SUPERFUND BENEFITS ANALYSIS

PARTIAL DRAFT – PREPARED EXCLUSIVELY FOR REVIEW BY THE EPA SCIENCE ADVISORY BOARD'S SUPERFUND BENEFITS ANALYSIS ADVISORY PANEL

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Acronyms and Abbreviations

ACLs	Alternate Concentration Limits
AM	Action Memorandum
ARARs	applicable or relevant and appropriate requirements
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
ATSDR	Agency for Toxic Substances and Disease Registry
BPb	blood lead
BLL	blood lead level
BLRA	baseline risk assessment
C&I	commercial and industrial
CAG	Community Advisory Group
CCD	construction complete or deleted
CEPP	Chemical Emergency Preparedness Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CI	confidence interval
CLU-IN	Hazardous Waste Clean-up Information Website
CNS	central nervous system defects
COI	cost of illness
CVM	contingent valuation method
CWA	Clean Water Act
DNAPL	dense non-aqueous phase liquid
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
EECA	Engineering Evaluation/Cost Analysis
EPA	United States Environmental Protection Agency
EPA ReachIt	Remediation and Characterization Technology Database
EPCRA	Emergency Planning and Community Right-to-Know Act
ERT	Superfund Environmental Response Team
ESD	Explanation of Significant Differences
ETV	Environmental Technology Verification Program
FY	fiscal year
GIS	geographic information system
GSI	Ground Water/Surface Water Interface Criteria
HazDat	Hazardous Substance Release/Health Effects Database
HC	Health Consultation
HPM	hedonic property model
HRS	Hazard Ranking System
HSEES	Hazardous Substances Emergency Events Surveillance Database
ICs	institutional controls
IEUBK	Integrated Exposure Uptake Biokinetic model
LA	Linear Absolute model

LP	Linear Percentage model
LULU	locally undesirable land use
MEI	maximally exposed individual
mg/kg	milligrams per kilogram
MSA	Metropolitan Statistical Area
µg/dL	microgram per deciliter
MUS	musculoskeletal system defects
NCEE	National Center for Environmental Economics
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFRAP	No Further Remedial Action Planned
NIEHS	National Institutes of Environmental Health Sciences
NLA	Non-Linear Absolute model
NLP	Non-Linear Percentage model
NOAA	National Oceanic and Atmospheric Association
NPL	National Priorities List
NRC	National Research Council
NRD	natural resource damages
NRDA	natural resource damage assessment
NTD	neural tube defect
O&M	operations and maintenance
OIRA	Office of Information and Regulatory Affairs
OMB	Office of Management and Budget
OR	odds ratio
ORD	Office of Research and Development
OSC	On-Scene Coordinator
OSWER	Office of Solid Waste and Emergency Response
OTA	Office of Technology Assessment
OU	Operable Unit
PA	preliminary assessment
Pb-B	blood lead
PBT	persistent bioaccumulative and toxic
PCBs	polychlorinated biphenyls
PHA	public health assessment
PPM	property-based pricing method
PRP	potentially responsible party
PV	present value
RA	remedial action
RCC	Resource Conservation Challenge
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
RSE	Removal Site Evaluation
RSEI	Risk-Screening Environmental Indicators Model
RTDF	Remediation Technologies Development Forum
RTU	Return to Use Initiative

SAB	Science Advisory Board
SACM	Superfund Accelerated Cleanup Model
SARA	Superfund Amendments and Reauthorization Act
SBA	Superfund Benefits Analysis
SBRP	Superfund Basic Research Program
SFIP	Sector Facility Indexing Project
SI	site inspection
SITE	Superfund Innovative Technology Evaluation Program
SOD	single-family, owner-occupied, detached home
SuperJTI	Superfund Job Training Initiative
SVOCs	semi-volatile organic compounds
TAG	Technical Assistance Grant
TCE	trichloroethylene
TOSC	Technical Outreach Services to Communities
TRI	Toxics Release Inventory
USDA	United States Department of Agriculture
UST	Underground Storage Tank
VCP	Voluntary Cleanup Program
VOC	volatile organic compound
WTA	willingness to accept compensation
WTP	willingness to pay

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EXECUTIVE SUMMARY

Following increased public awareness in the 1970s of the national problem of abandoned hazardous wastes, Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980 and the Superfund Amendments and Reauthorization Act (SARA) in 1986. These bills were signed by Presidents Carter and Reagan and form the basis of the Superfund program. Together, these and related laws established a federal program for preventing, mitigating, and responding to releases of hazardous substances that might threaten human health and the environment. Six major approaches to the problem are taken under Superfund, as seen in Figure ES.1 and defined in Table ES.1.

Figure ES.1 and Table ES.1 also show nine benefit categories, divided into fundamental and embedded categories. The fundamental benefit categories are those found in the EPA's *Guidelines for Conducting Economic Analyses* (Exhibit 7-1, p. 67), and are the most basic reasons for the Superfund program: to mitigate human and ecological health risks, to improve other amenities, and to reverse environmental damage to materials. In many cases, these benefits are generated directly. However, there are other important outcomes, that are labeled embedded because they are direct objectives of the Superfund program and would likely be ignored if only the fundamental benefit categories were considered. Of course, the embedded benefit categories are valued largely because they lead *in*directly to the fundamental benefits (or to lower costs). Since it is not possible to quantify any future fundamental benefits, the distinction between fundamental and embedded benefit categories is a response to difficulties in measurement. In the current study, only fundamental benefits are quantified, so no issue of double counting arises.

Figure ES.1. Approaches Taken Under Superfund, and Resulting Benefit Categories

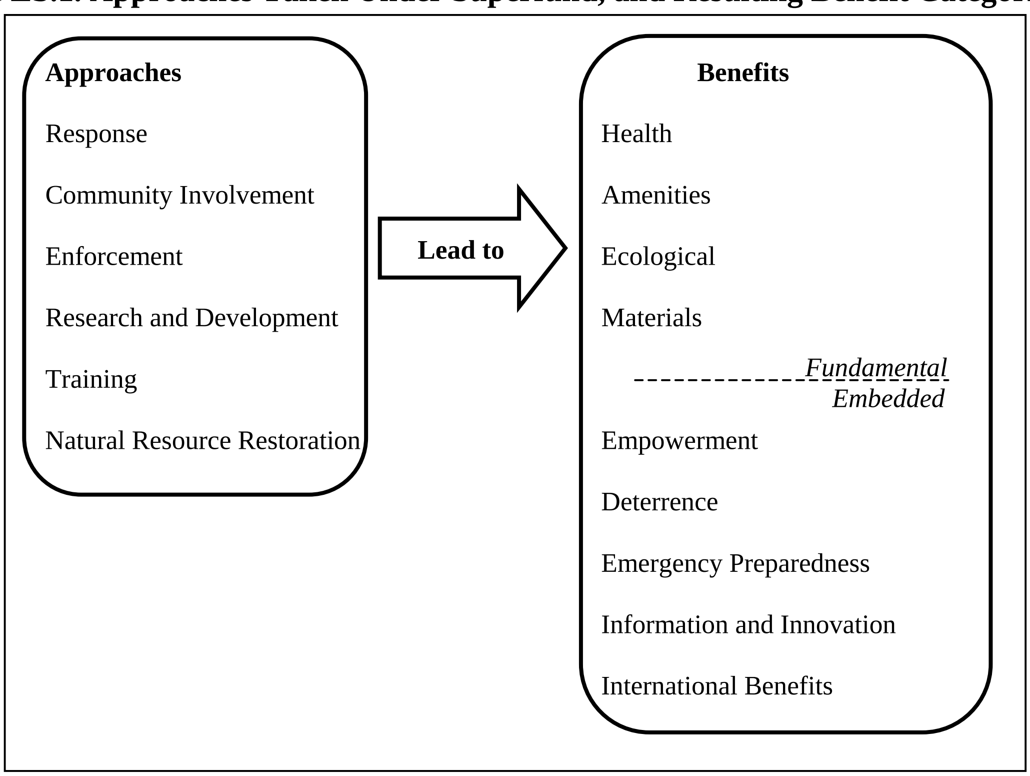

Table ES.1. Categories of Benefits of Superfund

Benefit	**Definition**
Fundamental	
Health	Actions taken to improve human health, which may include reducing the magnitude of exposure to contaminants, reducing the number of exposure pathways, reducing the length of exposure, and providing information so that individuals can reduce their exposure or seek medical treatment.
Amenities	Any feature of a place, object, or experience that enhances its attractiveness and increases the user's satisfaction, but is not essential to the place, object, or experience. In the context of Superfund, amenities include the removal of unsightly structures, the reuse of abandoned property, the avoidance of the stigma associated with contamination, and the reduction of perceived health risk from uncontrolled releases of hazardous substances.
Ecological	The restoration and maintenance of service flows to both humans and nature from natural resources, such as land, ground water, and habitat. These services may include recreation, clean water, shelter, food, timber, and others.
Materials	The reduction of risk and perceived risk associated with non-residential (i.e., commercial and industrial) properties, and the ensuing ability and willingness of the business and financial community to use these properties.
Embedded	
Empowerment	The ability of people who live near Superfund sites (especially NPL sites) to learn about the site(s) of interest, have questions about the site(s) answered, participate in decision-making associated with the site(s), and hold the relevant organizations accountable.
Deterrence	Incentives for firms and individuals that may create or use hazardous substances to handle and dispose of them properly and to avoid uncontrolled releases to the environment.
Emergency Preparedness	The knowledge, skills, organization, and technologies necessary to limit harm to human health and the environment following disasters involving the release of hazardous substances. Includes preparation for natural disasters, homeland security measures, and similar activities.
Information and Innovation	Increases in knowledge and technical capabilities created as a result of research, development, and deployment supported by the Superfund program. This includes both basic scientific research as well as efforts to develop and build experience and confidence in new technologies.
International Benefits	Any benefits from any of the other benefit categories that accrue to people or organizations outside of the United States. These benefits are generally coordinated with the State Department and often involve overseas response actions or training.

The Superfund program includes the following elements: enforcement authorities to negotiate or order response actions; a federal trust fund to pay for response to releases; and cost recovery authorities allowing the federal government to sue for costs of response actions under joint, strict, and several liability provisions. The Superfund program supports communities that are burdened with hazardous substance sites by providing them with a better understanding of, and opportunities to participate in decisions regarding the sites. The Superfund program supports a program for developing and deploying knowledge and technologies to better manage hazardous substances. This work provides a foundation for much of the current understanding and management of hazardous substances. The Superfund program provides training for thousands of first responders (fire fighters, police, emergency room nurses, etc.) so they can protect the public and themselves by detecting and identifying hazardous substances. This training provides essential elements of the homeland security capabilities of the United States. The Superfund program has enabled the restoration of hundreds of streams, rivers, wetlands, and other places. Finally, the Superfund program has created powerful incentives for industry innovation to reduce the creation of hazardous waste, reduce the need for hazardous substances, and manage hazardous substances responsibly.

For the first time, the current study addresses the full range of Superfund benefits with the question: ***What are the benefits of Superfund for the period 1980-2004?*** To do so, this study *enumerates* the benefits of Superfund and *describes* each one, *quantifies* those benefits for which the appropriate data and methods are available, and *monetizes* benefits when possible.

For the purposes of this study, the Superfund program includes all the provisions of and programs created by, or attributable to, CERCLA and SARA. Due to data and methodological limitations, almost all of the quantification of benefits is associated with sites on the National Priorities List (NPL), although there is evidence that this biases the quantitative estimates of the benefits of Superfund downward by a non-trivial amount.

Results and Discussion

This study develops three partial and slightly overlapping estimates of the monetary value of the benefits of the Superfund program.[1] Each estimate uses a benefits transfer approach of some variety.

Many of the benefits of the Superfund program derive from response actions, which include, but are not limited to, remedial actions at sites on the NPL. For most people, it is the NPL alone that characterizes Superfund. However, removal actions are also important, as are state response actions. Figure ES.2 illustrates the total number of response actions attributable to Superfund for the period 1980-2004. This figure shows all federal response actions and 25% of state response actions as reported by 33 states, based on a rough estimate of the fraction of state budgets for response actions that is derived from federal sources. This approach ignores any role that Superfund has in encouraging private firms to participate in state-run voluntary cleanup programs or any other forms of federal support for state programs (e.g., training, research, and so forth).

Importantly, these values do *not* address the risk addressed by any of these response actions; they only address the number of actions. There are no reliable data on the risk mitigation of removals or of state response actions, but there is some anecdotal evidence that at least some of these responses mitigate significant risks.

Based on these calculations, Superfund is responsible for slightly less than 17,000 response actions for the period 1980-2004, of which remedial actions at NPL sites make up less than 10%.

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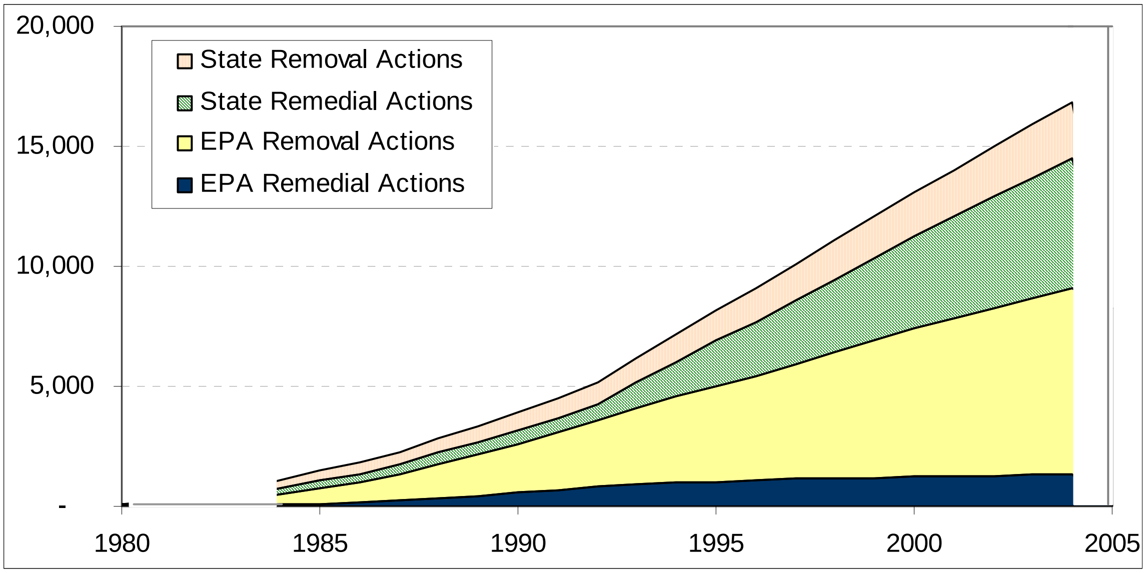
[1] The current version of this study is incomplete. By agreement with the EPA Science Advisory Board's Environmental Economics Advisory Committee, the analyses in Chapter 5 are not completed, only described. The agreed-upon process is for EPA to provide a description of the data and proposed methodology and submit a completed analysis based on input received from the Advisory Panel on the intended approach.

Figure ES.2 illustrates these results. States report very large numbers of sites "in need of attention," suggesting that this level of effort could continue for some time.

Figure ES.2. Total Superfund Responses

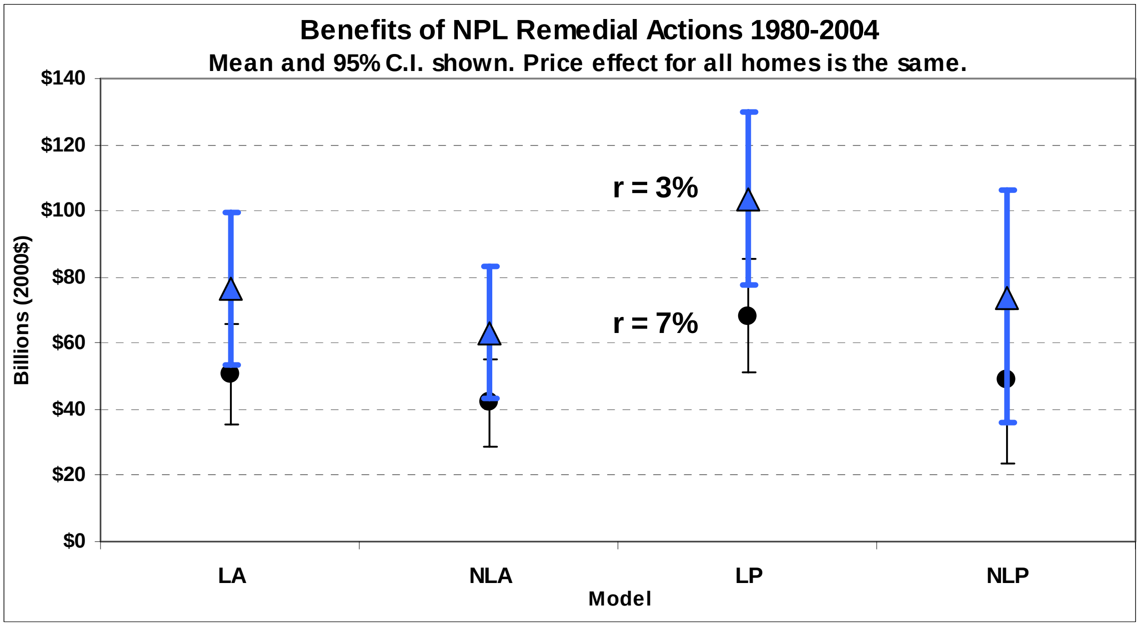


Chapter 4 presents an analysis that captures part or all of several benefits. It is a benefits transfer analysis of results from nine studies that have been published in the peer-reviewed literature that use market data about residential property sales.[2] This study performs a meta-analysis of the prior research, and applies the results in a benefits transfer analysis to all those NPL sites where remedial action occurred during the period 1980-2004. The meta-analysis indicates that homes within 2.5 miles of an NPL site experience a 7.4% decline in value at the time the site is discovered, or about $10,000, and that for most sites this decline is reversed after definitive plans for remedial action have been made. The negative price effect is non-linear, so homes closer to the NPL site boundary suffer a greater effect. The benefits transfer analysis yields a partial estimate of benefits; it excludes benefits not likely to be reflected in home prices (e.g., ecological values) and benefits created by other actions attributable to Superfund (e.g., health risk reductions due to removal actions, or increased preparedness to respond to certain emergencies due to Superfund-sponsored research and training). Four different models are used for the benefits transfer analysis.

