attained only if there were no releases that would occur from USTs or, alternatively, that there would be no serious UST releases in the future. Although the serious releases will be greatly reduced, there will be some releases

[9]We cannot say that none of these damages would have been avoided if the regulations had not been promulgated. As was previously discussed, there are other incentives that may have caused some of these damages to be avoided as well; particularly, tort liability and a greater sensitivity to environmental issues may have caused some of these benefits to be obtained. Unfortunately, it is impossible to determine what these effects would have been without the presence of the regulations.

with serious impacts and thus this examination of benefits likely overstates the effectiveness of the UST regulations.[10]

Although, as discussed in Chapter 2, these benefits as a whole may be difficult to quantify, these estimates can put the potential threats from UST releases over the five year period into some perspective. It does not appear that thousands of lives will be lost; the size of the problem is bounded. Contamination of drinking water sources may become a problem that, if allowed to go unchecked, may become significant in the future as more aquifers are contaminated. Yet, the benefits from avoiding contamination of drinking water sources come more in the form of costs avoided for alternate water sources than in human death or disease.[11] Combustible fumes, while not necessarily resulting in an explosion or in human illness from inhalation, do create a situation that can result in significant damage and which, with a few precautions could perhaps be avoided.[12] On the cost side, during the same five year period, cleanup costs are estimated to be over $23 billion dollars.

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[10]This is in keeping with the damages estimated here as constituting a worst case scenario or, alternatively, denoting an "upper bound" on the benefits that could be achieved with the UST regulations.

[11]On the other hand, there is also the issue of natural biodegradation. Although not a lot, some contamination, particularly petroleum products, can be broken down by natural processes.

[12]Confined areas such as basements, if properly ventilated, could alleviate much of the fire and explosion hazard. However, this would not eliminate the problem of the UST releases from which the fumes originated.

Table 17. Potential Statistical Threat to the Population (1990 through 1994)

THREAT TO THE POPULATION	NUMBER OF INCIDENTS	PERCENTAGE OF TOTAL INCIDENTS
Human Illness	616	.80 %
Human Death	12	.02 %
Private Well Contamination	4,612	6.02 %
Municipal Water Supply Contamination	246	.32 %
Combustible Fumes in Confined Areas	5,591	7.30 %
Fire/Explosion	954	1.24 %
Corrosion of Structures	209	.27 %
Aquatic Life Impacts	634	.83 %
Plant Life/Crop Loss	610	.80 %

Some of the impacts listed, such as property damage, may be easier to quantify than others (e.g. human health); yet even in this case, no information has been gathered on the extent of structural damage caused at UST sites that would allow conclusions to be drawn as to the typical number of structures destroyed in each incident, the dimensions of the structure (e.g. square feet) or the cost per structure. In addition, the impact on environmental ecosystems is almost impossible to identify if there is little knowledge about the extent of contamination; i.e., we may know that a stream was impacted but we may not know the extent of the impact. In short, there is not enough information available to monetize these impacts at this time; however, identifying and listing the possible impacts will assist in comparing the overall threat from releasing USTs to environmental threats from other sources.

There are clearly some gains to be made, in the form of damages avoided, from the UST regulations. But the appropriate question, in the larger scheme of things where resources are scarce and budgets are fixed, is what priority should be put on cleanup and prevention of these UST sites? If the goal of our society is to maximize its net benefits, the society would choose to divert scarce resources from one social program to another if the total gains (net benefits) from the second program were higher. The gains from both programs may be positive, however, with limited resources the program with greater gains associated with it will be chosen.[13] Among environmental programs, a means to assure that the greater social benefits are achieved is to compare the marginal benefits per dollar spent on one program to the marginal benefits per dollar spent on all other environmental programs.

Section 5. Benefits: A Comparison of Programs

It is no surprise to anyone who has ever juggled a budget that one cannot do all of the things that one would like to do given the limited income one has. Likewise federal, state and local governments cannot do all that they would like to do, given the limited resources that they have; thus, they must set priorities and make decisions about what will

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[13]Richard A. Musgrave and Peggy B. Musgrave, *Public Finance in Theory and Practice*, 5th ed., (New York: McGraw-Hill, 1973), 131-134. Although this is true with government budgets, the decision is not nearly so clear when one is talking about the direct withdrawal of funds from the private sector to address an environmental problem. Society may not perceive that it is "paying the bill" and therefore the budget constraint no longer holds. In such an instance, if the marginal benefits exceed the marginal costs of that level of the program, the project will be undertaken.

and what will not be accomplished. In the case of USTs, we assume the legislators decided that the resources devoted to UST cleanups were evidently of no greater use elsewhere and could do the "greatest good" if they were directed at regulating USTs. In addition, when the legislators decided that USTs should be regulated they observed the number of USTs to be quite large and recognized that the federal government would need help to regulate USTs--hence the state involvement--and that the federal government would not be able to afford to make the upgrades and clean up the contamination that was there--hence the owner responsibility.[14]

Let us contrast this environmental problem with another environmental problem that is currently being addressed, that of naturally occurring radon in homes. If comparing costs to benefits is difficult, perhaps comparing the benefits of different programs will be useful.