The mean estimates of the benefits measured by the four models range from $63-$100 billion over the period 1980-2004 (using a 3% discount rate). The 95% confidence intervals range from a low of $41 billion to a high of $130 billion. The best point estimate of the present value (1980, r=3% in year 2000$) of the benefits of NPL remedial actions for the first 25 years of the Superfund program appears to be about $63 billion. These results (for discount rates of both 3% and 7%) are shown in Figure ES.3. Converting these total estimates into annualized values yields an estimate of $3.6-$5.9 billion per year, assuming a 3% discount rate, with a best point estimate of $3.6 billion per year.

[2] The technical name for the approach these studies take is the hedonic price method.

Figure ES.4. Present Value of the Benefits of NPL Site Remedial Activities, 1980-2004
(Billion 2000$, Base year 1980, 2.5 miles)



Note: Only a portion of the total benefits of Superfund is captured in these estimates. See text.

Chapter 5 contains descriptions of several effect-by-effect approaches that are proposed to estimate some of the health and ecological benefits of Superfund. These approaches are designed to avoid problems associated with risk-based data that have been proposed for use in similar benefits estimates in the past. The basic approach to the health effects is to estimate the number of cases of various negative health outcomes that will be avoided using either epidemiological or integrated exposure uptake biokinetic models, and a cost of illness approach to valuing these avoided health outcomes. For ecological benefits, the proposed approach is to use information from natural resource damage assessments to illuminate the type and magnitude of ecological benefits created by Superfund. Monetary values for a fraction of these benefits can be obtained, but adequate data do not appear to be available to quantify or monetize the ecological benefits of response actions at this time. Finally, several possible approaches to quantify the benefits of protection and cleanup of groundwater are proposed, along with one to monetize these benefits. However, none of these analyses is completed in the current draft of this study. Once this analysis is completed, these benefits cannot be added to the benefits estimated in Chapter 4 due to possible double counting.

Chapter 6 contains a detailed description of a number of benefits that cannot be quantified at this time.

The report concludes with a short summary and suggestions for future research that would aid in the regulation and management of hazardous substances.

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CHAPTER 1: INTRODUCTION

Background

Growing public awareness that areas such as the Love Canal neighborhood in New York, the "Valley of the Drums" in Kentucky, the Stringfellow Acid Pits in California, and other sites across the nation were contaminated with hazardous substances, much of it industrial waste, sparked a national controversy in the 1970s. Dramatic events, like the 1978 fire at an illegal hazardous waste site in Chester, Pennsylvania that hospitalized over forty firefighters, only added to the sense of urgency (Wildavsky 1995). The ensuing debate over how best to deal with these problems led to the creation of the Superfund program under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980, and the Superfund Amendments and Reauthorization Act (SARA) in 1986. Together, these and related laws established a federal program for preventing, mitigating, and responding to releases of hazardous substances that might threaten human health and the environment. The term "Superfund" in this chapter will refer to this entire system of laws, regulations, and activities.

Superfund has many areas of accomplishment. It established a federal trust fund to pay for response to releases and other costs of implementing the statutes, and complementary liability mechanisms to recover these costs from the polluters. It led to support for communities that were burdened with hazardous material sites so they could better understand and participate in decisions about what to do with them. Superfund created a program for developing and deploying knowledge and technologies to better manage hazardous substances. It provided training for thousands of first responders (fire fighters, police, emergency room nurses, etc.) so they could detect and identify hazardous substances in order to protect themselves and the public. It has enabled the restoration of hundreds of communities and ecosystems. Finally, Superfund created a powerful incentive for innovation to reduce the need for hazardous substances in the economy and the amount of hazardous waste that is generated.

Through these efforts, the Superfund program has led to many benefits. These include reduced human health risks for cancer, lead poisoning, acute injuries involving hazardous substances, and probably birth defects. These benefits also include improved environmental quality at thousands of sites across the country, and the protection of a substantial portion of the nation's groundwater. CERCLA, SARA, and related laws have also increased knowledge about and capability to deal with accidents involving hazardous substances through research, development, and training. Recently, these capabilities have proven useful in counter-terrorism planning and response.

Contamination with hazardous substances is a massive problem. Over the last 24 years, the U.S. Environmental Protection Agency (EPA) has responded thousands of times under the authority of Superfund legislation (CERCLA and SARA) to deal with the problem of hazardous substances in the environment, and Superfund continues to respond to over 300 new (or newly discovered) releases every year. These actions have halted the exposure or potential exposure of millions of people to hazardous substances and permanently destroyed or isolated many tons more. R. N. Andrews referred to CERCLA, SARA, and related laws in the history of American environmental policy, describing that "the transformation of waste management practices was one of the most impressive yet least noted successes of American environmental policy" (1999, 249).

This study, the Superfund Benefits Analysis (SBA), has four objectives: to *enumerate* the benefits of the Superfund program, to *describe* each one, to *quantify* those benefits for which the appropriate data are available, and to *monetize* benefits when possible. It is a retrospective study, covering the benefits resulting from activities during the period 1980–2004. It looks at a wide array of programs and policies, as discussed below. Although this study is not, strictly speaking, a regulatory analysis, it follows the spirit and intent of guidance for regulatory analysis as closely as possible, such as EPA's *Guidelines for Preparing Economic Analyses* (EPA's *Guidelines*) and the Office of Management and Budget's *Circular A-4* (U.S. Environmental Protection Agency 2000, Office of Management and Budget 2003).

Original research was conducted for the current study. In addition, the current study summarizes and utilizes the large body of previous research on Superfund and related issues. This literature includes peer-reviewed papers, government reports, and prior external analyses of the program (e.g., Office of Technology Assessment 1989; Hird 1994; Probst and Konisky 2001; Hamilton and Viscusi 1999a) for concepts, methods, and data.[1] Notably, this study employs benefits transfer, which is a method that relies strongly on previous research (Rosenberger and Loomis 2003).

This study attempts to identify as comprehensively as possible the full range of Superfund benefits. Most public debate about and prior research on the Superfund program has focused almost exclusively on the NPL program, for reasons discussed in Chapter 2 (exceptions include pp. 153 and 186 of Wildavsky 1995; Chapter 3 of Probst and Konisky 2001; and Anderson, Thompson, and Suk 2002). An important outcome of this focus is that there are more data available about the NPL than on other parts of Superfund. Although EPA makes data available in multiple ways that are suitable for many groups (see Appendix A), gaps in the available data have limited the amount of quantification and monetization possible for benefits associated with non-NPL parts of Superfund. Nonetheless, by at least enumerating and describing these other benefits, the current study will improve the understanding of the value of the Superfund program. However, as a result of these gaps, the quantitative estimates of the benefits of the Superfund program presented in this study are likely to be biased downward, perhaps significantly.

Because numerous programs and activities are created by Superfund, it is helpful to use the term "approaches" as discussed in Chapter 4 of *EPA's Guidelines* . In this study, six basic approaches taken under Superfund are defined, as well as nine categories of benefits, as shown in Figure 1.1. These approaches are a useful way to conceptualize what the Superfund program does and are defined later in this chapter. However, these approaches do not necessarily match the programmatic elements of the Superfund Program (e.g., remedial investigation/feasibility study, remedial design, public health assessments by ATSDR, etc.). In most cases, more than one

[1] The book *Calculating Risks?* (Hamilton and Viscusi 1999a) contains research that also appeared in peer-reviewed journals (see p. xi of that volume), and for convenience the book will be referred to instead of the journal articles (e.g. Hamilton and Viscusi 1995; Viscusi, Hamilton, and Dockins 1997; Hamilton and Viscusi 1999b; Viscusi and Hamilton 1999; Gayer, Hamilton, and Viscusi 2000; Gayer 2000).

program or activity is included in each approach, while individual programmatic elements can be described as taking one or more approaches.

Figure 1.1 shows nine benefit categories, divided into "Fundamental" and "Embedded" categories. The fundamental benefit categories are those found in the EPA's *Guidelines for Conducting Economic Analyses* (Exhibit 7-1, p. 67) and are the most basic reasons for the Superfund program: to mitigate human and ecological health risks, to improve other amenities, and to reverse environmental damage to materials.[2] In many cases, these benefits are generated directly. However, there are other important outcomes of the Superfund program that are labeled embedded because they are direct objectives of the Superfund program and would likely be ignored if only the Fundamental benefit categories were considered. Of course, the embedded benefit categories are valued largely because they lead *in*directly to the fundamental benefits (or to lower costs). However, it is not possible to quantify any future fundamental benefits, so the distinction between fundamental and embedded benefit categories is a response to the difficulty in measurement. In the current study, only fundamental benefits are quantified, so no issue of double counting arises.

Figure 1.1. Approaches Taken Under Superfund and Resulting Benefit Categories

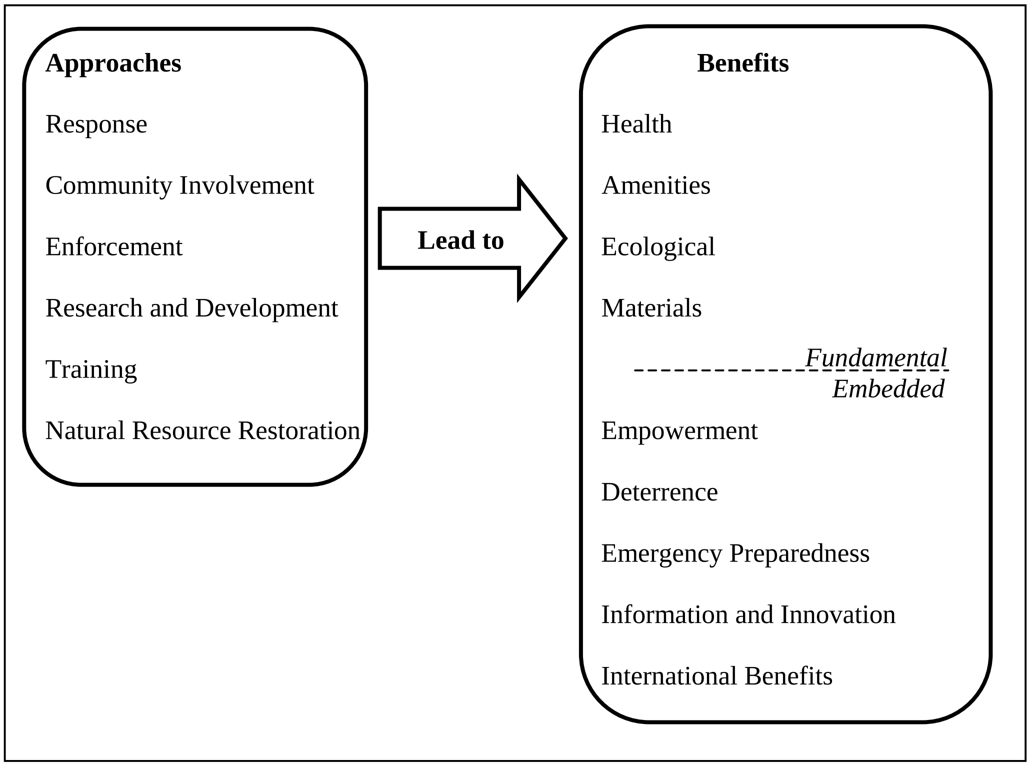

Figure 1.1 also shows the essential relationship between approaches and benefits. There are few one-to-one relationships between approaches and benefits. In general, several of the approaches contribute to each benefit category. The current study focuses on the benefits, shown on the right, but also describes the approaches where appropriate.

[2] The names of the fundamental benefit categories have been changed slightly for clarity.

The best known part of Superfund is the work to find remedies to actual or potential releases of hazardous substances (or, simply, "releases") at sites on the National Priorities List (NPL). These are part of the "Response" approach shown in Figure 1.1. Often, remedial action involves removal or destruction of the hazardous substances, but sometimes it involves containing them for the long-term in specially engineered systems. The NPL was originally created as a list of the worst hazardous substance sites in the country, but in the last decade many of the most serious problems have come to be addressed by state programs, often overseeing private remedial actions, and the NPL has become a tool for addressing the subset of worst sites at which federal resources are needed (e.g., abandoned sites), or at which federal enforcement powers are needed.

The remainder of this chapter addresses issues identified in pp. 5-17 of EPA's *Guidelines for Preparing Economic Analyses*, as applicable to a retrospective analysis, in order to provide a framework for understanding the SBA.

Problem Definition

The Superfund program addresses the problem of actual or potential uncontrolled releases of hazardous substances into the environment.[3] By the time CERCLA was passed in 1980, improvement of hazardous waste management in the United States was already under way following the passage of the Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA) in 1976. These laws governed the active production and controlled release (such as landfill disposal) of hazardous substances. However, there was growing evidence that substantial quantities of uncontrolled hazardous substances existed in places and in conditions throughout the United States that could present human health and ecological risks, or might reasonably be expected to do so in the future. These hazardous substances were the result of *prior* actions, which neither TSCA nor RCRA had addressed directly. Moreover, it was clear that many sites with hazardous substances at them had *potential* uncontrolled releases that had not yet leaked or spilled. Lastly, it was clear that accidents and illegal activities also created new uncontrolled releases (Landy, Roberts, and Thomas 1994, ch. 5).

Since the passage of CERCLA, many previously hidden instances of contamination have been discovered and new releases of hazardous substances have continued to occur. Most of these contaminations are located at either current or former industrial sites or waste disposal sites, but some are at military bases and facilities associated with nuclear weapons production. The Superfund program deals with places where releases have both occurred due to deliberate actions (sites) as well as those due to accidental actions (spills).

[3] Although it is common to use the terms 'hazardous substance,' 'hazardous material,' and 'hazardous waste' interchangeably, these terms have different statutory definitions. CERCLA and SARA authorize EPA to address hazardous substances, including wastes as well as other types of substances (e.g., product spills), but *excluding* petroleum and petroleum products. Oil spills are dealt with under the Oil Pollution Act by agencies authorized to address hazardous *materials*. The management of hazardous wastes, including the treatment, storage, and disposal of hazardous wastes, is regulated by the Resource Conservation and Recovery Act. CERCLA and SARA deal with *uncontrolled* releases of hazardous substances, both wastes and non-wastes.

It is important to place the concepts of *toxic, hazard,* and *risk* into perspective (Paustenbach 2002). Toxicity is an inherent property of all substances; that is, any chemical can cause adverse effects in sufficient concentrations (i.e., "the dose makes the poison"). In contrast, hazards are specific situations that raise the likelihood or severity of an adverse outcome, such as exposure to a substance at concentrations that could lead to an adverse effect. The term risk is used to refer to the probability (or likelihood) that an adverse health outcome will occur in a person or group exposed to a specific concentration of a hazardous agent. For ecological systems, risks are the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. Typically, risks associated with uncontrolled releases of hazardous substances are the result of a completed exposure pathway (CEP) linking the release with sensitive receptors (i.e., people or wildlife).

The principal inherent dangers presented by hazardous substances are negative health effects, including both acute effects (e.g., acute poisoning, injuries from fires or explosions) and a variety of long-term effects (e.g., cancers, birth defects) (Johnson 1999; Bove, Shim, and Zeitz 2002; Dolk and Vrijheid 2003). Hazardous substances found at Superfund sites that cause such effects include: lead, arsenic, benzene, trichloroethylene, and mercury, and over 250 other hazardous substances (Agency for Toxic Substances and Disease Registry 2003). In addition, the Superfund program sometimes deals with substances that are explosive or radioactive (Probst and Konisky 2001, 20; Johnson 1999, 85).

In order for a hazardous substance to present a health risk, a pathway for exposure to that substance must exist. A completed exposure pathway occurs when five elements are present: a source of contamination, an environmental media and transport mechanism, a route of exposure, a point of exposure, and a receptor population (for a general discussion of this issue, see Williams and Paustenbach 2002.) Since 1990, completed exposure pathways for hazardous substances have been found at over 15,000 sites (NPL and non-NPL) in the United States (Agency for Toxic Substances and Disease Registry 2003). Exposure to hazardous substances varies significantly from site to site, and human exposure to hazardous substances may occur through multiple routes. Data on human exposure due to uncontrolled releases of hazardous substances exist for some cases but no collection of exposure data useful for an overall analysis of expected risk is available.[4] Research based on site-specific investigations at NPL sites suggests that the most important exposure medium is ground water, followed by soil, air, biota, and other media, and that ingestion is by far the most important exposure pathway, followed by dermal contact and inhalation (Hamilton and Viscusi 1999a, 24-57). Nonetheless, the lack of definitive exposure data frustrates this area of research (Harrison 2003).

Uncontrolled releases of hazardous substances can also damage ecological systems that provide services to both humans and other species. Examples of ecological risks include contamination of ground water, wetlands, lakes and rivers, estuaries, and grasslands (Jones, et al. 1999; Morey et al. 2002). This contamination can reduce organism survival and growth rates, change species

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[4] Specifically, exposure and risk information for the maximally exposed individual (MEI) exists for most sites on the National Priorities List (NPL), but these data are contained in individual baseline risk assessments for each site and are not compiled in a single place, so are not readily accessible. Further, neither data for typical individuals nor population exposure data exist for these sites, and even less information is available for non-NPL sites with uncontrolled releases of hazardous substances, which are far greater in number (see Chapter 2).

composition, reduce ecosystem productivity, and have other effects which can lead to reductions in valued ecosystem services such as water filtration, nutrient cycling, fishing, and use of habitat.

Without the intervention of Superfund, the magnitude of such effects likely would have worsened over time, as more and more containers and facilities holding hazardous substances failed, as leaked substances spread through ground water, and as more people came to live near or even on such sites.

It is important to recognize that a crucial part of the hazardous substances problem in 1980 was that very little was known about the nature or extent of the problem. While there were indications that hazardous substances had contaminated many places throughout the country, and it was known that some of these substances had physiological effects, there was a great deal of uncertainty as to the number of such problems and the nature and magnitude of the associated risks to human health and the environment. There was also very little knowledge about how best to remediate contaminated sites. This lack of knowledge is unsurprising, given the laws and incentives up to 1980; there was no reason for private industry to invest in these scientific and engineering questions, and before the existence of a public policy problem was identified, little reason for government to sponsor such research (Norberg-Bohm 1999; Jaffe, Newell and Stavins 2002). However, this lack of knowledge created uncertainty and concern among the public about the potential impacts of hazardous substance releases on the health and well-being of their families. The Superfund program has greatly reduced the uncertainty associated with the problem of uncontrolled releases of hazardous substances and provided much better tools to manage the problem.

As part of the Federal Government, the Superfund Program is subject to Executive Orders, which in some cases mandate EPA and other agencies to pursue objectives that may have beneficial effects that are not included in either the fundamental or embedded categories. For instance, Executive Order 12898 requires federal agencies to identify and address, as appropriate, "disproportionately high and adverse human health or environmental effects … on minority populations and low-income populations" (President of the United States 1994). Executive Order 13132 requires consultation with affected state and local governments on rules that have "substantial direct effects on the States [and local governments] … or on the distribution of power and responsibilities among the various levels of government" (President of the United States 1999). Executive Order 13175 recognizes the unique legal relationship between the United States and Indian tribal governments as set forth in the Constitution, treaties, and other documents. It seeks to establish regular and meaningful consultation and collaboration with Indian tribal governments (President of the United States 2000). To the degree that the Superfund program achieves these goals, it can be said to be creating beneficial effects.

Reasons for Market Failure and the Need for Federal Action

Beginning in the nineteenth century, modern science and industry introduced compounds into the environment not found in nature, but useful for their new properties, such as persistence and ability to control pests. Unfortunately, these same properties make these materials potential hazardous contaminants. As industrial processes in the United States grew in size and began to use greater amounts of hazardous substances, contemporary waste management practices (described as "cheap and casual" in Andrews 1999, 245) were applied to hazardous materials as well. However, the effects of hazardous substances could be very different from those of traditional wastes, for which odor and infectious disease were the principal problems, so these practices resulted in significant potential exposures of humans and the environment to hazardous chemicals (Hays 1987, ch. 6). This situation began to change in 1976, when the Resource Conservation and Recovery Act (RCRA) was passed, but in the meanwhile the combination of lack of awareness of the attendant risks of hazardous wastes and little concern about these risks resulted in a sufficient number of abandoned hazardous waste sites that the public and Congress determined that federal action was needed (Hird 1994).

Problems of poor risk management fall into the category of *externalities*. Externalities are effects that are created by economic activity (e.g., manufacturing) but are not included in the decision-making about or the cost assigned to that activity. Manufacturers who produced hazardous wastes could legally dispose of these wastes without significant concern about future risks. Manufacturers could store wastes at their facilities, which they could readily abandon if the wastes became problematic without any sense of stewardship for the hazardous wastes. Waste storage and disposal facilities were also not required to consider potential risks. Government action is usually required to correct externalities (Baumol and Oates 1988).

An additional problem is the lack of incentives for discovery and innovation that are aimed at providing public goods, such as environmental quality (Orr 1976; Baumol and Oates 1988; Jung, Krutilla, and Boyd 1996). Public goods are products or services that if supplied to one person are available to others at no extra cost. Generally, public goods are considered non-rival in that consumption by one person does not reduce the amount available to others, and are considered non-excludable in that the producer is unable to prevent anyone from consuming it. For these reasons, markets in public goods rarely exist, which is why there are few incentives for discovery and innovation that are aimed at producing the public goods. Thus, there may be no market demand whatsoever for environmental information. In this case, private firms tend to find it uneconomic to invest in research and development to provide either information or technologies (Taylor, Rubin, and Hounshell 2003). For the case of sites contaminated with hazardous substances, the cost of remedial action is generally not justified by increased returns in real estate markets. Thus, government action is required to both learn about and remedy contaminated properties.

Defining Superfund Approaches

CERCLA and the various Superfund programs address the problem of uncontrolled releases of hazardous substances using a wide range of approaches. The federal government implements many of these approaches. CERCLA and SARA are the authority for all of the federal actions, and they provide strong support for many state and private actions. The federal government also provides significant budgetary support for state environmental programs. Hence, the state and private actions can be partially attributed to the federal statutes. Together, federal, state, and private industries take actions under Superfund, which can be classified into six basic approaches, as shown in Figure 1.1 and defined in Table 1.1.

Table 1.1. Superfund Approaches

Name	Description
Response	Remedial Activities: Activities associated with sites (including the NPL, non-NPL federal sites, state sites, private sites) and spills to reduce the amount, toxicity, and mobility of hazardous substances in order to reduce human health and ecological risks. As used here, "cleanup" includes institutional controls designed to prevent exposure. Remedial actions tend to address only actual releases, but may address potential releases as well.
	Removals: Activities designed to address immediate human health risks due to uncontrolled releases of hazardous substances. Removals may occur at all types of sites and spills, and may be taken by federal or state agencies. Emergency responses include actions taken following terrorist attacks. Removal actions may address either potential or actual releases, and account for most of the potential releases addressed by response actions.
Community Involvement	Activities that assist citizens and businesses located near sites undergoing cleanup to better understand and participate in the process.
Enforcement	Actions taken by federal and state governments to effect response actions by potentially responsible parties, to recover costs of federal and state responses, and to restore natural resources.
Research and Development	Efforts to better understand hazardous substances and their effects on human health and the environment, to develop new technologies and strategies for reducing the risks of hazardous substances, and to lower the cost of cleanup.
Training	Activities designed to improve the capability of professionals (e.g. paramedics and firemen) and organizations (e.g. hospitals and municipal governments) that may be required to address releases of hazardous substances, often state and local first responders and first receivers (i.e., hospital emergency departments). Includes homeland security preparedness.
Natural Resource Restoration	Actions taken to return ecological features (rivers, prairie, scenic vistas) back to conditions similar to those before hazardous substances were introduced and thus restore the flow of valued services (e.g., fishing, Tribal uses, wildlife habitat, protection of resources for future generations).

Response is the most direct and obvious of the approaches taken under the Superfund program, and by far the most expensive, accounting for perhaps as much as 90 percent of all resources (public and private) expended under CERCLA and SARA.[5] Superfund is not really a regulatory approach, but encompasses a broad set of activities that can be grouped into two sets, based largely on size and underlying legal authority. Superfund responses are designed to address the continuum of health and environmental risks ranging from emergencies to long-term problems. Technical options include containment, chemical neutralization, biodegradation, incineration, ground water treatment, institutional controls (e.g., temporary access control by fencing or permanent restrictions on activities such as digging), and others. Statutory authority for removal actions, and in particular time-critical removals, provides for rapid response where the problem needs to be addressed in an urgent manner. Time-critical removals are conducted without the level of administrative and planning activities needed to support remedial actions. They are typically used to respond to chemical spills, human health threats that might cause harm from short-term exposures (e.g., lead-contaminated residential soils), and situations that may cause a sudden release (e.g., leaking drums). Remedial actions and some removal actions (non-time

[5] This value is calculated by adding EPA's expenses that are directly related to response (~$1 billion annually), to Department of Energy, Department of Defense, state, and private expenditures (>$4 billion annually), assuming the latter four all go to response, and dividing this by the sum of all Superfund-related expenditures (~$5.5 billion annually) (Probst et al. 1995, 111; Probst and Konisky 2001, 9-12).

critical removals) address situations where the response can be taken in a more deliberate fashion, allowing for more in-depth planning and evaluation. Remedial actions are limited by regulation to sites on the NPL.

However, the distinction between remedial actions and removals is not as sharp as it might seem. The types of response actions that can be taken (e.g., waste treatment, excavation and disposal, providing alternate water supplies) are identical under both sets of authorities, except that permanent relocation of residents is only specifically authorized as a remedial action. In practice, the removal program is often used to address completed exposure pathways with higher levels of exposure, while the remedial program addresses risks where there are no current exposures or where the levels of exposure allow for a more deliberate planning process.

State agencies and private firms also respond to potential or actual releases of hazardous substances. The benefits of these responses are partially attributable to Superfund due to funding and technical assistance provided to states, the ability to use (or at least threaten to use) CERCLA's liability provisions, and the availability of information and technological innovations created by the Superfund program. Many, but not all, of these state and private responses are smaller and simpler than those handled by the federal government (Probst and Konisky 2001, 93-97). Further, state hazardous substance cleanup programs rely heavily on the federal Superfund program in a number of ways. The federal Superfund program has created the knowledge, technology, and skills needed to assess the risks of hazardous substance sites and clean them up safely. In addition, the existence of the Superfund law, with its very significant liability provisions, supports state programs, which can use the threat of federal enforcement actions to elicit cooperation from private firms. Moreover, under the Core State and Tribal Cooperative Agreements, the federal Superfund program has invested over $300 million to build and maintain state capabilities (see also Chapter 3).

The second approach includes efforts to improve the involvement of communities near remedial action sites. These efforts help individuals, families, and communities understand sites near them, and participate in Agency decisions about those sites. One example is the Technical Assistance Grant (TAG), which is described in Chapter 6 of the current study.

The third approach includes enforcement efforts, which have brought far more resources to bear on the problem of releases than the federal government had available. This has led to many more response actions and the cleanup of many more contaminated sites. In addition, enforcement activities help ensure that the parties responsible for the contamination problem pay the costs of cleaning it up. That is, enforcement helps make certain that the "polluters pay" as much as possible. Much of the authority for enforcement derives from the stringent liability provisions of Superfund, along with the enforcement provisions. These provisions are also powerful incentives for private innovation in products and processes that need fewer hazardous substances as inputs and produce less hazardous waste, although RCRA and other laws also contribute to this effect. These provisions also serve as a backstop to state response programs and help encourage private firms to respond to releases on their own.

The fourth approach to address the problem of uncontrolled releases of hazardous substances is research and development, which are conducted by EPA's Office of Research and Development

(ORD) and Environmental Response Team (ERT), the Agency for Toxic Substances and Disease Registry (ATSDR), and the National Institutes of Environmental Health Sciences through the Superfund Basic Research Program (SBRP). These organizations also engage the fifth approach, the training for a variety of groups, including first responders (e.g., firefighters), first receivers (i.e., emergency room staff), and scientists. While there are still limitations in the understanding of hazardous material risks and in the methods and technologies for managing releases, these research and training efforts have gone a long way toward improving our scientific knowledge and practical capabilities since 1980.

The fifth approach, called training, involves efforts to make professionals in many different fields more capable of identifying and responding safely to uncontrolled releases of hazardous substances. It differs from the empowerment approach in that it is focused on professionals and relevant organizations like hospitals and municipal governments, not the public. Many different Superfund-supported organizations conduct training in this sense, including especially OSRETI , the Environmental Response Team (ERT), and ATSDR. These activities include training to deal with some types of homeland security issues, for instance attacks with biological agents.

The sixth response-related approach is natural resource restoration,[6] which frequently occurs at NPL sites, but which can also occur at accidental spills. These efforts are aimed mainly at restoring ecological functions that have been damaged or destroyed by uncontrolled releases of hazardous materials. Natural resource restoration has become an increasingly important approach taken under Superfund in the last decade. Natural resource restoration activities are undertaken by organizations that act as public trustees, including several federal departments (e.g. Commerce and Interior), states, and tribes, but not EPA. This approach is included in this discussion for completeness, and the analysis of natural resource restoration in Chapter 5 is included because it is the only approach available to quantify and monetize ecological benefits associated with the Superfund program.

Defining Superfund Benefits

In this section, the types of benefits created by the Superfund program are briefly described, as are the methods used in the remainder of the study to quantify and monetize them. Subsequent sections of this study that discuss these benefits are identified.

The framework described in section 7.4 of EPA's *Guidelines for Preparing Economic Analyses* identifies four benefit categories: human health, amenities, ecological/agricultural, and materials. In this study, these four are labeled as fundamental benefits because they are the basic reasons for the Superfund program and are the benefits linked in economic theory to improvements in welfare. The Superfund program creates benefits in all four of these benefit categories, as defined in Table 1.2.

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[6] Executive Order 12316 (46 FR 42237) delegated the Presidential authorities of CERCLA to various federal agencies. While EPA is charged with implementing most of the response provisions of CERCLA and many of the enforcement provisions, the natural resource damages provisions of trustees are assigned to the various federal agencies (e.g., the Departments of Agriculture, Commerce, and Interior). CERCLA also authorizes states to act as trustees. Hence, for the purpose of conducting a comprehensive evaluation of Superfund benefits, this study is not limited to those programs implemented by EPA.

However, there are real but unmeasurable benefits of the Superfund program, labeled as embedded. These embedded benefit categories are valued largely because the lead *in*directly to the fundamental benefits (or to lower costs). However, it is not possible to quantify any future fundamental benefits, so the distinction between fundamental and embedded benefit categories is a means of identifying important outcomes that might be ignored if only the direct, fundamental benefits were considered. Another way of making this distinction might be to think of the fundamental benefits as direct, and the embedded benefits as describing routes by which the fundamental benefits may be indirectly achieved.

In Chapters 3, 4, and 5, only the fundamental benefits are quantified and monetized. The embedded benefit categories are not. The only exception to this statement is for the property-value based estimate in Chapter 4. As described in that chapter, it is not possible to know exactly what benefit categories are being measured.

Table 1.2. Brief Definitions of Benefit Categories

Benefit	**Definition**
Fundamental	
Health	Actions taken to improve human health, which may include reducing the magnitude of exposure to contaminants, reducing the number of exposure pathways, reducing the length of exposure, and providing information so that individuals can reduce their exposure or seek medical treatment.
Amenities	Any feature of a place, object, or experience that enhances its attractiveness and increases the user's satisfaction, but is not essential to the place, object, or experience. In the context of Superfund, amenities include the removal of unsightly structures, the reuse of abandoned property, the avoidance of the stigma associated with contamination, and the reduction of perceived health risk from uncontrolled releases of hazardous substances.
Ecological	The restoration and maintenance of service flows to both humans and nature from natural resources, such as land, ground water, and habitat. These services may include recreation, clean water, shelter, food, timber, and others.
Materials	The reduction of risk and perceived risk associated with non-residential (i.e., commercial and industrial) properties, and the ensuing ability and willingness of the business and financial community to use these properties.
Embedded	
Empowerment	The ability of people who live near Superfund sites (especially NPL sites) to learn about the site(s) of interest, have questions about the site(s) answered, participate in decision-making associated with the site(s), and hold the relevant organizations accountable.
Deterrence	Incentives for firms and individuals that may create or use hazardous substances to handle and dispose of them properly and to avoid uncontrolled releases to the environment.
Emergency Preparedness	The knowledge, skills, organization, and technologies necessary to limit harm to human health and the environment following disasters involving the release of hazardous substances. Includes preparation for natural disasters, homeland security measures, and similar activities.
Information and Innovation	Increases in knowledge and technical capabilities created as a result of research, development, and deployment supported by the Superfund program. This includes both basic scientific research as well as efforts to develop and build experience and confidence in new technologies.
International Benefits	Any benefits from any of the other benefit categories that accrue to people or organizations outside of the United States. These benefits are generally coordinated with the State Department and often involve overseas response actions or training.

In the *health* category, the Superfund program prevents potential releases, interrupts exposure pathways, and destroys or isolates hazardous substances, reducing both morbidity and mortality risk. Potential negative effects that are prevented include health endpoints such as acute effects (e.g., explosions or poisoning), cancer, and long-term non-cancer effects (e.g., increased birth defect rates). These benefits can be described as reductions in actual health risks. Some aspects of health benefits are discussed in the literature review in Chapter 2; others are discussed in Chapter 5.

The *amenities* benefit category is associated with the removal of unsightly facilities, often abandoned, as well as the psychological benefits associated with reducing the uncertainty and fear of unknown risks that might exist at nearby hazardous substance facilities. Direct amenities include improvements in aesthetic attributes associated with environmental commodities. This includes improvements in taste, odor, appearance, or visibility. In short, these benefits are determined by how the senses are affected and how an individual's welfare is changed as a result. This class of benefits is unique in that the focus is on the sensory experience and not on a physical or material effect. Despite this conceptual distinction, aesthetic benefits are often intertwined with other benefit categories, such as health and recreation. A policy that improves air quality, for example, might simultaneously improve visibility and reduce mortality risks associated with airborne contaminants. New treatments for drinking water might reduce health risks as well as alter the taste and odor of tap water. These relationships may make it extremely difficult to separately quantify and value improvements in aesthetic qualities. Many types of policies can be expected to have some impact on these kinds of amenities, and they may be the focus of a given policy. Chapter 6 of the current study discusses benefits in the amenities category.

Another part of the *amenities* benefit category is reduced uncertainty about the nature and extent of actual health risks associated with releases. By providing information about sites where releases of hazardous substances have occurred and by implementing remedies at these sites, the Superfund program also reduces perceived health risks. Even in cases where there may be little health risk, psychometric research has shown that individuals can experience genuine discomfort and anxiety if exposed to risks that are dreadful, imposed by others, out of their control, hard to understand, or have other features that hazardous substance sites are likely to have (Slovic, Fischhoff, and Lichtenstein 1979; Slovic 1987). These effects can lead to larger, more permanent damages, sometimes called stigma (Gregory, Flynn, and Slovic 1995; Satterfield et al. 2001). These issues are discussed in Chapters 2, 4, and 6 of the current study.

Benefits of Superfund in the *ecological* category come about through the restoration, or enhanced recovery, of natural resources that have been damaged by uncontrolled releases of hazardous substances. These benefits include restoration of market products (e.g., commercial fishing) as well as a number of non-market ecological benefits. Some non-market benefits can be called "active uses," such as recreational fishing, while others can be called "passive uses." Passive uses include maintaining the option to use a natural resource in the future (e.g., planning to visit a nearby park or golf course), the enjoyment of knowing that natural resources are preserved for future generations (e.g., maintaining ground water quality so it can be used for drinking in the future), and preserving ecosystem services that both humans and wildlife depend on (e.g., nutrient cycling).