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[14] It is interesting to note the process whereby the UST legislation was passed. Two Congressmen took particular interest in the problem of UST releases. Both had experienced some problems within their own districts with UST contamination and were aware that there was a potential for very real problems to result from UST releases. In addition, it was an election year and Congress in general wanted to pass at least one environmental bill. The EPA initially resisted attempts to pass a bill directed at USTs and maintained that there was adequate authority under existing statutes to address the issue. Although EPA recognized the potential problem, the massive size of the problem in the number of tanks thought to exist was unlike any other problem EPA had encountered. For future research, it may be of interest to develop the discussion of USTs within the public choice framework, examining the legislative process within the framework of the desires of the public (voters). However, that discussion is beyond this present work.

Radon is an invisible, odorless, tasteless gas that occurs with the breakdown of naturally occurring uranium in soils.[15] It is estimated by EPA to cause between 5,000 and 20,000 lung cancer deaths per year in this country.[16] To date, there are no effects other than human health effects that have been identified as being associated with radon; therefore, no ecological effects such as groundwater contamination need to be considered (Table 18).

Table 18. Comparison of Benefits in Terms of Damages Avoided: UST Releases and Radon

IMPACT	UST RELEASES[1]	RADON
Human Death	2	5,000 - 20,000
Water Supply Contamination[2]	972	none
Structural Damage[3]	1,351	none
Aquatic/Plant Life Impacts	249	none

[1] Results from the five year period, 1990-1994, are equally divided over the period and the results are rounded.
[2] Includes both private and municipal water supplies.
[3] Includes combustible fumes in confined areas, fires, explosions and corrosion damage.

In order to draw any conclusions from this comparison, difficult questions need to be asked, for example, regarding the value of human life and the value of a water supply for a household or community. The choice of emphasis of one program (USTs) over another program (radon) implicitly deems a particular number of wells supplying drinking water

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[15] Specifically, radon is a by-product of the breakdown of radium which is formulated by the radioactive decay of uranium.

[16] Environmental Protection Agency, Office of Air and Radiation, *A Citizen's Guide to Radon: What It Is and What To Do About It*, (August 1986), 1.

to be more valuable than a human life. Whether in terms of dollar value or other less quantifiable "tradeoffs," such decisions about the value of human life are made, either explicitly or implicitly. Implicitly or explicitly, national priorities are set and followed in environmental policy practices. In the case of USTs it is too late to evaluate the priorities of the program before the fact, however, in hindsight we can evaluate the environmental priorities that are implied from the emphasis that is placed on this program as compared to the emphasis given to other programs. Further, the factors that establish one program to be of greater importance than another may also be examined.

Section 6. Comparison of Benefits: A "Pseudo" Before and After Look

The number of UST releases will be reduced as a result of the UST regulations; however, that does not imply that releases will never occur thereafter. As was made clear in Chapter 3, there will be release incidents that will continue to occur and cause some of the more serious impacts listed above, albeit at a reduced level compared to before the regulations. The technical requirements of the legislation will assure, to the extent possible, that USTs retain their integrity during their lifetime of use and that they are retired after that life span has been completed. The retirement of USTs after a designated useful lifetime will insure against owners pushing the replacement schedule as far back as they can or prevent them from waiting until there is a problem (i.e. a release) to address the issue of replacement.

Ideally, the comparison of losses resulting from UST releases, or conversely, the illustration of gains resulting from the regulatory action taken, should be done with information obtained both from prior to the regulations and after the regulations were instituted. This would allow a "before and after" picture of the effects of the regulations. That not being an option in this case due to the paucity of information about USTs, an examination of the first period number of USTs estimation results will reflect, at least in part, the unprotected USTs and the reduction in damages by regulating them.

Table 19 below enumerates the potential reduction from the regulations. The estimates attributed to the 1990-1994 period are identical to those presented earlier in this chapter in Table 17. The estimates attributed to 2010-2014 are based on the estimates derived for the last period evaluated in Alternative 3 using the Scenario A assumptions for the distribution of sites among contamination categories. These reductions have been made possible for the most part through the technical requirements of the UST regulations. More releases are likely to be avoided in the future as a result of the precautions provided by the regulations.