In the category of benefits due to *materials restoration*, the Superfund program transforms unusable commercial and industrial properties back into productive real estate. In many cases, the avoided damage is associated with removal of both uncertainty about the presence of hazardous substances and with uncertainty about the cost of restoring the site to a usable condition. It is important to note that these benefits are related to but independent of the liability provisions of the Superfund program.

The category *empowerment* refers to situations in which citizens are knowledgeable about and involved in Superfund-related decisions that affect their communities. Empowerment permits citizens to participate meaningfully in actions associated with Superfund and to hold the Agency accountable for its decisions. This benefit category is described further in Chapter 6.

The liability provisions of CERCLA, along with information provisions such as the Toxic Chemical Release Inventory (TRI) and Emergency Planning and Community Right-To-Know Act (EPCRA) provide opportunities for the Superfund program to act as a deterrent to possible hazardous releases. In the enforcement of CERCLA's liability provisions, EPA typically seeks to identify the potentially responsible parties (PRPs), those individuals or organizations responsible for creating or contributing to a hazardous waste site. Benefits in the deterrence category are described further in Chapter 6.

Emergency preparedness is an important but often poorly recognized category of benefits created by the Superfund program. The Superfund program has created a significant portion of the capability of the United States to respond successfully to attacks by weapons of mass destruction. These benefits stem from the large scale of its removal program, which allows for a critical mass of resources and expertise necessary to undertake responses at nationally significant hazardous substance problems (U.S. Environmental Protection Agency 1996). These benefits are described further in Chapter 6.

Superfund benefits in the category of *information and innovation* stem from three basic efforts: basic research into the toxicology and environmental processes associated with hazardous substances in the environment; epidemiology and health impacts information associated with contaminated sites; and technology innovation and transfer associated with various cleanup methods. This benefit category is described further in Chapter 6.

The category *international benefits* refers to any benefits described by any of the previous categories that accrue to citizens of countries other than the United States. It also includes improved relations with other countries as a result of assistance with the management of hazardous substances in those countries, which is a benefit that accrues to U.S. citizens. These benefits can help support environmental, diplomatic, and security goals of the United States. They have been achieved through EPA's Office of International Activities, often in cooperation with the State Department. To achieve these benefits, Superfund staff has provided training to a number of countries in such areas as preparedness, incident response, site assessment, and chemical safety audits. These benefits are described further in Chapter 6.

Study Question and Baseline

This study addresses the question: *What are the benefits of the Superfund program?* For the purposes of this study, the Superfund program includes everything authorized by or attributable to CERCLA and SARA. As discussed above, this includes response actions by EPA, state agencies, and private firms, as well as activities authorized by provisions of CERCLA and SARA taken by various programs and agencies, such as ATSDR, Department of Justice, the TAG program, the SBRP, natural resource trustees, the ERT, and similar activities undertaken by state and local programs that are authorized or supported by Superfund (General Accounting Office 1996, 1999; National Research Council 1997; Johnson 2001).

A retrospective analysis such as the current effort can use reality as the baseline, which is simply the actual history of the management of uncontrolled releases of hazardous substances from 1980–2004. In order to estimate the benefits of the Superfund program, it is necessary to consider a without-Superfund scenario that assumes that no new policies relating to abandoned hazardous waste sites were established in 1980 or subsequently.[7] In this scenario, emergencies due to releases of hazardous substances might have been ignored, or handled as state and federal disasters, as occurred at Love Canal when the Federal Emergency Management Agency took charge. Moreover, this scenario assumes that the research, innovation, training, and enforcement supported by CERCLA and SARA would not have taken place. The benefits of these secondary impacts would be hard to estimate. For instance, capabilities developed with support from Superfund were crucial to recovering from the terrorist attacks in the fall of 2001, when, for example, the EPA Superfund program responded to anthrax contamination and monitored public and worker safety at the World Trade Center. In the without-Superfund scenario, the time and cost to recover from these attacks would likely have been much higher. Similarly, without the enforcement activities of Superfund, more uncontrolled releases of hazardous substances would likely have occurred, and the first responders who would have had to deal with the releases would have been less well prepared because they would not have benefited from Superfund-supported training. Such secondary benefits are only described (see Chapter 6 of the current study) because it would be speculative to attempt to quantify or monetize them.

Methodology

The current study addresses the benefits of the Superfund program for the period 1980-2004. All dollar values are reported in year 2000 dollars using the Consumer Price Index as calculated by the U.S. Bureau of Labor Statistics. Although this study is a retrospective evaluation, and not exactly a regulatory analysis, it was conducted as much as practicable according to the guidance relevant to regulatory analysis (U.S. Environmental Protection Agency 2000; Office of Management and Budget 1992; Office of Management and Budget 2003).

Because of the large size of the Superfund program, the diverse nature of its activities, and the lack of quantitative data available for many aspects of it, a detailed, quantitative analysis of the entire Superfund program is far beyond the scope of this study. Thus, several strategies were employed in order to achieve the study's four objectives of enumerating and describing all of the benefits, and quantifying and monetizing benefits when possible. The description given in the

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[7] See pp. 2-3 of *The Benefits and Costs of the Clean Air Act* for a similar example.

current chapter of the six approaches taken by the Superfund program and the nine benefits categories it creates accomplishes the enumeration and begins to achieve the goal of description. Chapters 3, 4, and 5 provide further description of the benefits created by response actions, and also quantify and monetize some of them. Chapter 6 completes the description of the non-quantified benefits.

Recently, the Science Advisory Board made recommendations on proposals to assess the benefits of EPA programs similar to Superfund (EPA Science Advisory Board 2002). Many of these recommendations are relevant to the design of the current study. One such recommendation is to use existing data as much as possible in the estimation of benefits, but to avoid the application of conservative risk data designed for regulatory purposes. The analyses in Chapters 3, 4, and 5 reflect these and other Science Advisory Board recommendations. It is important to recognize the limitations of the current study. In general, the quantitative estimates capture only part of the benefits and have considerable uncertainty. In particular, the monetized benefits presented in Chapter 4 may underestimate the total benefits of Superfund significantly. In addition, the benefits estimated in Chapter 5 partially overlap those estimated in Chapter 4, and therefore cannot be added.

Thus, benefits transfer analysis will be needed in order to draw on published valuation studies of Superfund (or other hazardous substance) sites (U.S. Environmental Protection Agency 2000, 59-112, 85-87; Rosenberger and Loomis 2003). In a benefits transfer analysis, rather than collecting primary data, the results of existing studies are transferred to the policy being analyzed. The case for which the existing estimates exist is often called the 'study case' and the case under consideration is often called the 'policy case.' In this analysis, the study case varies depending on the benefit being considered, because various studies have looked at different benefits, while the policy case is always the same – the existing Superfund program as a whole.[8]

Because most of the direct benefits of the Superfund program are attributable to responses and most of the available data are related to Superfund response, the number and type of these activities tend to drive the results of this study. Conducting a benefits transfer analysis requires an understanding of the characteristics of the study cases (the previous work used as inputs) as well as the characteristics of the policy case (the situation being studied). Thus, Chapter 3 discusses Superfund responses in some detail.

Like many environmental policies, the Superfund program produces many different benefits that do not have a common metric for valuation. Thus, an "effect-by-effect" approach must be used to create individual values in terms of a common unit of measurement, which can then be aggregated to estimate the total benefits (U.S. Environmental Protection Agency 2000, 59, 62-65). Where possible, effect-by-effect analysis is used. However, the detailed data needed to conduct this analysis are often lacking, so another approach is also used.

[8] Various methodological issues make it necessary to consider subsets of the entire Superfund program in some cases.

One solution to the lack of detailed data for specific effects is the use of a property-based valuation[9], an indirect method for estimating benefits (Freeman 1993, 23-26; U.S. Environmental Protection Agency 2000, 77-79). This approach has the advantage of being based on observed behavior; thus it is often considered more reliable than studies that depend on people's memories or survey responses. In addition, there is a large, high-quality literature on property-based price studies from which to draw for a benefits transfer analysis. However, this approach is also limited because not all benefits may be captured. EPA's Science Advisory Board recently found that "this approach may be a relatively simple way to get obtain *[sic]* a 'ball park' or order-of-magnitude estimate of benefits … However, if this approach is followed, the review of the literature should be updated and restricted to peer-reviewed economics journals" (EPA Science Advisory Board 2002, 3, 22).

A significant disadvantage, however, is that property-based price studies do not provide information on any *specific* benefit category; any effects that are found must be interpreted as the residual effect of *all* the relevant attributes associated with the site. In addition, some benefits are not likely to be incorporated in home prices, such as bequest values that apply across an entire population. Chapter 6 of the current study contains the non-quantified benefits analysis.

Figure 1.2 illustrates the relationships between the benefits of the Superfund program and the various methods of measuring them. Each of the nine benefit categories is shown as a separate, shaded circle. (Not any of the sizes or shapes has a specific meaning). The types of benefits captured by three methods used in the SBA and by the Hamilton and Viscusi (1999b) study are shown by three types of dashed lines.

Property-based pricing studies capture all of the benefits that accrue to the consumers of the product being evaluated; here those consumers are residents close to NPL sites, labeled 'neighbors.' However, it is not possible to differentiate between the different benefits that produce this effect. Because it is based on the results of property-based pricing studies, the analysis in Chapter 4 of the current study has the same properties. Several types of benefits accrue preferentially to consumers residing near NPL sites: health, amenities (including reductions in perceived risks), deterrence (possibly due to better management of hazardous substances at facilities near their homes), empowerment, and ecological (for instance, use of parks at a remediated site near their homes). However, several benefits of the Superfund program are excluded in this type of analysis, including all those benefits that accrue to non-neighbors, such as the nonuse (or passive use) value of natural resources (e.g., rivers) that have been restored to healthy conditions.

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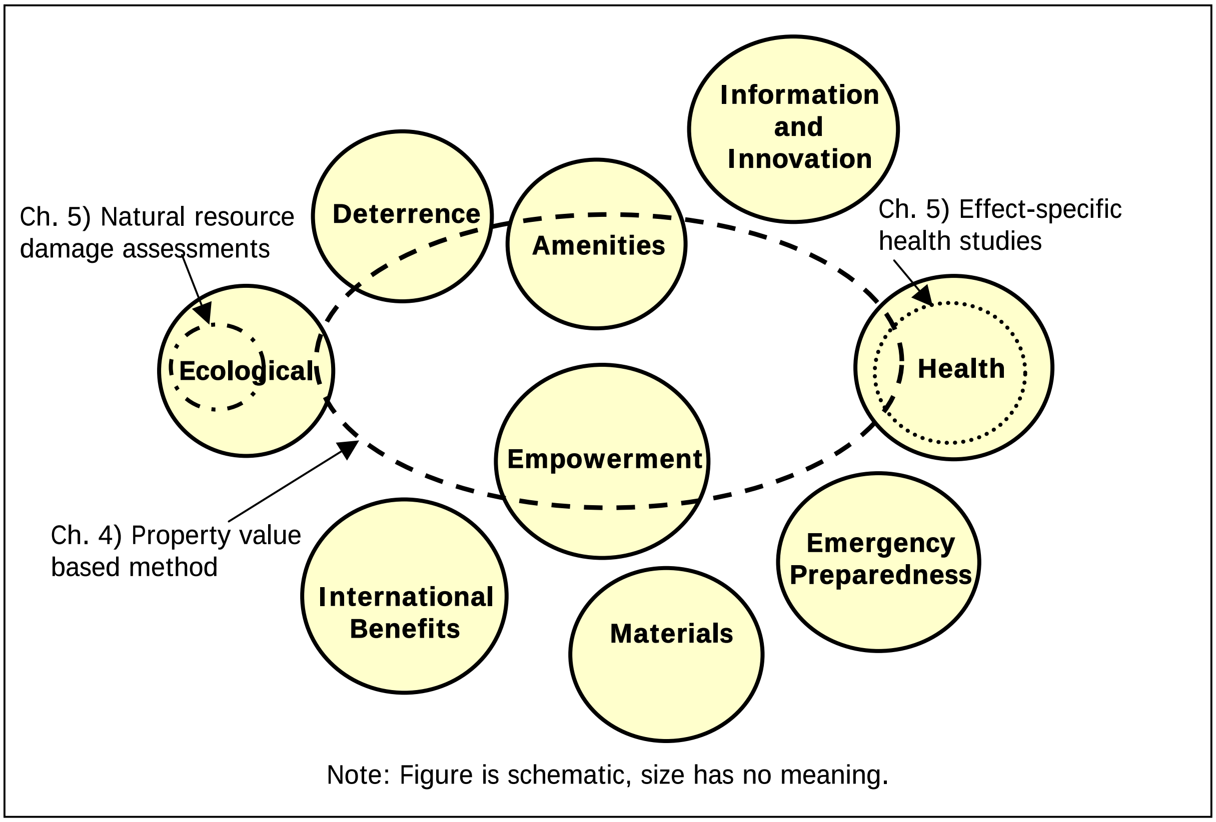
[9] Throughout this study, "property-based valuation" and similar terms are used for simplicity to refer to analyses that rely on hedonic price theory (Taylor 2003).

Figure 1.2 Benefits of the Superfund Program and Quantitative Estimates



Benefits that are associated with improved conditions of natural resources (e.g., a river or wilderness area) are categorized as ecological benefits. Natural resources can also be viewed as assets that provide flows of services over time to other natural resources and to people. When natural resources are damaged, the flows of ecological and human services provided by those natural resources (and thus the values they provide) may be interrupted for some time. Restoring these service flows can create a benefit. Response actions that halt or reverse the exposure of wildlife to hazardous releases can create ecological benefits. In addition, CERCLA authorizes the federal and state governments to act as trustees for the public and seek damage claims in court against potentially responsible parties (PRPs) in order to improve the natural resource and return much of the original service flow (even if a complete restoration is not achieved). There is very limited data on potential natural resource damages, and those that exist address only damages associated with restoration activities, not responses. The Natural Resource Damage Assessments (NRDAs) associated with some of these lawsuits will capture some of these benefits, but for reasons discussed in Chapter 5, not all of them.

Ecosystems also provide services that benefit humans. For example, a freshwater lake may provide recreational and boating sites; a wetland provides a service by being a breeding ground for fish and fowl. Although ecosystems have a profound impact on human well-being, the quantitative assessment of ecological benefits presents a formidable challenge for several reasons. First, natural systems are inherently complex. The many services they provide and how they provide them may be poorly understood, even by the scientific community. Second, ecological risks vary widely in terms of persistence (e.g., eutrophication versus species extinction), geographic extent (e.g., toxic contamination versus global climate change), and the degree to which the overall threat can be predicted (e.g., effects of ozone on crops versus developmental and behavioral effects of chemicals on wildlife populations). Third, many of the less tangible benefits are not readily amenable to monetary valuation.

Structure of the Report

The current study consists of seven chapters and three appendices. This introduction constitutes Chapter 1. Chapter 2 provides a general literature review. Chapter 3 provides a quantitative analysis of the number and type of Superfund responses. Chapter 4 provides an analysis that uses property value data to monetize some of the benefits of the Superfund program associated with the NPL. Chapter 5 provides a description of methods that are proposed to be used to monetize different aspects of the Superfund program, an effect-by-effect analysis of the health impacts and an analysis of ecological benefits. Chapter 6 provides a description of the non-quantified benefit categories. Chapter 7 provides a summary of the current study and identifies opportunities for future research.

Appendix A provides a list and description of data sources used. Appendix B provides a list of case studies, which are located throughout the text where the case studies illustrate an important point. Appendix C provides an alternative presentation of the results from Chapter 4 that uses 2004 as the base year for discounting instead of 1980.

References

Agency for Toxic Substances and Disease Registry. 2003. ATSDR CEP site count report.

Anderson, B., C. Thompson, and W. A. Suk. 2002. The Superfund Basic Research Program - making a difference: past, present, and future. *International Journal of Hygiene and Environmental Health* 205 (1-2):137-141.

Andrews, R. N. L. 1999. *Managing the environment, managing ourselves*. New Haven, CT: Yale University Press.

Baumol, W. J., and W. E. Oates. 1988. *The theory of environmental policy*. 2nd ed. New York: Cambridge University Press.

Bove, F., Y. Shim, and P. Zeitz. 2002. Drinking water contaminants and adverse pregnancy outcomes: A review. *Environmental Health Perspectives* 110:61-74.

Dolk, H., and M. Vrijheid. 2003. The impact of environmental pollution on congenital anomalies. *British Medical Bulletin* 68:25-45.

EPA Science Advisory Board. 2002. *Underground storage tanks (UST) cleanup & Resource Conservation & Recovery Act (RCRA) Subtitle C program benefits, costs, & impacts (BCI) assessments: An SAB advisory*. Washington, DC: USEPA.

Freeman, A. M. 1993. *The measurement of environmental and resource values: theory and methods*. Washington, DC: Resources for the Future.

Gayer, T., J. T. Hamilton, and W. K. Viscusi. 2000. Private values of risk tradeoffs at Superfund sites: Housing market evidence on learning about risk. *Review of Economics and Statistics* 82 (3):439-451.

Gayer, T. 2000. Neighborhood demographics and the distribution of hazardous waste risks: An instrumental variables estimation. *Journal Of Regulatory Economics* 17 (2):131-155.

General Accounting Office. 1996. *Superfund: How states establish and apply environmental standards when cleaning up sites.* Washington, DC.

———. 1999. *Superfund program: Activities of the Agency for Toxic Substances and Disease Registry and Department of Justice.* Washington, DC.

Gregory, R., J. Flynn, and P. Slovic. 1995. Technological stigma. *American Scientist* 83 (3):220-3.

Hamilton, J. T., and W. K. Viscusi. 1995. The magnitude and policy implications of health risks from hazardous waste sites. In *Analyzing Superfund: Economics, science, and law*, edited by R. L. Revesz and R. B. Stewart. Washington, DC: RFF Press.

———. 1999a. *Calculating risks? The spatial and political dimensions of hazardous waste policy*. Cambridge, MA: MIT Press.

———. 1999b. How costly is "clean"? An analysis of the benefits and costs of Superfund site remediations. *Journal of Policy Analysis and Management* 18 (1):2-27.

Harrison, R. M. 2003. Hazardous waste landfill sites and congenital anomalies: Where do we go from here? *Occupational and Environmental Medicine* 60 (2):79-80.

Hays, S. P. 1987. *Beauty, health, and permanence: Environmental politics in the United States, 1955-85*. Edited by D. Worster and A. Crosby, *Studies in environment and history*. New York: Cambridge University Press.

Hird, J. A. 1994. *Superfund: the political economy of environmental risk*. Baltimore: Johns Hopkins University Press.

Jaffe, A. B., R. G. Newell, R. N. Stavins. 2002. Environmental policy and technological change. *Environmental & Resource Economics.* 22 (1-2): 41-69.

Johnson, B. L. 1999. *Impact of hazardous waste on human health: Hazard, health effects, equity, and communications issues*. Boca Raton: Lewis Publishers.

———. 2001. The 20th anniversary of Superfund: Does this law matter? An opinion. *Human and Ecological Risk Assessment* 7 (2):221-225.

Jones, D. S., L. W. Barnthouse, G. W. Suter, R. A. Efroymson. 1999. Ecological risk assessment in a large river-reservoir: 3. Benthic invertebrates. *Environmental Toxicology and Chemistry.* 18 (4): 599-609.

Jung, C., K. Krutilla, and Roy Boyd. 1996. Incentives for advanced pollution control abatement technology at the industry level: An evaluation of policy alternatives. *Journal of Environmental Economics and Management* 30 (1):95-111.

Landy, M. K., M. J. Roberts, and S. R. Thomas. 1994. *The Environmental Protection Agency (expanded edition): Asking the wrong questions from Nixon to Clinton*. New York: Oxford University Press.

Morey, E. R., W. S. Breffle, R. D. Rowe, D. M. Waldman. 2002. Estimating recreational trout fishing damages in Montana's Clark Fork River basin: Summary of a natural resource damage assessment. *Journal of Environmental Management.* 66 (2): 159-170.

National Research Council. 1997. *Innovations in ground water and soil cleanup: From concept to commercialization*. Washington, DC: National Academy Press.

Norberg-Bohm, V. 1999. Stimulating 'green' technological innovation: An analysis of alternative policy mechanisms. *Policy Sciences*. 32 (1): 13-38.

Office of Technology Assessment. 1989. *Coming clean: Superfund problems can be solved*. Washington, DC: U.S. Congress.

Office of Management and Budget. 1992. *OMB Circular A-94: Guidelines and discount rates for benefit-cost analysis of federal programs.* Washington, DC: Executive Office of the President.

———. 2003. *OMB Circular A-4: Regulatory Analysis.* Washington, DC: Executive Office of the President.

Orr, L. 1976. Incentive for innovation as the basis for effluent charge strategy. *American Economic Review* 66 (2):441-447.

Paustenbach, D. J. 2002. Primer on Human and Environmental Risk Assessment. In *Human and ecological risk assessment: Theory and practice*, edited by D. J. Paustenbach. New York: John Wiley & Sons.

President of the United States. 1993. *Executive Order 12866: Regulatory planning and review.*

———. 1994. *Executive Order 12898: Federal actions to address environmental justice in minority and low-income populations.*

———. 1999. *Executive Order 13132: Federalism.*

———. 2000. *Executive Order: 13175: Consultation and coordination with Indian tribal governments.*

Probst, K. N., D. Fullerton, R. E. Litan, and P. R. Portney. 1995. *Footing the Bill for Superfund Cleanup: Who Pays and How?* Washington, DC: Brookings Institution and RFF Press.

Probst, K. N., and D. M. Konisky. 2001. *Superfund's future: What will it cost?* Washington, DC: RFF Press.

Rosenberger, R. S., and J. B. Loomis. 2003. Benefit transfer. In *A primer on non-market valuation*, edited by P. A. Champ, K. J. Boyle and T. C. Brown. Boston: Kluwer Academic Press.

Satterfield, T. A., P. Slovic, R. Gregory, J. Flynn, and C. K. Mertz. 2001. Risk lived, stigma experienced. In *Risk, media and stigma*, edited by J. Flynn, P. Slovic and H. Kunreuther. Sterling, VA: Earthscan Publishers.

Slovic, P. 1987. Perception of risk. *Science* 236:280-5.

Slovic, P., B. Fischhoff, and S. Lichtenstein. 1979. Rating the risks. *Environment* 21 (3):14-20, 36-39.

Taylor, L. O. 2003. The Hedonic Method. in *A Primer on Non-Market Valuation.* Champ, P. A., K. J. Boyle, and T. C. Brown, eds. Boston: Kluwer Academic Publishers. 331-393.

Taylor, M. R.; E. S. Rubin; D. A. Hounshell. 2003. Effect of government actions on technological innovation for SO2 control. *Environmental Science and Technology.*

U.S. Environmental Protection Agency. 2000. *Guidelines for preparing economic analyses*. Washington, DC.

Viscusi, W. K., and J. T. Hamilton. 1999. Are risk regulators rational? Evidence from hazardous waste cleanup decisions. *American Economic Review* 89 (4):1010-1027.

Viscusi, W. K., J. T. Hamilton, and P. C. Dockins. 1997. Conservative versus mean risk assessments: Implications for Superfund policies. *Journal of Environmental Economics and Management* 34 (3):187-206.

Wildavsky, A. 1995. *But is it true? A citizen's guide to environmental health and safety issues*. Cambridge: Harvard University Press.

Williams, P. R. D., and D. J. Paustenbach. 2002. Risk characterization. In *Human and ecological risk assessment: Theory and practice*, edited by D. J. Paustenbach. New York: John Wiley & Sons.

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CHAPTER 2: LITERATURE REVIEW

This chapter makes a survey of the literature on evaluating environmental regulation, with emphasis on guidance relevant to the current Superfund Benefits Analysis (SBA) [this report]. In particular, the chapter focuses on literature that addresses the benefits of Superfund or provides important insights into understanding the SBA. The several sections of this chapter address the evaluation of environmental regulation, health risks, ecological risks, previous studies of the overall Superfund program, and emergent themes. Subsequent chapters contain further reviews of topical and methodological literature as required (for instance, Chapter 5 reviews the literature on property-based price analysis).[1]

Evaluating Environmental Regulation

EPA's Regulatory Policy Council, Science Advisory Board, and National Center for Environmental Economics (NCEE), as well as the Office of Management and Budget (OMB)—specifically the Office of Information and Regulatory Affairs (OIRA)—have provided clear, and in the case of OIRA, authoritative guidance for regulatory analysis in support of rulemaking. The intellectual foundations for this guidance can be found in the literature on public health, welfare and environmental economics, risk assessment, and related topics (e.g., Arrow and Fisher 1974; Sen 1982; Slovic 1987; Morgan and Henrion 1990; d'Arge 1993; Freeman 1993; Arrow et al. 1996; Bockstael et al. 2000; Arrow et al. 2000; Hammitt 2000; Paustenbach 2002). While the SBA is a retrospective analysis and not a rulemaking, effort has been made to be consistent with the established standards and to rely on the above foundations. This chapter addresses how the above guidance applies to the central question of the SBA: "What are the benefits of the Superfund program?"

The relevant EPA and OMB guidance generally anticipates a prospective study of new regulations, not a retrospective evaluation (President of the United States 1993; Office of Information and Regulatory Affairs and Council of Economic Advisors 1996; U.S. Environmental Protection Agency 2000; Office of Management and Budget 2003a). However, the approach of prospective versus retrospective does not alter the fundamentals of good regulatory analysis, including objectivity, reliable theoretical foundations, suitable data, clarity of explanation (transparency), adequate treatment of uncertainty, and completeness (Morgan and Henrion 1990). One important exception is that the EPA and OMB guidance requires that alternative modes of regulation be considered; there is no point in doing so in a retrospective analysis. Thus, the SBA analyzes the benefits of the existing Superfund program and compares these to a single scenario that assumes there is no Superfund program (see Chapter 1).

Executive Order 12866 and related guidance provide important and authoritative guidance for regulatory analyses, and thus are relevant to the SBA (President of the United States 1993; Office of Information and Regulatory Affairs and Council of Economic Advisors 1996; President of the United States 2002; Office of Management and Budget 2003a). The portions of this Executive Order relevant to the SBA are described in Section 1, parts (a), (b)(1), (b)(4), (b)(6), (b)(7), and (b)(9). These portions require: identifying the problem; considering the risks of

[1] For simplicity, terms like "property-based valuation" are used in this study to refer to analyses that rely on hedonic price theory (Taylor 2003).

various substances; assessing the benefits, using reasonably obtainable scientific, technical, economic, and other information; and paying appropriate attention to state, local, and tribal views. The remainder of the Executive Order addresses the form of regulation selected, which is irrelevant for a retrospective analysis.

The OMB's *Best Practices Guidances* and *Circular A-4* provide explicit guidance on numerous issues that are at the heart of regulatory analysis and that reflect the intent of Executive Order 12866 (Office of Management and Budget 2003; Office of Information and Regulatory Affairs and Council of Economic Advisors 1996). Many of the principles and practices identified by the OMB have been included in EPA's guidance, which was rated as "excellent" by the Science Advisory Board (U.S. Environmental Protection Agency 2000 p. A-1).

The SBA conforms to the guidance in the following ways. Chapter 1 of the SBA describes the need for Superfund, which is due to both externalities and a lack of incentives for producing the information or technologies needed to adequately manage uncontrolled releases of hazardous substances. Chapter 1 also describes the baseline for the SBA.

The SBA considers benefits created by all actions taken under the Superfund program from 1980-2004, using discount rates of 3% and 7% where discounting is appropriate, and discusses the possible implications of intergenerational effects where these are appropriate. All of the chapters that include quantitative information include discussions of risk and uncertainty, as well as discussions of the assumptions underlying the analysis. Non-monetized benefits are described, and where possible they are quantified.

The structure of this analysis, as described in Chapter 1, follows the *EPA Guidelines for Preparing Economic Analyses (EPA Guidelines)*, including the use of effect-by-effect and benefits transfer analyses (U.S. Environmental Protection Agency 2000). In addition, the SBA follows the *EPA Guidelines* in the use of specific techniques. These include revealed preference methods such as property-based price studies and cost of illness analyses to estimate the benefit of reduced incidence of disease, and EPA's recommended value of a statistical life ($6.1 million (2000$)).[2] Chapters 4 and 5 describe the methods used for each benefit in detail, referring to the general guidance discussed above as well as more specific guidance as appropriate (e.g., U.S. Environmental Protection Agency 2002). Chapter 10 of the *EPA Guidelines* provides guidance on presenting the results of economic analyses and also helped shape the SBA.

The methods employed in Chapters 4 and 5 are used to develop estimates of the monetary value of using benefits transfer methods, which *Circular A-4* indicates should be avoided under some conditions. These cases include the evaluation of unique attributes, the use of *ex ante* data, and the use of data from cases with significantly different magnitudes than the case to which the data are being applied. None of these conditions holds here. Another key issue for benefits transfer analysis is to ensure the demographics and market sizes of the study cases and policy case are similar. The analyses in Chapters 4 and 5 meet this requirement because they are conducted at the level of individual sites, and then aggregated. Thus, for instance, the analysis treats the housing market as a set of local markets, not as a national market.

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[2] Note that the sections in which this is relevant (in Chapter 5) have not been completed due to prior agreement with the EPA's Science Advisory Board. Thus, this value is not actually used in this draft.

Although it is not guidance, the recent *Benefits and Costs of the Clean Air Act (Clean Air Act)* study is a very useful reference since it shares many features of the SBA (U.S. Environmental Protection Agency 1997). Its structure and content influenced the SBA's analysis of the Superfund program. Critiques of the *Clean Air Act* study also offered useful insights, especially that aggregation of large environmental programs can be less useful than detailed treatment of individual parts when it is possible to take this approach (Krupnick and Morgenstern 2002; Freeman 2002). This insight, for instance, emphasizes that the individual quantitative estimates of benefits found in Chapters 4 and 5 should be kept separate.

Understanding the Health Risks of Hazardous Substances

Reducing human health risk is among the most important benefits of the Superfund program and there is a vast literature on the subject, including several major reviews that have been completed in the last several years. This section briefly discusses three of these reviews, leaving more detailed discussion of the literature to Chapter 5.

An appropriate starting place is a 1991 review by the National Research Council (NRC), which reviewed then-current knowledge of the human health effects caused by exposure to hazardous substances in the environment (National Research Council 1991). The NRC concluded that despite poor data "the committee does find sufficient evidence that hazardous wastes have produced serious health effects in some populations" but that the data then available made it impossible to determine the effect of regulation (National Research Council 1991, 19-21).

The NRC panel noted that studies of specific sites have documented symptoms of ill health, including low birth weight, birth defects such as cardiac anomalies, and a variety of neurobehavioral problems. Health problems with long latency periods are more difficult to detect, but some of the studies reviewed by the NRC detected increased incidence of cancer in people exposed to compounds similar to those that occur at hazardous waste sites. In addition, it appeared that risks to future populations might be larger than current risks, mostly due to ground water exposure routes: "Although current risks could be negligible, studies show that millions of tons of hazardous materials are slowly migrating into ground water in areas where they could pose problems in the future" (National Research Council 1991, 259).

The level of potential exposure to contaminated ground water found by the NRC was high:

> In 1984 an evaluation of 93 sites on the California Department of Health State Superfund list showed … 46 of the sites showed evidence of waste release into ground water, and in 34 of these cases the ground water was known to be used for drinking. Extensive or systematic sampling occurred in only 22 of the sites, despite the evidence of potential contamination … Moreover, in all of the sites where there was known contamination of ground water, more than 10,000 persons were potentially exposed. (259)

The NRC panel noted that serious health effects have occurred at some hazardous waste sites, that hazardous waste abounds in the U.S., and that people live and work in close proximity to some of this waste (National Research Council 1991, 1-2). However, the NRC panel are quick to point out that proximity to hazardous waste does not necessarily imply exposure and health risk, only that the potential for exposure is increased. Perhaps the most important gap was in exposure data, which the NRC felt had received inadequate support. The data that are available tend to "reflect data requirements of environmental engineering and site remediation, rather than public health considerations" (National Research Council 1991, 142).

Several features of the NRC study are worth noting, including an exclusive focus on National Priorities List (NPL) sites, an emphasis on ground water contamination, and an emphasis on the risks to future generations. Another key feature is the poor quality of exposure data that are readily accessible to researchers, which limits their ability to determine causal linkages between hazardous wastes at sites and negative health outcomes (National Research Council 1991, 101-153). Importantly, a wide array of health outcomes were examined in the studies reviewed by the NRC, including damage to the nervous system, cancer, birth defects, and a host of lesser symptoms (e.g., eye irritation, fatigue).

A second review covers much of the research published up to 1998 on the health effects of hazardous substances, including over 450 journal articles, books, reports, and other sources (Johnson 1999a). Some parts of this volume had appeared previously in the peer-reviewed literature (e.g., Johnson 1995, 1999b; Johnson and DeRosa 1995). A significant portion of this research was conducted by (or for) the Agency for Toxic Substances and Disease Registry (ATSDR), the Superfund Basic Research Program (SBRP), and EPA's Office of Research and Development (ORD). A former director of ATSDR is the author of the 1999 review.

Johnson documents the widespread *potential* for exposure to hazardous wastes using data and methods that are better than those available to the researchers in the 1991 NRC report (Johnson 1999a, 41-73). At NPL sites the ATSDR examines, completed exposure pathways are common. Two percent of these sites present an "urgent hazard," 21% present a "hazard," and the remainder are less hazardous or not at all (Johnson 1999a, 33). Most of these sites indicate a need for action to reduce ongoing exposure pathways (Johnson 1999a, 38). The chemicals that are most frequently found with completed exposure pathways are lead, arsenic, benzene, trichloroethylene, mercury, and cadmium. Combinations of these chemicals are also frequently seen. (For updates, see Agency for Toxic Substances and Disease Registry 2003a; 2003b.)

These studies tend to understate the total risk of a site as it was originally discovered because the Public Health Advisories (PHAs) that ATSDR performs are generally conducted after removal actions designed to mitigate imminent risk to the public are complete (see Chapter 3 for a definition and discussion). Thus, PHAs will only evaluate the residual risk. Evaluation of residual risk is appropriate for making further decisions about improving public health at a site but tends to underestimate the total risk originally presented by the site, and is an example of the problems associated with data collection identified by the NRC panel above. Other studies have observed similar phenomena (e.g., Hamilton and Viscusi 1999a, 105-7, 231).

The survey of over 60 health studies in Johnson's review (Johnson 1999a) is the most relevant foundation for the SBA. Studies reviewed in this survey included both state-based surveillance programs and studies of individual hazardous waste sites. A few studies found no associations, but others showed associations between proximity to sites with hazardous substances and congenital malformations, especially birth defects of the heart, neural tube, and oral cleft palate, reduced birth weight, and decreased fertility. In general, these studies utilize better (but still very limited) data and improved methodologies compared to those reviewed by the NRC in 1991. Johnson's overall assessment is that:

> The most compelling health findings are those from studies of reproductive outcomes in populations living near certain kinds of hazardous waste sites. The weight of evidence associates select birth defects and reduced birth weight of infants born to parents who lived near sites. The release of VOCs into ground water seems a common factor in studies of increased rates of birth defects and lower birth weight. The birth defects most often reported are malformations of the heart, neural tube, and oral cleft palate. There is also troubling evidence that human fertility in adults can be reduced from exposure as children to high lead levels … The association between increased cancer rates and exposure to substances released from hazardous waste sites is less well documented than for reproductive outcomes. (196-199)

Johnson (1999a) also provides some data about uncontrolled chemical releases that lead to emergencies. These events present significant risks. For instance, in 14 states there were 5,502 such events in 1996, which led to 1,620 victims and 33 fatalities. Victims included employees, the public, and first responders.