These reductions must be interpreted carefully. First, it should be understood that these reductions result more from the technical upgrades and reporting requirements than from the cleanup of UST releases. These reductions reflect the fact that fewer UST releases will occur in the future, as a result of measures instituted like leak detection methods and corrosion protection, rather than the cleanup of old sites. Second, and corollary to the first, it is not necessarily

Table 19. Potential Statistical Threat to the Population: A Before and After Picture

THREAT TO THE POPULATION	ESTIMATED NUMBER OF INCIDENTS 1990-1994	2010-2014[*]
Human Illness	616	210
Human Death	12	4
Private Well Contamination	4,612	1571
Municipal Water Supply Contamination	246	84
Combustible Fumes in Confined Areas	5,591	1904
Fire/Explosion	954	325
Corrosion of Structures	209	71
Aquatic Life Impacts	634	216
Plant Life/Crop Loss	610	208

[*] These calculations use Scenario A assuming that 40 percent of all UST releases occurring are in the three more serious contamination categories; using Scenario B assumptions would yield approximately half of the incidents indicated by Scenario A.

the case that $64.5 billion was spent to achieve the reduction in lives lost, and in other reduced damage to structures and the environment. There is no way to predict the effects of UST releases that had already occurred and would not have been cleaned up or those releases that would have occurred otherwise had there been no intervention into UST activities. Third, we cannot easily value these reductions. Fourth, even if we were able to fully value the reductions, the full cost of all of the requirements of the UST regulations has not been examined herein. A comparison of value of the benefits achieved as outlined here with the estimated $64.5 billion cost would be incomplete because it would not include many other costs incurred to obtain those benefits as a result of the regulations.

What can be gained from comparison of these before and after estimates is perspective on the nature of the savings to the public in terms of human health and the environment. This will enable a rough evaluation of national environmental priorities, or at least, allow decision-makers to understand the full nature of the tradeoffs that are being made in any policy decision affecting the UST regulations. It is very difficult to make decisions about where environmental contamination can be allowed to exist and where it must be prohibited; where the cleanups will occur and where they will not; and where the priorities of the environment will be and where they will not.

Section 7. Environmental Priorities

Once we raise the question of environmental priorities, or more specifically, when we consider what we can or should do with our limited resources to protect our natural resources, we must recognize that it is not an easy question to formulate and even more difficult to answer. Further, it is not within the scope of this present work to address this question in any significant manner. However, we know that we must make choices, choosing between a life now or two lives in ten years. We are also asked to choose where, in which environmental program, the life will be lost because not all lives can be saved.

This is not the first time that environmental priorities and the cruel choices of environmental management have been discussed. As the focus on risk management has been highlighted in the past decade the making of these environmental priority decisions has moved from smoke-filled rooms to televised debates and hearings.

In the case of USTs, to deal with the broader issue of environmental priorities, the question we should be asking is not whether USTs should be remediated, but rather, whether the UST priority is higher than other environmental programs, and on what basis environmental priorities will be determined. To combat all environmental concerns with limited resources, priorities must be determined to obtain the greatest benefit from the funds available. Yet, as noted previously, priorities as determined by environmental scientists differ markedly from priorities as determined by the public. It appears that one key to understanding the differences in priority

rankings as they exist today may be found in public perceptions of risk. Recall that the public has a richer definition of risk than does the "expert" in matters of judgement of risk. No doubt given the evidence of its human health risks the expert would agree that radon poses a greater risk than the releases that occur from USTs. The expert bases judgement on the statistical lives lost, on the potential for human death, not on whether or not the risk is voluntary, or familiar, or equitable. So, why were USTs the target of the legislation and not homeowners, or alternatively, why didn't the legislature mandate that every house in the country be tested for radon rather than regulating USTs?

Perhaps the answer to some of these questions lies in how policy-makers respond to public perceptions of risk. The assessment of environmental problems conducted by EPA supports this notion in its findings. On the one hand, radon is a threat with high risk of human health affects associated with it, yet receives a low level of EPA effort. On the other hand, UST releases considered to be of relatively low risk by experts receive a high degree of EPA effort.[17] That is not to say that EPA's emphasis is in error; it is a public regulatory agency serving the citizens.[18] However, if a goal of environmental policy

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[17]EPA, *Unfinished Business: A Comparative Assessment of Environmental Problems*, 95.

[18]William Ruckelshaus, then EPA Administrator, put it this way, "EPA is an instrument of public policy, whose mission is to protect the public health and the environment in the manner laid down by its statutes." (William Ruckelshaus, "Science, Risk, and Public Policy," *Science*, 9 September 1983, 1026.)

and, hence, EPA is to reduce risks to the public, perhaps its direction of emphasis should be reevaluated.