Johnson (1999a, 201-218) also surveys studies of occupational risk associated with remediation of hazardous substances and finds very limited data. The existing information suggests that first responders, health care providers, waste disposal workers, and site remediation workers face no significant *health* risks due to their employment. However, one study based on average *safety* risk data for various trades (especially truck driver, laborer, oiler, and bulldozer operator) from the 1970s and early 1980s showed significant occupational risk of fatalities due to accidents during some types of site remediation.

The most recent review discussed in this section looks at five studies of the effect of drinking water contamination by solvents on birth defect rates and reported mixed evidence (Bove, Shim, and Zeitz 2002). The review found evidence of excess neural tube defects and of congenital cardiac abnormalities, but was limited by lack of exposure data. Because birth defects are relatively rare events, it is difficult to detect changes in their rate of incidence without very large population samples, which are typically not available. In addition, difficulties in estimating exposure are likely to result in misclassification biases that underestimate risk. Nonetheless, depending on the specific solvent, odds ratios for various serious birth defects (e.g., neural tube defects, fetal deaths) were found to have means well above 1.0 (with a range of 1.25 to 5.39).[3]

[3] The odds of an event is the number of those who experience the event divided by the number of those who do not, and the odds ratio is simply the ratio of the odds in the two groups of interest. If the odds ratio is less than one, then the odds have decreased (and therefore so has the risk), but if the odds ratio is greater than one then the odds have increased. When the risks in the two groups being compared are both small (e.g., less than 20%) then the odds will approximate the risks, and the odds ratio will approximate the relative risk. The odds of any congenital malformation is less than 2% in the United States, and the odds of specific conditions is much lower than that (Anonymous 2003). Thus, odds ratios for birth defects closely approximate increased risks; an outcome with an odds ratio of 1.25 implies approximately a 25% increased risk.

However, scarce data yielded large confidence intervals that sometimes included 1.0. The review also found that studies often looked for confounding effects and generally found that factors such as smoking, alcohol consumption, maternal illness, socio-economic status, and demography had little influence.

Overall, these three reviews indicate there is lack of evidence about the health effects of uncontrolled releases of hazardous substances, although there is relatively more evidence for increased rates of congenital malformations than for cancer or other diseases. The major problem is a lack of accessible high-quality exposure data, which is a widely recognized problem (Harrison 2003). Studies published after the periods covered by these three reviews are discussed in Chapter 5, and although some of these find stronger statistical associations, the lack of exposure data persists. Furthermore, it is not clear if this problem is likely to be solved, especially for historical exposures. While dose reconstruction may be possible for some substances (e.g., lead), the lack of long-term indicators and data about past ambient concentrations and activity levels diminish the prospects for reliable estimates of past exposures.

Understanding the Ecological Risks of Hazardous Substances

Ecological risk assessment has become a more well-understood and more widely-practiced activity in the last decade (Suter et al. 2000). EPA's guidelines require that ecological risk assessments (ERAs) be conducted at every site at which there is a response action (i.e., a remedial or removal action) according to a well-established, consistent process (Luftig 1999; U.S. Environmental Protection Agency 1998). However, ecological risks play a relatively small role in determining the directions of Superfund responses, compared to health risks (Walker, Sadowitz, and Graham 1995, 29; Suter et al. 2000, Chapter 8). Further, the problems of lack of accessibility and inappropriate assumptions for a benefits estimation that plague health risk assessments of Superfund sites also apply to ERAs.

The growing literature on ecological risk tends to be in biology, toxicology, and similar fields, while there is relatively little literature on the economics of these issues (Barnthouse and Stahl 2002). The current economics-oriented literature focuses on the concept of natural resource damages, which are closely related to the natural resource provisions of CERCLA (Kopp 1989; Dunford 2000; Stopher 2000; Reisch 2001; Morey 2002; Damage Assessment and Restoration Program 2004). In particular, there is a lack of economic analysis of potential ecological improvements due to response actions. Searches in the published and gray literature for quantitative estimates of the ecological risks addressed by Superfund responses yielded no results.[4]

Previous Analyses of the Benefits of the Superfund Program

This section reviews the numerous prior studies that have evaluated benefits of the Superfund program or that provide insight into how to evaluate these benefits. In some cases, detailed literature reviews are deferred until relevant sections of the report (e.g., Chapter 4 contains a detailed review of evaluation methods that rely on real estate sales data). Four studies are discussed in some detail (Hamilton and Viscusi 1995; Walker, Sadowitz, and Graham 1995; Hamilton and Viscusi 1999a; Probst and Konisky 2001) and several others are mentioned briefly.

[4] This search included the use of multiple electronic tools including online search engines, EPA's Web sites, and various databases such as EconLit and Web of Knowledge.

Finally, two proposed studies of closely related efforts under the Resource Conservation and Recovery Act (RCRA) and comments on these proposals by the Science Advisory Board are reviewed (EPA Science Advisory Board 2002; Office of Solid Waste and Emergency Response 2000a, 2000b).

The most recent large study of Superfund contains an overview of the Superfund program and provides insight to understanding its benefits (Probst and Konisky 2001). This study focuses on the NPL and cleanup of NPL sites, and provides considerable information about the character of various response actions. This information shows great variation in the character and sizes of various sites (Probst and Konisky 2001, 21, 22, 28-30, 39, 40, and 47). The heterogeneity among sites that Superfund addresses is a common issue. This study also stresses the importance of three other features of Superfund: the removal program, "NPL equivalent sites," and support activities. Each of these is discussed briefly below.

Probst and Konisky (2001) stress that the removal program, which addresses about four times as many sites as the NPL program, is potentially important in mitigating health risk. Of the approximately 315 removals that occurred each year during 1992-99 (Probst and Konisky 2001, 19), more than 90% are categorized as "time-critical" and the short descriptions of four such cases (Probst and Konisky 2001, 20-21) provide stark (qualitative) evidence of the severity and immediacy of the risks the removal program addresses. Further, the authors argue that under the Superfund Accelerated Cleanup Model (SACM), removals substitute for remediations at some sites (Probst and Konisky 2001, 24, 99).

Probst and Konisky (2001) also highlight the typically overlooked concept of "NPL equivalent sites" (or, "Superfund alternative sites") that are eligible for NPL listing (i.e., they have an HRS score greater than 28.5) but are not listed. Instead, "responsible parties perform cleanup under EPA enforcement authority and with EPA oversight" (Probst and Konisky 2001, 40). In some cases, NPL equivalent sites are included in state Superfund programs, but they never enter the NPL. Without the existence of the Superfund program, it is very likely that these sites would not be cleaned up, so any reduced health and ecological risks at these sites are a benefit of the Superfund program. However, it is not clear what fraction of the benefit should be assigned to the Superfund program. This issue is analyzed quantitatively in Chapter 3 of the SBA.

Probst and Konisky (2001, 107-120) also describe the importance of support activities and programs. These support activities include program staff, management, and support; program administration; and other programs and agencies. These activities and programs account for about one-third of the cost of the program and without them "it is simply not possible to have a national Superfund Program" (Probst and Konisky, 107). Most of these costs are for items such as rent, payroll, and benefits that do not directly produce benefits; others are for programs that have impacts other than health risk reductions at Superfund sites.

Several important prior studies looked in some detail at specific NPL sites, usually by examining the Record of Decision (ROD) for each site. This approach provides insight because it makes use of some of the "extensive documentation [that] is publicly available … for each site" but which is usually evaluated on a site-by-site basis only (Walker, Sadowitz, and Graham 1995, 25). For instance, the study by Walker et al. (1995) evaluated 148 RODs and found that 81% of the sites they examined had maximum cancer risks that exceeded EPA standards, and (to the surprise of the authors) that the non-cancer health risks also exceeded acceptable standards at 74% of the sites. However, these standards are designed to be protective of human health and are thus conservative (Viscusi, Hamilton, and Dockins 1997). Nonetheless, almost half of the sites had non-cancer risks ten times the EPA standard, and almost one-fifth had non-cancer risks one hundred times the EPA standard (Walker, Sadowitz, and Graham 1995, 31). To these researchers, "the magnitude of the hazard indices reported for the hazardous waste sites in the database suggests the need for better understanding of the potential for non-cancer health effects."

This study also stressed the importance of "environmental and welfare risks that sites pose in addition to current and future health risks … [including] the nonuse value of ground water, which includes the psychological comfort of knowing that ground water is clean.… One of the hidden yet worthy objectives of the program is to protect the quality of our nation's ground water for future yet unspecified uses by humans and nonhuman species" (Walker, Sadowitz, and Graham 1995, 49-50). Neither of these benefits (psychological comfort and future use) seems to have been quantified in any way in the literature. Note, however, that they may be part of the rationale for the application of "applicable or relevant and appropriate requirements" (ARARs) to NPL sites (for instance, the application of state drinking water standards to groundwater).

The only significant study to go beyond reviewing RODs collected data from Baseline Risk Assessments (see Chapter 3 of the SBA for a discussion of these assessments) and estimated reductions in adult cancer risk due to remedial actions at NPL sites, as well as the costs (Hamilton and Viscusi 1999a, 1999b). This study ignored removal actions, largely because it was focused on decisions associated with remedial actions at NPL sites (Hamilton and Viscusi 1999a, 105). Note, however, that this approach would likely create an underestimate of the total benefits of the Superfund program if removals reduce significant risk.

The Hamilton and Viscusi (1999) study evaluated non-cancer risks, finding that 125 of 150 NPL sites evaluated had hazard index values greater than the allowed standard of one (Table 2.10, p. 53).[5] However, as discussed below, these are conservative estimates; thus it may be illuminating to consider the number of sites that have hazard quotients more than ten times the standard (which is 78), or more than half of the NPL sites evaluated. Most of these risks are to future populations; counting only the current exposure pathways leaves only 17 sites with a hazard quotient of greater then ten. Non-cancer risks are ignored in most of the rest of their analysis, principally because of "the difficulty of comparing non-cancer risks across chemicals, since the adverse outcomes range from drowsiness to death" (Hamilton and Viscusi 1999a, 53). In addition, although hazard quotients are numbers, they are not quantitative estimates of risk. The authors note that, "in a full benefit-cost analysis, EPA decision makers would collect more information on the harms of non-cancer health effects" (Hamilton and Viscusi 1999a, 231). Nonetheless, this research highlights the great heterogeneity of risks found at NPL sites.

The most well-known result of the Hamilton and Viscusi (1999) study is that the benefits they examine are concentrated in a small number of sites, creating a very wide range of site-specific

[5] A hazard index is the sum of the hazard quotients. The hazard quotient is the ratio of the intake of a contaminant to the reference dose of the contaminant.

costs per cancer case avoided (see, for instance, Hamilton and Viscusi 1999a, Figure 2). This conclusion also points to the very large variety in the type and magnitude of risks found at NPL sites. They also analyze the use of conservative values in the risk assessments upon which RODs are based (Viscusi, Hamilton, and Dockins 1997). Specific parameters treated this way include ingestion rate, exposure duration, and contaminant concentration. Conservative (i.e., high) values are used for these risk parameters to protect the public, and especially vulnerable individuals, from errors in regulatory decisions (such as the standard to which a remedial action will clean up an NPL site) due to variability in risk estimates. However, the use of such conservative risk estimates, and values derived from them, will tend to overstate the mean (average) benefits of the regulatory decision.

In addition, because of the high variability of benefits and costs across different sites, mean values are not useful in describing a “typical” NPL site or for providing an estimate of the central tendency of the population of NPL sites. This is because a small number of sites have most of the benefits while most NPL sites have few benefits, when measured in this way. However, this distribution of benefits across NPL sites does not affect estimates of the aggregate benefit, which is the relevant value for the SBA. That is, when calculating the total benefit of all NPL sites, the fact that most of the benefits are found at only a few sites makes no difference. Hamilton and Viscusi (1999a) describe the issue as follows:

> Overall, at these 150 sites, $2.2 billion dollars (1993$) in current and planned remediation actions are slated to be expended to avert 731 cancer cases, which yields a mean cost per cancer case averted of $3 million for remediation actions at the sites. This indicates that on balance the program is cost-effective in the aggregate using a mean cost per cancer case avoided. Yet the analysis in previous sections indicates that both risks and costs are concentrated in a small number of sites, so averages may not be fully informative. The median cost per cancer case averted is $388 million, without factoring in cost growth. (18)

In order to be more informative, Hamilton and Viscusi (1999a) also present statistics to better describe these results (Hamilton and Viscusi 1999a, Figure 2 and Table 6). However, the results described in the paragraph above rely on assumptions that take the conservative risk and cost estimates found in RODs on their face value and thus are not reliable for considering the benefits of risk mitigation.

To correct for the effects of conservatism, Hamilton and Viscusi (1999) present results for two other cases. In the least conservative case (case three), mean values are used for contaminant concentration and intake rate, a ten-year latency period is assumed, a 3% discount rate is used, and historical growth rates in the cost of NPL sites are used. While these adjustments do not account for all of the conservatism in EPA’s risk estimates, they address most of them. This suggests that the mean cost per cancer case averted in case three would be more useful in understanding the aggregate benefits of remedial actions at NPL sites than the values given above (which are for case one).

However, Hamilton and Viscusi (1999a) do not give the mean value for case three, only the median, which is extremely high at $7.2 billion. This value indicates that *most* NPL site remediations do not cost-effectively reduce cancer risk, but does *not* indicate whether, in aggregate, NPL site remediations are cost-beneficial, given the three assumptions. To investigate this issue requires estimating the mean value for case three. Unfortunately, Hamilton and Viscusi (1999a) do not present the information needed to make the needed calculation. Specifically, the cost for the NPL sites in case three is not given. These costs vary from those for the NPL sites in case one because only 99 of the original 150 NPL sites in case one had mean concentration data and could be included in case three.

Nonetheless, a mean value for case three can be roughly estimated given the values found by Hamilton and Viscusi (1999a). The first step is to divide the cost of the remedial actions at the 150 sites in case one ($2.2 billion) by the number of cancer cases avoided in case three (p. 204), which results in a value of about $11 million. The second step is to consider the number of sites in each case. If the distribution of costs for case one sites and case three sites is such that the 51 NPL sites that are included only in case one and not in case three contribute very little total costs, then the mean cost per cancer case avoided in case three is slightly under $11 million. If the two distributions are similar, then the mean cost per cancer case avoided in case three is slightly over $7 million. And if the distribution of costs for case one sites and case three sites is such that the 51 NPL sites that are included only in case one account for more than the average of total costs, then the mean cost per cancer case avoided in case three is less than $7 million.

Hamilton and Viscusi (1999a) compare mean and median values of cost per cancer case avoided to values for avoided mortality found in studies of risk in the workplace and in use by regulatory agencies. They find that, "cleanup efforts with a cost per case of cancer prevented in the general range of $6 million or even $10 million are generally in the range of reasonableness, whereas expenditures of $50 million, $1 billion or possibly more would be outside this range" (Hamilton and Viscusi 1999a, 118).

Thus, the data provided in the only comprehensive study of site-specific risk mitigation at NPL sites (Hamilton and Viscusi 1999a), suggest that, based on reasonable risk parameter estimates, the mean cost of adult cancer risk reduction for the average of all NPL sites is reasonable and close to the EPA's recommended value of a statistical life. This implies that, roughly speaking and in aggregate, the benefits of adult cancer risk reduction at NPL sites is about equal to costs. However, this is *not* true for most NPL sites—benefits and costs are distributed widely, so for most sites benefits are much less than costs, as suggested by the median values given above.

The Office of Solid Waste and Emergency Response (OSWER) developed a set of proposed methodologies for assessing the costs, benefits, and other attributes of two OSWER programs with some similarities to Superfund: the RCRA Subtitle C prevention and waste minimization program, and the Underground Storage Tank (UST) cleanup program (Office of Solid Waste and Emergency Response 2000a, 2000b). These reports did not characterize or quantify any of the measures that they proposed. In December 2002, the EPA's Science Advisory Board prepared an advisory report on these two OSWER proposals (EPA Science Advisory Board 2002). While there are similarities between these programs and Superfund, there are also dissimilarities. One key difference is that the two RCRA programs are narrower than the entire set of approaches established by CERCLA and SARA, which are being evaluated in the present study. Thus, although the overall approaches proposed in the OSWER reports are not suitable for this study, the proposals and comments provided a valuable input to the design and implementation of the current study.

The OSWER proposals included an "Attributes Matrix" that the Science Advisory Board felt "creates potential problems … by loading too many extra considerations onto the conceptual framework provided by EPA's *Guidelines for Preparing Economic Analyses* (*Guidelines)* and by introducing distinctions that are not useful to the analysis" (p. 1). However, the Board did provide a modified Attribute Matrix that went beyond the *Guidelines* framework (pp. 12-13). In this spirit, the concepts of approaches and benefit categories discussed in Chapter 1 of the current study were developed by adding to the original framework from the *Guidelines* in a limited way.

The UST study proposed to assess cancer risks of benzene using data from three contingent valuation studies of the value of groundwater cleanup. The Science Advisory Board noted that studying the cancer risks of benzene was a "reasonable simplification of the problem" but that "the three studies cited, and to our knowledge any existing contingent valuation groundwater research, should not be used as estimates of total value (or the subset of health benefits) for the UST program" (pp. 15-16). The Board also noted difficulties with using avoided cost measures to estimate this benefit. In the context of the current study, a simplification to consider the benefits of just one compound would likely be unacceptable, given the wide range of hazardous substances found at sites addressed by Superfund. The current study also proposes (in Chapter 5) a less ambitious approach to evaluating the benefits of groundwater protection and cleanup that is focused more on the quantification of the amount of groundwater protected and remediated. A method is also proposed in the current study for dealing with some of the problems with contingent valuation data noted by the Board.

The Board is particularly concerned with the use of available risk data for estimating the benefits of cleanup of both carcinogens and non-carcinogens (p. 17). The problem for most carcinogens is that the available risk data is the 95% upper confidence interval on cancer potency or cancer risk. For non-carcinogenic substances, the available data are in the form of Reference Doses and Reference Concentrations, which are not suitable for use in estimating health benefits. These risk characterizations may be appropriate for environmental regulatory purposes, but are not useful for estimating benefits. In the context of the current study, these concerns have led to the methodology proposed in Chapter 5 to utilize an epidemiology-based approach similar to one found in the peer-reviewed literature (Lybarger et al. 1998).