Section 8. Possible Secondary Effects of the Cost of UST Cleanups

The fact that the extent of contamination varies across UST cleanups causing cleanup costs to range from a few thousand to millions of dollars, and the fact that cleanups will not affect all users of USTs equally will have a major impact on the way these regulations will be received in the industries that utilize USTs. If all UST owners were faced with an increase in operating costs, economic theory suggests that these owners would attempt to shift costs backward onto their inputs or to pass the costs forward to the consumers of their goods and services in order to be compensated for some of the increase in costs.[19] In a relatively competitive market[20] each owner would respond similarly to the cost increases; therefore, the market would reflect the responses of the owners to the increase in costs. The relatively elastic demand curve facing each firm, determined by the market supply and demand relationships, would reflect the cost increases. For example, in the retail motor fuel market, the marketers could experience increased operating costs as a result of regulatory action (e.g. monitoring of tanks). The market for retail fuel would react to the increase in costs

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[19]The extent to which the owners would be able to shift these costs depends on the price elasticities of supply and demand for both the inputs and the final goods.

[20]No obvious disparities exist between the size of firms nor among the cost functions of the firms.

with the supply curve for fuel shifting upward to the left. As a result, the price for fuel would likely increase, depending on the price elasticities of supply and demand. Likewise, an increase in costs through a one-time lump sum payment would, if equally imposed on all firms, affect all firms in a relatively competitive market in a similar way.[21]

In light of this discussion, consider the nature of the cleanup costs that will be incurred by the owners of USTs. First, the extent of contamination found will differ at each site. Thus, the increase in costs is not equal across all owners; some owners will pay a few thousand in cleanup costs while others will pay hundreds of thousands. Owners are not likely to respond in a similar manner to costs that are not similar. Second, some owners will find contamination and some will not; this "tax" is not levied on all owners. Rather, the costs are incurred by owners in an almost random way. For example, suppose that two service station owners with roughly equal financial situations (i.e., fixed and variable costs, capital investment, debt/equity) and roughly equal market shares, operating in the same relatively competitive local market, decide to upgrade their tanks to comply with the UST technical regulations. Upon excavation of the tanks one of the owners finds evidence of contamination while the other does not. The former will be forced to invest time and money in order to clean up the site to "satisfactory" levels, as determined by the state or local

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[21]Granted, the distortionary effects of a one-time lump sum transfer will be minimal. However, if cost structures are similar, the firms will all be in the same position looking to recoup the costs of cleanup. In reality, there will be some firms better able, through their financial positions, to deal with the cost increases.

government office in charge of UST cleanups. The cost could, as has been noted, range anywhere from a few thousand to several million dollars. In such a scenario, the owner who finds contamination will be unable to pass on the additional costs to consumers because the other station will operate without such costs and thus charge a lower price for the goods and services provided.[22] The prices of the marketed fuel are dictated by the market outcomes and are not influenced by the individual sellers in the market.

An owner who is responsible for the cleanup of UST contamination will likely face what can be considered a lump-sum outlay of funds for the UST cleanup. If such a fixed cost increase is large, relative to the financial position of the firm, the firm may not be able to cover the cost of the cleanup with its present financial assets. Economic theory would suggest that since the marginal cost and average variable cost of operating and the marginal revenue gained from sales do not change that the firm would continue to operate, at least in the short run.[23] However, it is likely that in the case of very high fixed costs that must be paid, the firm may not be able to maintain its liquidity or

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[22] It may be possible to pass on some of the costs if these dealers represent the whole market in their area (i.e. duopoly); a deal may be struck between the owners to maintain prices such that some of the cost of the cleanup can be recouped.

The owner may also try to shift costs backward onto his inputs. Economic theory suggests that in factor markets, if a factor is fixed in supply (inelastic) it may be possible to pass taxes backward onto those factors of production. If, however, the factors are elastically supplied, which is likely to be the case for the retail motor fuel marketers, the owner will be unable to pass on any costs.

[23] The firm may be able to continue operating in the short-run; however, in the long run the firm will cease operations if it is not making normal profits.

credit status. The firm may have cash flow problems from the time of the first payment for cleanup services and also may not be able to obtain credit, based on the financial position of the firm, necessary to operate. The asset value of the firm can be devastated; the liabilities on the balance sheet may swamp the value of the assets. Although theory may suggest that the firm will continue operation in the short run, the above reasons suggest otherwise in this particular instance. It may also be the case that the owner views the cleanup costs as overwhelming to the extent that his ability to make normal profits in his business for many years will be affected. At such a conclusion the owner may opt for the shelter of bankruptcy or may simply flee leaving the cleanup to be handled by authorities. No studies have as yet been undertaken to determine the extent of such secondary changes in the retail motor fuel market nor in the market structure.

There is some anecdotal evidence that markets outside the retail motor fuel sector may be affected as well, particularly some in small communities and rural regions. To illustrate, consider the plight of the small independent jobber in Illinois. Prior to the onset of the UST regulations, in one small rural community four independent jobbers served the fuel needs of farmers and other UST owners in the community. Because the farmers did not want to take on the responsibility and expense involved with owning a tank, particularly in registering their USTs and assuring technical and financial compliance, they opted to discontinue use of their tanks. By 1991, two of the independent operators had already closed and a third was in negotiations with the

fourth to buy them out.[24] Thus in essence, in just a short time, a competitive market disappeared and a monopoly was formed to supply the area with the remaining jobber services demanded. It is interesting to note what happened to the demand-side of the market for gasoline--the fuel that was demanded by the farmers. The farmers still used gasoline to power their farm machinery, but where did they now get their fuel? An interesting substitution effect seems to have taken place: some farmers have begun to use mobile tanks placed on the back of their pickup trucks so that they can haul their own fuel from the local station to their farms. In the interests of reducing the risks to human health and the environment it is questionable to maintain that a pickup driving down the road at 55 mph hauling a fuel tank on its back is safer than the truck of a jobber that is equipped with appropriate safety equipment. In short, has risk to human health in the environment been reduced? It doesn't appear to have been in this case. Other costs such as the unemployment of the three smaller firms will also contribute to the impact of the regulations on the rural communities. The overall income of the community may not have changed, but the distributional effects of the gains and losses may be significant. Although these costs and others discussed in this dissertation have not been measured, they are likely to be substantial as illustrated by this example.

[24]The latter agreed to the buy out on the condition that the third operator would run the business.

Section 9. Conclusion

The analysis herein is ex post, not ex ante; thus a decision was made to alleviate the problem of UST releases, regardless of the findings of this current economic analysis. As a result of the UST regulations, the costs of remediation activities alone will be in the tens of billions of dollars and additional indirect costs are likely to increase that total significantly. Further, the distribution of costs is likely to have strong regional differences, that implies that there will be some areas bearing a greater share of the "burden" of this regulation. These costs, weighed against the benefits, seem to swamp the potential "gains" of the program. Moreover, if one raises the question of whether the UST regulations represented a more urgent environmental priority than others, notably radon, we must ask whether these dollars will be spent in the most socially beneficial way.

CHAPTER 6

CONCLUSION

Section 1. Introduction

This chapter summarizes the significant findings of this study regarding the present UST regulations, proposes feasible alternatives to the present policy approach, and suggests future research activities that may shed further light on the UST situation.

Section 2. Present UST Activities

At present, UST activities operate under the auspices of the UST regulations promulgated in 1988. There are technical and financial requirements as well as cleanup requirements that the UST owner must observe. The present activities may or may not reflect the "best" way to approach the problem of releases from USTs; however, it is the approach that has been chosen by legislators and regulators.

The discrepancy in risk perceptions discussed earlier and other political factors probably contributed to development of the current policies adopted toward USTs. First, the legislation was conceived and enacted within the period of one year. This is a short time when considering the number of economic agents that would be affected by the legislation and the extent of that effect. It is interesting to note the process whereby this legislation was adopted. There doesn't appear to have been any firm support for the UST legislation; environmentalists

and the general public, while interested, were not aggressive or overly concerned with the issue. The result of this lack of support may have been what determined the need for a "vehicle" for the UST issue to ride on to assure passage; the UST legislation was not sent to the full Congress as a bill standing on its own merit.[1] The UST legislation, while not particularly advocated by any one group, may simply have been caught up in a larger environmental push; 1984 was an election year and the desire to pass a piece of environmental legislation appeared to have been high.[2]

Second, after the passage of the legislation, Congress exerted considerable pressure to get the regulations adopted quickly. As it turned out, it was difficult for EPA to convince Congress to allow a period as long as ten years for compliance to take place when many members thought the job should be completed at a faster rate. The reality of the situation--the number of tanks and the time it would take to identify and remediate releases--meant that no less than ten years would be required for remediation. The writers of the regulations, despite pressure from Congress, set the ten year compliance schedule in an attempt to conform to a realistic estimation of compliance,

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[1]Amendments to the Resource Conservation and Recovery Act and the reauthorization of Superfund were both under consideration at the time and considered as potential means whereby the UST issue could be addressed.

[2]Steffen W. Plehn, *Underground Storage Tanks: The Liabilities of Leaks*, 2nd ed., (Alexandria, Virginia: Petroleum Marketing Education Foundation, April 1986), 31.

particularly given the sparse information about the condition of the UST universe and the limited release information available.[3]

Finally, there were no economic considerations mandated in the legislative statute; neither cost-benefit analysis nor cost-effectiveness were mentioned in the mandate. Thus, when writing the regulations, available techniques could not be used to determine whether specific cleanup activities were warranted on an economic basis, i.e., whether the benefits outweighed the costs of the action. Rather, attention turned to what actions could be taken to reduce risk, with no economic baseline considered. It could be that the short time frame of the adoption of the legislation may have precluded any helpful and perhaps necessary investigation of potential costs and benefits of the law. It could be that a longer dialogue may have brought some of these considerations into the final legislative directives.