The OSWER proposals include several ideas for estimating ecological improvements, all using concepts and models from the physical sciences and engineering, such as "pathway modeling." The Science Advisory Board criticizes this approach because it "bears only a crude relation to the social benefits of the program" (EPA Science Advisory Board 2002, 17). The Board goes on to suggest that monetized benefit estimates are most appropriate, and to note that ecological benefits are highly idiosyncratic to local conditions. The Board suggests that "[d]etailed analysis of a small number of sites could yield defensible benefits estimates at a relatively high cost. But the transfer of such benefits to the universe of sites is, in our judgment, not defensible" (p. 18). The Board then recommends that EPA develop quantitative indicators of ecosystem service benefits, perhaps using geographical information systems, and integrating this data into a "contamination events avoided" analysis (pp. 18-19). The current study adopts these recommendations as much as possible. The natural resource damage assessments associated with certain provisions of CERCLA actually comprise detailed analyses of specific sites, and these are proposed to be investigated more fully (Breffle et al. 2005; Barnthouse and Stahl 2002). In addition, a limited attempt to transfer these benefits to other restoration activities is proposed. Further, these studies, which evaluate restoration activities, may provide some qualitative insight into the ecological benefits of response actions; however, it is *not* proposed to attempt to transfer any of these benefits quantitatively. Finally, the use of GIS modeling is proposed for evaluating the benefits of the cleanup of groundwater.

The OSWER proposal for the UST study includes the use of property-value data (i.e., results from hedonic price studies) to estimate the benefits of cleanup, an analysis very similar to the one described in Chapter 4 of the current study. The Science Advisory Board concluded that this approach could be used to develop a 'ball park' or order-of-magnitude estimate of benefits" as long as certain theoretical and data issues were dealt with satisfactorily (EPA Science Advisory Board 2002, 3). Chapter 4 discusses these issues in detail and shows how all of the necessary conditions to yield a reliable estimate have been met.

The Science Advisory Board (2002, p. 23) also made the following comment: "Our skepticism about the value of a retrospective analysis and its accuracy (given the difficulty of any certainty about the without RCRA counterfactual) make us discourage a large commitment of resources to this exercise. As a result, we encourage the use of available data…" This recommendation has been followed in the design and implementation of the current study, as discussed in Chapters 3, 4, and 5.

Most recently, EPA published a study of the past accomplishments and future challenges of Superfund (U.S. Environmental Protection Agency 2004). One of the key challenges identified by this study is the backlog of NPL sites ready for long-term cleanup but for which there are inadequate resources. In particular, the study notes that, "the universe of Superfund sites [is] expanding in both number and type. Sites now entering the long term cleanup phase tend to be larger, require multiple remedies and are more complex than those originally placed on the NPL" (U.S. Environmental Protection Agency 2004, 9). This finding suggests that the heterogeneity of sites addressed by Superfund is growing.

General Themes Arising in the Literature

In addition to the detailed analyses presented above, there are a number of more general treatments of the Superfund program, including books, book chapters, and reports (e.g., Landy, Roberts, and Thomas 1994; Wildavsky 1995, Ch. 5; Andrews 1999; Nakamura and Church 2003; General Accounting Office 1999, 2003). This literature focuses almost entirely on the NPL. For instance, a fairly large group of studies has evaluated changes in the property values of residences near NPL sites in order to understand the benefits of remediation. Recent surveys of this literature indicate that there may be significant impacts of NPL sites on nearby home prices, but the magnitude of this effect can vary substantially from site to site (Farber 1998; Boyle and Kiel 2001). This literature is reviewed in detail in Chapter 4.

From the literature reviewed in this chapter, three key themes relevant to the SBA emerge: (i) the importance of the removal program, (ii) the heterogeneity of sites that Superfund has addressed, and (iii) the lack of adequate data to evaluate many of the benefits of Superfund.

The first major theme is that removal actions may account for a significant portion of the reduction in health risk. Many studies of the Superfund program do not mention the removal program at all, focusing instead on remediations at sites on the National Priorities List (NPL). Those that do consider the removal program make brief mention of it but are unanimous in finding that removals are a successful but poorly recognized part of the Superfund program. For instance, Hird (1994) identifies the removal program as the most important "hidden accomplishment" of the Superfund program, and quotes a former EPA Regional Office director, then in private industry, who "credits the removal action program for the fact that 'no site today poses an immediate health risk to the public'… despite the fact that final remediation was completed at fewer than four percent of the NPL sites" (Hird 1994, 29). Even harsh critics of the Superfund program believe the removal program is effective at reducing health risks (Wildavsky 1995, 183).

The second major theme is that releases of hazardous materials are highly heterogeneous and can pose a wide variety of risks. This is clearly a key message of the epidemiological reviews and site-specific risk analyses described above. The key implication is that sites at which the Superfund program takes an important role are likely to be quite heterogeneous as well. The case studies (one of which appears on the next page, and all of which are listed in Appendix B) provide an illustration of how different NPL sites are, and there is possibly even greater variety among response actions (see Table 3.2). The great variety of risks present at these sites suggests a corresponding variety of benefits from reducing or eliminating these risks.

The third theme is that there is a lack of adequate data with which to evaluate Superfund. Recognition of the third theme has led to the choice of approaches in Chapters 4 and 5, and to the extended narrative discussion of the non-quantified benefits in Chapter 6.

Case Study: Butterworth #2 Landfill

The Butterworth #2 Landfill Superfund site is located on approximately 180 acres within a primarily industrial area of Grand Rapids, Michigan.[1] It is also one of the study sites investigated by Hamilton and Viscusi (1999) and one of the property value study sites used in the analysis of Chapter 5. Kent County, which includes the city of Grand Rapids, is home to 13 Superfund National Priorities List (NPL) sites and over 590,000 people. The Butterworth #2 Landfill was operated by the city of Grand Rapids from 1950 until 1973, when the state of Michigan ordered that the landfill close due to improper operations. During operations, the Butterworth #2 Landfill accepted municipal and industrial wastes, including plating wastes, paint sludges, and organic solvents. The Butterworth #2 Landfill site was proposed to the NPL in 1982 and listed in 1983. At that time, the site was an environmental hazard due to an insufficient landfill cover allowing leachate to enter the adjacent Grand River.

Contaminants at the Butterworth #2 Landfill site include volatile organic compounds (VOCs) (such as benzene and vinyl chloride), polychlorinated biphenyls (PCBs), pesticides, and heavy metals (including arsenic and chromium) in site soils and the underlying aquifer. The site is "generally isolated from the public," and ground water is not currently used as a drinking water source. The ground water underlying the site discharges to the Grand River, but contaminants have not been detected in biota from the river.

During site investigations in 1988, EPA identified a hotspot of PCB and chromium contamination. A removal action was initiated to address this contamination and was completed in June 1990. In the baseline risk assessment for this site, EPA determined that if children were to play on the site they would be exposed to significant health risks even after the removal action is taken into account. The hazard index of non-cancer risks from exposure to contaminants in site soils (including VOCs, semi-volatile organic compounds (SVOCs), PCBs, and metals) was 13, compared to EPA's acceptable level of one.

The remedy selection process for this site is rather complex, and illustrates how the relevant federal and state agencies work together to deal effectively with landfill sites. The main challenge at many landfills is that they may have only a few hotspots that contain high concentrations of hazardous substances, while a large majority of the site is contaminated at lower levels, and some of the site is an uncontaminated buffer. The usual approach is to identify and then either remove or destroy the contaminants in the hotspot(s), and then to place a cap over the remainder of the contaminated portions of the site.

Butterworth #2 provides an example of how the federal and state governments work together to make difficult decisions about appropriate levels of remediation. The original remedy documented in the 1992 Record of Decision (ROD) called for capping the landfill and established alternate concentration limits (ACLs) for groundwater contaminants.[2] EPA proposed these ACLs because remediation to meet the applicable or relevant and appropriate requirements (ARARs) for this site (Michigan's water quality standards that had been established under the Michigan Water Resources Commission Act and the Michigan Environmental Response Act) would have been impracticable. However, the state of Michigan did not concur with this approach and sought more stringent cleanup.

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[1] Most of the information used to create this case study was obtained from various documents available on the internet in July 2004. These sources include: EPA's CERCLIS record of actions at the Butterworth #2 Landfill site; EPA's Explanation of Significant Differences for the Butterworth #2 Landfill site, October 23, 1998, www.epa.gov/superfund/sites/rods/fulltext/e0599138.pdf; EPA's NPL site fact sheet, updated January 2003, www.epa.gov/R5Super/npl/michigan/MID062222997.htm; EPA's NPL site listing narrative, December 1982, www.epa.gov/superfund/sites/npl/nar563.htm; EPA's Record Of Decision for the site, September 29, 1992, www.epa.gov/superfund/sites/rods/fulltext/r0592221.pdf; and the U.S. Census Web site, http://www.census.gov.

[2] See http://www.epa.gov/superfund/resources/remedy/pdf/540g-89006-s.pdf for information about ACLs.

As a result, in 1998 EPA produced an Explanation of Significant Differences (ESD) that modified the remedial decision from the 1992 ROD. In addition to a modification of certain capping requirements, the ESD revised the ACLs for ground water contaminants using ground water/surface water interface (GSI) criteria established by the Michigan Department of Environmental Quality, Surface Water Quality Division. Because these standards were developed, the "monitoring program used to measure compliance for the GSI numerical criteria would also replace the ROD requirement for surface water, river sediment, and biological monitoring". With this modification, the Michigan Department of Environmental Quality concurred with EPA's remedy. In addition, this approach saved $700,000 by eliminating the need to conduct the surface water, river sediment, and biological sampling, and by reducing the number of monitoring events needed to establish the ACLs.

The Butterworth #2 Landfill site remedy incorporates institutional controls (ICs)—administrative or legal controls placed on land parcels that help to minimize the potential for human exposure to contamination and/or protect the integrity of a remedy. The ICs were not specifically named in the 1992 Record of Decision, but rather were generally defined to include: "as necessary, restrictions to control future development of the landfill area and to prohibit the installation of ground-water drinking water supplies at the Butterworth Landfill property and an isolation zone" of land surrounding the site.

The Return to Use Initiative (RTU) is the latest phase of the Superfund Redevelopment Initiative. It facilitates Superfund site reuse by removing barriers that are not needed to protect human health, the environment, or the remedy. Butterworth Landfill #2 was the location of the national announcement of the RTU on November 10th, 2004. At Butterworth Landfill #2, EPA Region 5 worked with the city of Grand Rapids to conduct a new risk assessment and approve removal of a portion of the fence surrounding the site so that two adjacent biking and hiking trails can be connected. Region 5 is also working with the city to open major portions of the site to recreational use in the near future.

Since the remedy results in hazardous substances remaining on the site above health-based levels, EPA will conduct recurring Five-Year Reviews to ensure that the remedy remains protective of human health and the environment. Operations and maintenance (O&M) activities will also continue; these activities include maintenance of the landfill cap and monitoring of the level of contaminants in ground water and surface water. The site's ground water will be monitored for a minimum of 30 years after the remedy's completion in 2000. Ground water monitoring may be extended beyond 30 years if EPA finds it necessary in order to protect human health and the environment.

The cleanup of the Butterworth #2 Landfill site, one of a cluster of Superfund sites in and around Grand Rapids, illustrates a typical approach to a landfill-type NPL site. It also illustrates EPA's commitment to working with states, as the original remedy was revised to accommodate Michigan's preferred ARARs. It also represents a good example of how EPA works with communities to allow them to return sites to productive use after cleanup. Finally, the site's cleanup demonstrates the importance of institutional controls and O&M activities at Superfund sites.

References

Agency for Toxic Substances and Disease Registry. 2003a. ATSDR CEP site count report.

———. 2003b. CERCLA Priority List of Hazardous Substances.

Andrews, R. N. L. 1999. *Managing the environment, managing ourselves*. New Haven, CT: Yale University Press.

Anonymous. 2003. Birth defects surveillance data from selected states, 1996-2000. *Birth Defects Research Part a-Clinical and Molecular Teratology* 67 (9):729-818.

Arrow, K., M. Cropper, G. Eads, R. Hahn, L. Lave, R. Noll, P. Portney, M. Russell, R. Schmalensee, V. Smith, and R. Stavins. 1996. Is there a role for benefit-cost analysis in environmental, health, and safety regulation? *Science* 272 (5259):221-222.

Arrow, K., G. Daily, P. Dasgupta, S. Levin, K.-G. Maler, E. Maskin, D. Starrett, T. Sterner, and T. Tietenberg. 2000. Managing ecosystem resources. *Environmental Science & Technology* 34:1401-1406.

Arrow, K., and A. Fisher. 1974. Environmental preservation, uncertainty, and irreversibility. *Quarterly Journal of Economics* 88:312-319.

Barnthouse, L. W., and R. G. Stahl. 2002. Quantifying natural resource injuries and ecological service reductions: Challenges and opportunities. *Environmental Management* 30 (1):1-12.

Bockstael, N. E., A. M. Freeman, R. J. Kopp, P. R. Portney, and V. K. Smith. 2000. On measuring economic values for nature. *Environmental Science & Technology* 34 (8):1384-1389.

Bove, F., Y. Shim, and P. Zeitz. 2002. Drinking water contaminants and adverse pregnancy outcomes: A review. *Environmental Health Perspectives* 110:61-74.

Boyle, M. A., and K. A. Kiel. 2001. A survey of house price hedonic studies of the impact of environmental externalities. *Journal of Real Estate Literature* 9 (2):117-144.

Breffle, W. S., E. R. Morey, R. D. Rowe, and D. M. Waldman. 2005. Combined stated-choice and stated-frequency data with observed behavior to value NRDA compensable damages: Green Bay, PCBs and fish consumption advisories. In *The handbook of contingent valuation*, edited by D. J. Bjornstad, J. Kahn and A. Alberini. Northhampton, MA: Edward Elgar.

d'Arge, R. 1993. Marking Time with CERCLA: Assessing the effect of time on damages from hazardous wastes. In *Valuing natural assets*, edited by R. J. Kopp and V. K. Smith. Baltimore: The Johns Hopkins University Press.

Damage Assessment and Restoration Program (DARP). 2004. Natural Resource Damage Settlements and Judgments. Washington, DC: National Oceanic and Atmospheric Administration.

Dunford, R. W. 2000. Estimating ground-water damages from hazardous-substance releases. *Journal of Water Resources Planning and Management-Asce* 126 (6):366-373.

EPA Science Advisory Board. 2002. *Underground storage tanks (UST) cleanup & Resource Conservation & Recovery Act (RCRA) Subtitle C program benefits, costs, & impacts (BCI) assessments: An SAB advisory*. Washington, DC: USEPA.

Farber, S. 1998. Undesirable facilities and property values: A summary of empirical studies. *Ecological Economics* 24 (1):1-14.

Freeman, A. M. 1993. *The Measurement of environmental and resource values: Theory and methods*. Washington, DC: Resources For the Future.

———. 2002. Environmental policy since Earth Day I: What have we gained? *Journal of Economic Perspectives* 16 (1):125-146.

General Accounting Office. 1999. *Superfund: Progress and Challenges*. Washington, DC.

———. 2003. *Superfund Program: Current Status and Future Fiscal Challenges*. Washington, DC.

Hamilton, J. T., and W. K. Viscusi. 1995. The magnitude and policy implications of health risks from hazardous waste sites. In *Analyzing Superfund: Economics, science, and law*, edited by R. L. Revesz and R. B. Stewart. Washington, DC: RFF Press.

———. 1999a. *Calculating risks? The spatial and political dimensions of hazardous waste policy*. Edited by N. L. Rose and R. Schmalensee, *Regulation of Economic Activity*. Cambridge, MA: MIT Press.

———. 1999b. How costly is "clean"? An analysis of the benefits and costs of Superfund site remediations. *Journal of Policy Analysis and Management* 18 (1):2-27.

Hammitt, J. K. 2000. Valuing mortality risk: Theory and practice. *Environmental Science & Technology* 34 (8):1396-1400.

Harrison, R. M. 2003. Hazardous waste landfill sites and congenital anomalies: Where do we go from here? *Occupational and Environmental Medicine* 60 (2):79-80.

Hird, J. A. 1994. *Superfund : the political economy of environmental risk*. Baltimore: Johns Hopkins University Press.

Johnson, B. L. 1995. Nature, extent, and impact of Superfund hazardous-waste sites. *Chemosphere* 31 (1):2415-2428.

———. 1999a. *Impact of hazardous waste on human health: hazard, health effects, equity, and communications issues*. Boca Raton: Lewis Publishers.

———. 1999b. A review of the effects of hazardous waste on reproductive health. *American Journal of Obstetrics and Gynecology* 181 (1):S12-S16.

Johnson, B. L., and C. DeRosa. 1995. Chemical mixtures released from hazardous waste sites: Implications for health risk assessment. *Toxicology* 105:145-156.

Kopp, R. J., and V. K. Smith. 1989. Benefit Estimation Goes to Court: The Case of Natural Resource Damage Assessments. *Journal of Policy Analysis and Management* 8:593-612.

Krupnick, A., and R. Morgenstern. 2002. The future of benefit-cost analyses of the Clean Air Act. *Annual Review of Public Health* 23:427-448.

Landy, M. K., M. J. Roberts, and S. R. Thomas. 1994. *The Environmental Protection Agency (expanded edition): Asking the wrong questions from Nixon to Clinton*. New York: Oxford University Press.

Luftig, S. D. 1999. *Issuance of final guidance: Ecological risk assessment and risk management principles for Superfund sites*. Washington, DC: U.S. Environmental Protection Agency Office of Emergency and Remedial Response.

Lybarger, J. A., R. Lee, D. P. Vogt, R. M. Perhac, R. F. Spengler, and D. R. Brown. 1998. Medical costs and lost productivity from health conditions at volatile organic compound-contaminated Superfund sites. *Environmental Research* 79 (1):9-19.

Morey, E. R., W. S. Breffle, R. D. Rowe, and D. M. Waldman. 2002. Estimating recreational trout fishing damages in Montana's Clark Fork River basin: Summary of a natural resource damage assessment. *Journal of Environmental Management* 66 (2):159-170.