The existing legislative and regulatory approach has been examined herein to determine the impacts on those affected by the regulations. The analysis estimates that the costs of the cleanup portion of the regulations alone will approach $64.5 billion. With USTs numbering in the millions and less than half of them located in any particular industry, the regulations have, of necessity, been broad, introducing sweeping changes to UST management within specified time

[3]Personal correspondence with Ronald Brand, former Director of the Office of Underground Storage Tank Office at EPA, 10 August 1991.

frames. As discussed previously, many people have been affected, both directly and indirectly, by the regulations.[4]

Section 3. Possible Alternatives to the Present Regulations

To address alternatives to the present UST regulations it is necessary to backtrack to the discussion of the incentives that existed for cleaning up UST releases prior to the regulations adopted in 1988. Although, as discussed previously, alternative solutions to this environmental problem can range from taking no action to outlawing the use of underground storage tanks and mandating the use of substitutes, these two extremes are not likely to be considered feasible. There is a documented threat from UST releases and it is unlikely that these threats will be viewed by the public and policy-makers in all geographic areas as negligible. It is also unlikely that moral suasion would be a permanent solution to the problem, permanence being a quality to be desired according to the guidelines for good environmental policy.

As noted previously, there were both UST releases and cleanups occurring prior to the regulations. If an owner loses product from an UST, product that has been purchased and is intended for a specific use, the owner also loses revenue. It may be that the product was to be sold as in the retail motor fuel marketer case or it may have been slated for

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[4]For a discussion of secondary effects in the retail motor fuel market see, Donna Bueckman, Sunita Kumar, and Milton Russell, "Environmental Legislation and Market Structure: The Case of the Underground Storage Tank Legislation and the Retail Motor Fuel Industry," Paper presented at the Southwestern Social Science Association Sixty-Ninth Annual Meeting, San Antonio, Texas, March 1991.

consumption in the production of another good or service. To be specific, there is a level of product release where detection and repair of the leak will reduce the loss of product so that the repair will "pay for itself." Such an incentive could be capitalized on, for example, by making the product being lost more valuable and thereby instilling more zealous action on the part of the UST owner at an earlier stage of product loss. Further investigation may uncover other methods by which to capitalize on UST owners' incentives.

The liability of the owner for damage caused by the spill can also be utilized to deter UST releases or, at least, to minimize the extent of the damage from a release. Tort liability can be an effective means of deterring UST owners from neglecting maintenance and repair of their UST systems. The legal system of liability that is already in place could be augmented so as to develop an effective means of decreasing UST releases; for example, a set of penalties specific to environmental damage could be developed. An important key to using this approach effectively would be the reduction of transaction costs. If the transaction costs required for initiating and pursuing legal action could be reduced, the threat of liability would provide an incentive for owners to maintain UST systems carefully; thus, the viability of this potential remedy for UST releases would be increased. The UST financial requirements as they have been adopted do operate, to some extent, on this concept. However, the mandatory requirements do not allow the owners flexibility to choose the optimum amount of financial assurance for their USTs. In other words, UST owners who operate in an area that is highly populated with drinking water sources nearby should be more

concerned about liability than a rural UST owner. In the same manner UST owners who operate in a high water table area and who are aware of high soil conductivity would be expected to be more concerned about the construction materials of an UST than an owner with a lower water table and soil that is less likely to conduct currents. The current regulations determine the level of financial assurance necessary based on the number of USTs an owner has and not on the factors that may determine the probability that an UST will actually have a release of product. An optimum solution to the problem of releases from USTs should allow for the differences between UST systems and in the environments in which the USTs exist and operate.

The flexibility of the regulations to encompass differences in ownership should also include differences in locality. Regional concerns should be taken into consideration when establishing the regulating criteria for the UST systems. Some areas of the country are made up of fragile ecosystems that necessitate stronger regulations or requirements of the UST owners to assure protection of the environment.

Direct control through regulation could be used in a number of different frameworks to establish a variety of UST programs to address specific concerns. However, it would appear that a decision rule could be included to determine whether or not situation-specific efforts should be undertaken to prevent or clean up a release. For example, cleanup action could be required when the cost of damage from a release is greater than the cost of the cleanup. Such specific UST regulations could also include other cost considerations if legislation would allow.

Section 4. Further Research

Extensions of this research could shed light on the current UST situation and the unanswered questions raised in the course of this analysis. First, the UST program should be monitored closely to determine both the positive and negative impacts of the program. Close observation of the UST program may bring to light some possible negative secondary effects of the regulations that have not been noted previously; it may also aid in understanding the degree of those effects and who bears the burden of those effects. As more data are available a more confident estimate of the costs of the regulations may also be possible. This could, in turn, assist state officials who are attempting to assist UST owners financially by providing knowledge of the extent of the resources that may be required for the task. Specifically, cost information should be gathered and examined. Costs should be examined as they relate to the extent of contamination as well as over the period they are incurred. To help understand the financial burden of the regulations, the source of payment for the costs of cleanup (e.g. insurance companies, owners, state funds) as well as other financial burdens such as the cost of insurance should also be examined. Other information that should be gathered includes an on-going measure of the number of UST closures and the number of new UST going in as well as the use of substitutes such as aboveground tanks.[5] New and

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[5]Most of this information will be difficult to collect. Some states that have fairly well-defined and successful UST programs (e.g. Minnesota) may be the place to start introducing such data collection measures.

unintended risks may be introduced as a result of people avoiding the use of USTs and finding substitutes to their use. In an attempt to assess secondary affects, regions that appear to be particularly plagued by cleanups should be examined for employment changes. To assess any overall economic impact, economic activity of the area should be examined as well.[6]

Second, continued work in the valuation of ecosystems and plant and animal life will help us to understand and identify the benefits of these regulations better. This information would also make analysis of the costs and benefits of these UST, and other, regulations more comparable. This would also help to assign the UST program to its appropriate priority among all environmental issues by allowing a more complete comparison of benefits obtained from this program with the benefits obtained from other environmental programs.

Third, and more broadly, the overall focus of environmental research should look toward establishing such environmental priorities. Through continuing surveys of the popularly-held environmental priorities of the general population, such as that done by EPA[7], and the more risk-based environmental priorities held by the scientific community we can understand what the priorities currently are and perhaps what they should be. Research could then be undertaken to close the perception gap through risk communication activities. Research

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[6] It may well be that there is no change in the economic activity of the community and that the impact on the region will be more distributional in nature.

[7] See, Environmental Protection Agency, *Unfinished Business: A Comparative Assessment of Environmental Problems*, February 1987.

should be conducted both to develop new means of risk communication and to analyze the effectiveness of these communication activities.

Section 5. Conclusion

Several general conclusions can be made from the above estimation and discussion. First, it appears that the corrective action requirements of the UST regulations are costly, in both absolute and relative terms, and that the value of the human health and environmental gains made from the expenditures, while positive, are not of a particularly large magnitude. Although this analysis was unable to quantify the benefits of the UST program, the perspective gained regarding the benefits likely to be obtained suggests that human health gains are small. Environmental gains are somewhat larger than the human health gains but, again, do not appear to be substantial. Second, given the nature of the problem caused by UST releases, there may have been viable alternatives to the present regulatory approach. Tort liability, a mechanism already in place, could have been augmented by other means such as a system of penalties to address the problem. Third, if regulations were indeed necessary, more flexible technical and financial requirements could have been phased in over a longer time frame, perhaps even beginning with recommended standard codes of practice with the intention of later adopting the codes as regulations. It appears that the deadlines that were assigned to the UST regulations were more the result of political phenomena than of practical consideration. More importantly, the corrective action requirements could have been

introduced with a cost consideration included. In our budget-constrained society reducing the resources required by the UST problem might free up resources that may be allocated to address other environmental concerns.[8] Finally, further analysis of the UST situation could provide legislators, regulators, and policy analysts with a better understanding of the primary and secondary effects of such regulations. This would allow consideration of these impacts when addressing similar environmental problems in the future and perhaps encourage greater regulatory flexibility, wherever possible, to eliminate unnecessary costs and to reduce other costs associated with corrective action.

It is likely that the costs associated with the UST regulations, as with so many other regulatory changes, will become internalized into the behavior of the industry within a short time. The industries affected by the UST regulations will come to consider the changes that were introduced by the legislation as standard practice and no "distortion" will be evident. As has been stated, in the case of USTs the changes that have been and will be made over the next decade are not insignificant, yet these changes are likely to be incorporated into the behavior of industries, particularly the retail motor fuel industry. It would seem that the irreversibility of a decision to change the standard practices of an entire industry would merit some contemplation, study and scrutiny. Yet, this legislation went from inception to law within one year. This essentially permanent change in the behavior of industry

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[8]These resources, while not purchased by the public sector, are kept from other possible uses by the mandate that they must be used to clean up UST sites.

has implications for the adoption of regulatory changes; once behavior has been internalized by an industry in response to such changes, the process is not easily reversed.

In retrospect, two additional observations can be made. First, in the UST case, assessment of risk and economic analysis, if undertaken prior to the specific decision-making process, could have determined the risks caused by leaks from USTs and recommended whether or not there existed sufficient reasons to regulate them. Second, and more generally, such a recommendation could have been fed into a larger analysis of many proposals for policy options that draw on the nation's purse strings. It may be the case that legislative bodies get caught in the middle between the risk perceptions of the public and the real risk viewed by the experts. After all, politicians are at the mercy of the public as to whether or not they are re-elected to their positions, and experts in analyzing risk are not likely to constitute a majority of any individual legislator's constituents. As a former Administrator of EPA put it, "...we must confront one of the inevitable dilemmas of leadership in democracy, that of choosing between telling the people what they want to hear and telling them what they ought to know."[9]

[9]Ruckelshaus, "Risk, Science, and Democracy," 35.

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APPENDIX

COST SIMULATION PERCENTAGES

The following are the percentages used for the first and second intermediate estimations, the number of USTs and the percent releasing, for all cases examined. The percentages for the protected USTs are used for all cases.

Open: Active or inactive, registered status is "open."
Close: Formal closure procedure, services of the UST are not replaced.
Replace: Services of an UST that was closed are reopened with a new tank system--on the same site or elsewhere.
Add Prot: An unprotected UST may be upgraded/retrofitted to obtain a protected status.

Base Case and Alternatives: Protected USTs						
	1990-1994			1995-1999		
AGE	Open	Close	Replace	Open	Close	Replace
0-5 Years	0.97	0.015	0.015	0.97	0.015	0.015
6-10 Years	0.97	0.015	0.015	0.97	0.015	0.015
11-15 Years	0.95	0.025	0.025	0.95	0.025	0.025
16-20 Years	0.95	0.025	0.025	0.95	0.025	0.025
> 20 or Unk	0.00	0.25	0.75	0.00	0.10	0.90

Base Case and Alternatives: Protected USTs 2000-2004, 2005-2009, 2010-2014			
AGE	Open	Close	Replace
0-5 Years	0.97	0.015	0.015
6-10 Years	0.97	0.015	0.015
11-15 Years	0.95	0.025	0.025
16-20 Years	0.95	0.025	0.025
> 20 or Unk	0.00	0.00	1.00

Base Case and Alternative 1: Unprotected USTs, 1990-1994				
AGE	Open	Close	Replace	Add Prot
0-5 Years	0.60	0.075	0.025	0.30
6-10 Years	0.60	0.075	0.025	0.30
11-15 Years	0.60	0.10	0.15	0.15
16-20 Years	0.60	0.10	0.25	0.05
> 20 or Unk	0.00	0.40	0.60	0.00

Base Case and Alternative 1: Unprotected USTs, 1995-1999				
AGE	Open	Close	Replace	Add Prot
0-5 Years	0.00	0.00	0.00	0.00
6-10 Years	0.00	0.10	0.20	0.70
11-15 Years	0.00	0.20	0.50	0.30
16-20 Years	0.00	0.25	0.70	0.05
> 20 or Unk	0.00	0.30	0.70	0.00

Alternatives 2 and 3: Unprotected USTs, 1990-1994				
AGE	Open	Close	Replace	Add Prot
0-5 Years	0.75	0.05	0.02	0.18
6-10 Years	0.75	0.05	0.02	0.18
11-15 Years	0.75	0.05	0.10	0.10
16-20 Years	0.75	0.05	0.15	0.05
> 20 or Unk	0.50	0.20	0.30	0.00

Alternatives 2 and 3: Unprotected USTs, 1995-1999				
AGE	Open	Close	Replace	Add Prot
0-5 Years	0.00	0.00	0.00	0.00
6-10 Years	0.75	0.05	0.02	0.18
11-15 Years	0.75	0.05	0.10	0.10
16-20 Years	0.75	0.05	0.15	0.05
> 20 or Unk	0.00	0.30	0.70	0.00

Alternatives 2 and 3: Unprotected USTs, 2000-2004				
AGE	Open	Close	Replace	Add Prot
0-5 Years	0.00	0.00	0.00	0.00
6-10 Years	0.00	0.00	0.00	0.00
11-15 Years	0.75	0.05	0.10	0.10
16-20 Years	0.75	0.05	0.15	0.05
> 20 or Unk	0.00	0.30	0.70	0.00

Alternatives 2 and 3: Unprotected USTs, 2005-2009				
AGE	Open	Close	Replace	Add Prot
0-5 Years	0.00	0.00	0.00	0.00
6-10 Years	0.00	0.00	0.00	0.00
11-15 Years	0.00	0.20	0.50	0.30
16-20 Years	0.00	0.25	0.70	0.05
> 20 or Unk	0.00	0.30	0.70	0.00

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