Morgan, M. G., and M. Henrion. 1990. *Uncertainty: a guide to dealing with uncertainty in quantitative risk and policy analysis*. New York: Cambridge University Press.

Nakamura, R. T., and T. W. Church. 2003. *Taming regulation: Superfund and the challenge of regulatory reform*. Washington: Brookings Institution Press.

National Research Council. 1991. *Environmental Epidemiology, Volume 1: Public Health and Hazardous Wastes*. Washington, DC: National Academy Press.

Office of Information and Regulatory Affairs, and Council of Economic Advisors. 1996. *Economic analysis of federal regulation under Executive Order 12866.* Washington, DC: Office of Management and Budget.

Office of Management and Budget. 2003a. *OMB Circular A-4: Regulatory analysis*. Washington, DC: Executive Office of the President.

———. 2003b. *Proposed bulletin on peer review and information quality*.

Office of Solid Waste and Emergency Response. 2000a. *Approaches to assessing the benefits, costs, and impacts of the RCRA Subtitle C program.* Washington, DC: U.S. Environmental Protection Agency.

———. 2000b. *Approaches to assessing the Office of Underground Storage Tanks cleanup program.* Washington, DC: U.S. Environmental Protection Agency.

Paustenbach, D. J. 2002. *Human and ecological risk assessment: Theory and practice*. New York: John Wiley and Sons.

President of the United States. 1993. *Executive Order 12866: Regulatory planning and review*.

———. 2002. *Executive Order 13258: Amending Executive Order 12866 on regulatory planning and review*.

Probst, K. N., and D. M. Konisky. 2001. *Superfund's future: What will it cost?* Washington, DC: RFF Press.

Reisch, M. 2001. Superfund and Natural Resource Damages. In *CRS Report for Congress*, edited by Congressional Research Service. Washington: U.S. Congress.

Sen, A. K. 1982. Approaches to the choice of discount rates for social benefit-cost analysis. In *Discounting in time and risk for energy policy*, edited by R. C. Lind. Washington, DC: RFF Press.

Slovic, P. 1987. Perception of risk. *Science* 236:280-5.

Stopher, M. C. 2000. Hindsight analysis for the Cantara spill natural resource damage assessment. *California Fish and Game* 86 (1):87-100.

Suter, G. W., R. A. Efroymson, B. E. Sample, and D. S. Jones. 2000. *Ecological risk assessment for contaminated sites*. Washington, DC: Lewis Publishers.

U.S. Environmental Protection Agency. 1997. *The benefits and costs of the Clean Air Act, 1970 to 1990*. Washington, DC.

———. 1998. *Guidelines for ecological risk assessment.* 63 *FR* 93. May 14. 26846-26924.

———. 2000. *Guidelines for preparing economic analyses*. Washington, DC.

———. 2002. *A framework for the economic assessment of ecological benefits*. Washington, DC.

———. 2004. *Superfund: Building on the past, looking to the future.* Washington, DC.

Viscusi, W. K., J. T. Hamilton, and P. C. Dockins. 1997. Conservative versus mean risk assessments: Implications for Superfund policies. *Journal of Environmental Economics and Management* 34 (3):187-206.

Walker, K. D., M. Sadowitz, and J. D. Graham. 1995. Confronting Superfund mythology: The case of risk assessment and management. In *Analyzing Superfund: Economics, science and law*, edited by R. L. Revesz and R. B. Stewart. Washington, DC: RFF Press.

Wildavsky, A. 1995. *But is it true? A citizen's guide to environmental health and safety issues*. Cambridge: Harvard University Press.

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Chapter 3: Characterization of Superfund Responses

Of the approaches used in the Superfund program described in Chapter 1, responses, including both removal actions and remedial actions, are the most complex, account for a majority of Superfund spending, and probably account for most of the benefits. To support the benefits transfer analyses in Chapters 4 and 5, this Chapter describes Superfund responses, quantifies them, and characterizes sites on the National Priorities List (NPL). Superfund responses to uncontrolled releases of hazardous substances are taken by the federal government directly under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA), as well as response actions taken by states and private parties to the degree that CERCLA and SARA provide a basis for those actions.[1] This Chapter is organized in three major parts: first, Superfund responses are described; second, methods used to quantify responses are presented and applied; and third, sites on the National Priorities List (NPL) are characterized.

Description of Superfund Responses

Overview

The National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 CFR 300) is the regulation that specifies how CERCLA remedial and removal actions are conducted. The NCP was first established in 1968 to deal with oil spills. CERCLA added authority to respond to uncontrolled releases of hazardous substances in a manner consistent with the NCP. Today the NCP is managed jointly by the U.S. Coast Guard and the Environmental Protection Agency (EPA), and the program involves over 16 federal agencies, as well as many state and local representatives. The NCP provides a national framework for emergency response capabilities and promotes coordination among the hierarchy of responders and contingency plans. A Superfund response is triggered by the discovery of a hazardous substance release, or a substantial threat of a release. CERCLA Section 101 defines a release as "… any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment (including the abandonment or discarding of barrels, containers, and other closed receptacles containing any hazardous substance or pollutant or contaminant.)" The release must be of a hazardous substance as defined in CERCLA or must present an imminent or substantial danger to public health or welfare. Petroleum spills are specifically excluded from the authority of the Superfund program and are ignored here.

Many CERCLA responses involve the enforcement of CERCLA's liability provisions, in which EPA seeks to identify the potentially responsible parties (PRPs) – those individuals or organizations responsible for creating or contributing to uncontrolled releases of hazardous substances. CERCLA's two basic liability provisions permit EPA to either compel a PRP to abate an endangerment to public health, welfare, or the environment, or to recover the costs of response. The law also provides for citizen suits to enforce CERCLA's provisions (Section 310), and it provides authority for federal agencies, states, and tribes to bring actions for damages to natural resources (Section 107).

[1] The current study defines Superfund responses as those responses to uncontrolled releases of hazardous substances that can be attributed to the Superfund program.

Liability can extend to site owners, facility operators, waste transporters, or anyone who generates hazardous substances that contaminate other sites. This liability is strict, joint, and several, with no requirement that a PRP's hazardous substance be the sole cause for a response action. Legal proof of negligence is not required, and conducting activities consistent with standard industry practices is not considered an adequate defense. The original draft of CERCLA contained no statute of limitations. This was altered in 1986 with SARA's inclusion of limits on recovery actions and natural resource damages.

Superfund responses address the continuum of health and environmental risks ranging from emergencies to long-term problems. Removal actions, in particular time-critical removals, provide for rapid response where the problem needs to be addressed in an urgent manner. They are typically used to respond to chemical spills, human health threats that might cause harm from short-term exposures (e.g., lead-contaminated residential soils), and situations that may cause a sudden release (e.g., leaking drums). The technological options that can be used (e.g., waste treatment, excavation and disposal, providing alternate water supplies) to conduct both removal and remedial actions are identical under the authority granted to EPA, except that permanent relocation of residents is specifically authorized only as a remedial action. However, removal actions are limited in monetary and temporal scope ($2 million and one year, with occasional exceptions). As a result, removal actions do not support the detailed investigation and planning needed to ensure that the locations of all hazardous substances on a site are identified, that the extent of contamination is fully characterized, or that all the hazardous substances on the site are treated. For this reason, detailed risk information is generally not available for releases associated with removal actions. In practice, the removal program is often used to address completed exposure pathways with high levels of exposure, and the remedial program is used to address such risks where there are future risks but no (or limited) current exposures, or where a completed exposure pathway is interrupted temporarily (e.g., with a fence).

Based on these regulations and complementary state laws and programs, EPA and the states have over time crafted a set of response options that are flexible and accountable, and that maximize PRP involvement in response actions. In situations where there is an obvious, immediate health risk, the NCP authorizes limited federal expenditures to deal with the problem. In situations where the cost of remediating a site is larger, the NCP requires more testing and analysis to determine more definitively the nature and extent of contamination and select the best method for dealing with the release. In both cases, the liability provisions of CERCLA and SARA apply, so PRPs can be required to reimburse EPA for the cost of remediation. This highlights the importance of the Trust Fund – it can be used to begin to address without delay releases that could be harmful to the public and then the costs incurred can be recovered from the PRPs. In part to avoid the liability provisions of the Superfund program and in part to restore more power to local decision-makers, the states have developed complementary programs to deal with releases, and PRPs have undertaken voluntary remedial actions (usually under the supervision of state Voluntary Cleanup Programs, or VCPs).

Thus, the primary distinction between NPL sites and other hazardous waste sites is often a question of whether federal authorities or resources will be needed, not the risks presented by the site, or even the cost of remedial action. For this reason, while NPL sites tend to have serious contamination problems, not all sites with serious contamination end up on the NPL, and the NPL does not include all of "the worst of the worst" (General Accounting Office 1998b, 1999; Varney 2000; Probst and Konisky 2001 pp. 75-6, 81-5). The key implication of this is that when considering the benefits of Superfund, examining only NPL sites is likely to be inadequate. Other response actions should also be included.

A simplified diagram of the processes (or "pipelines") for the various Superfund responses is shown in Figure 3.1.[2] Note that there are three essentially separate pipelines: a site screening or pre-remedial action (left pipeline); a removal action (upper right pipeline); and the remedial action (lower right pipeline). The site screening pipeline is used to sort out the many notifications and discoveries that are referred to EPA to ensure that each site receives an appropriate response, or receives no response if that is appropriate. It is important to keep in mind while reading the description of the site screening pipeline (as well as the NPL pipeline) that at any time during these processes the need for a removal action may arise, in which case the screening and analysis are temporarily stopped to deal with whatever immediate health risk has created the need for the removal action.

The use of the site screening process through the NCP has helped reduce the uncertainty associated with actual and potential releases. Local first responders (e.g., fire, police) and others who discover what they believe to be a hazardous substance release have a single place to report the discovery: the National Response Center (800-424-8802 or www.nrc.uscg.mil/nrchp.html). As a result, adequately trained personnel determine if the substance is hazardous, and if so, what to do about it. Many sites that were suspected of contamination by hazardous waste have been assessed through this mechanism, and most of them were found not to qualify for the NPL. Thus, the site screening process reduces the uncertainty associated with many potentially contaminated sites, which is generally considered a benefit in the *amenities* category (see Chapter 1).

Sites are not legally defined by property boundaries, but it is common to use property boundaries to describe sites. When a hazardous material is released into a medium (ground water, soil, surface water, or air), it may remain close to where it was released or it may migrate quite far, and sometimes rapidly. The release event, or series of events, implies a location, typically called the "site." The "release," often synonymous with the "site," is broadly defined in CERCLA as "any area where a hazardous substance release has 'come to be located.'" Often, this area does not match property boundaries.

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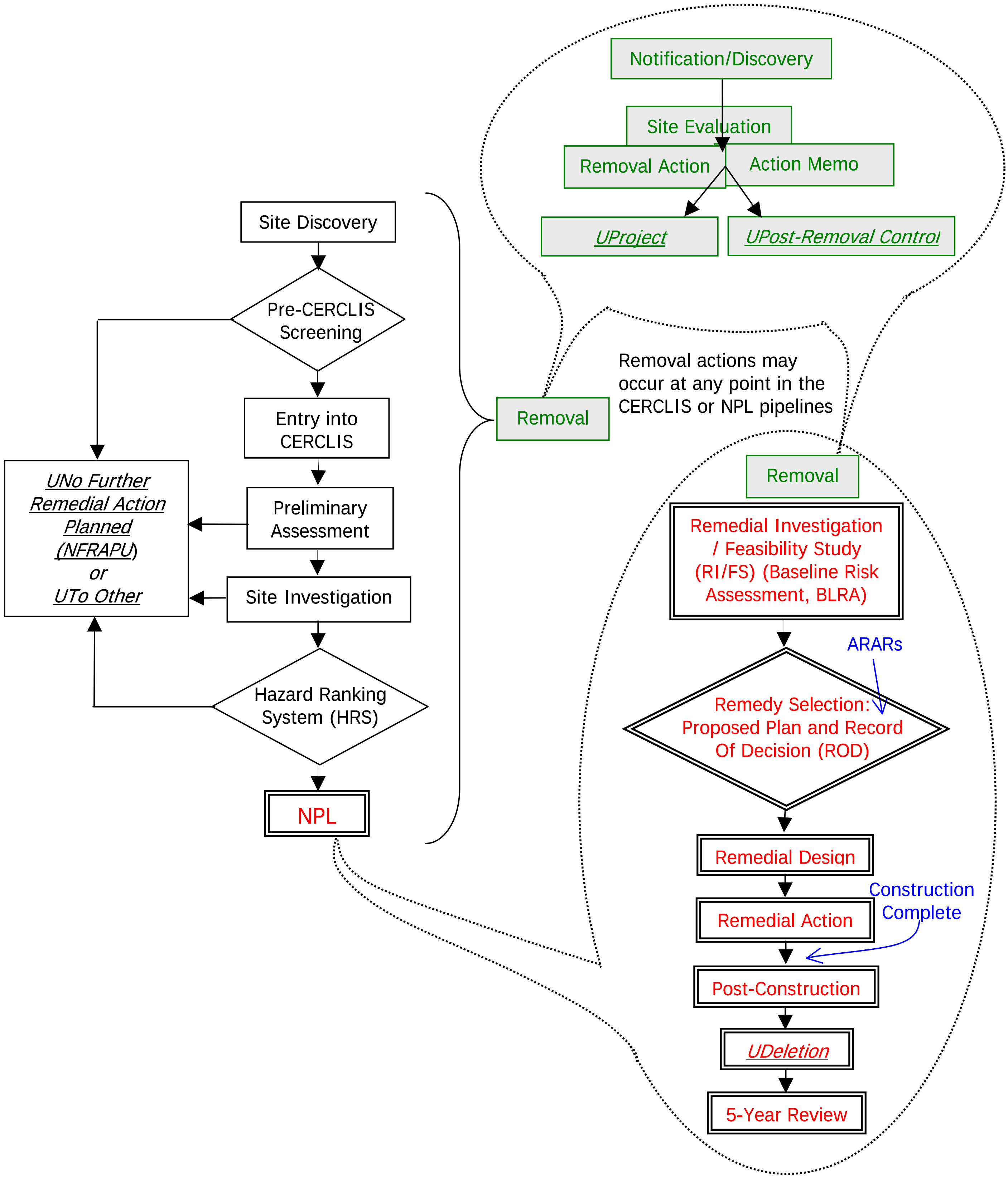
[2] More information can be found at www.epa.gov/superfund/action/process/sfproces.htm.

Figure 3.1. Superfund Response Pipelines



<u>The Site Screening Pipeline</u>

Overview

A process of screening sites of releases and potential releases reduces the uncertainty about potential health or environmental risks at many sites around the country. This process is shown in the left-hand side of Figure 3.1 and is described below. If at any stage in this process an imminent and substantial threat is discovered, the site screening process stops to allow a removal action to address the problem promptly.

The site screening process has four possible endpoints, plus the potential to identify the need for one or more removal actions. First, some sites are eliminated from the process without formality because there is no risk (e.g., a sales office for pressure treated lumber that never harbored any hazardous substances). Second, sites may be entered into the screening process and evaluated, but eventually designated as requiring no further response action planned (NFRAP). In the latter case, the Superfund program is no longer involved, and these sites are designated as "archived." Third, some sites may go to other agencies (e.g., federal CWA officials or States). Fourth, sites may be proposed to the NPL, and after public comment be designated as final, which makes them eligible for remedial action funding. Each site that enters the site screening pipeline will end up at one of these four endpoints and may also have a removal action performed.

Site Discovery and Initial Screening

There are various ways in which uncontrolled releases of hazardous substances can come to the attention of EPA. Sometimes, the Agency discovers them through inspections or other investigations. For example, the contamination of a drinking water supply may be the initial sign of a release. If EPA conducts an investigation of a contaminated drinking water supply, the Agency will search the region for the sources of that contamination, and may identify sites requiring a response action. States discover most of the sites that require a Superfund response action, often through first responders, such as police, firefighters, and paramedic personnel. Other agencies within the federal government may refer sites to EPA, or site discoveries can result from information and reports from local authorities, businesses, and concerned citizens.

After discovery, the next step is an initial screening. EPA maintains a large database to track sites that may require a response action, called the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). States perform much of the pre-CERCLIS screening work with EPA funding. This initial screening step comes before entering a site into CERCLIS, and ensures that the site represents a release or potential release that warrants Superfund assessment. For example, sites that are regulated under other federal authorities (e.g., the Clean Water Act (CWA)) that have their own cleanup processes would typically be screened out. Sites that are in other cleanup programs (e.g., state voluntary cleanup programs) might also be screened out. Moreover, some sites found through active discovery programs might not actually have handled hazardous substances and would not be entered into CERCLIS. For instance, the discovery of an uncontrolled release at a former chemical plant could result in a search for other properties owned by the firm that owned the chemical plant. Some of the properties identified in this way might be investigated. Others, such as a sales office that never had chemicals onsite, would be eliminated in the initial screening.

After pre-CERCLIS screening, sites are entered into CERCLIS, and are assigned a unique CERCLIS identification number. This number becomes the key to tracking all the elements of a site's history with EPA. Sites entered into CERCLIS are evaluated to determine what, if any, action is necessary under Superfund.

Site Assessment

EPA assesses all sites that are entered into CERCLIS. Initial site assessment comprises two phases: preliminary assessment (PA) and site inspection (SI). The PA is a relatively rapid, low-cost compilation of readily available information pertaining to the site and its surroundings. The data collected during the PA emphasize sensitive populations and other receptors or targets (e.g., ecosystems) that may be affected by contamination at the site. The SI builds on the PA by gathering enough information to determine whether a Superfund response or some other action (possibly by another agency) is warranted, or if no further remedial action is planned. During either of these steps it may be determined that no further response action is needed and the site will enter NFRAP status.

A key step in the site assessment process is the use of the Hazard Ranking System (HRS) to screen sites for potential inclusion on the NPL and for remedial action as defined by the NCP. The HRS is a standardized, objective method for providing an approximate quantitative evaluation of a potential release. Although the HRS characterizes the risks at each site and assigns a numerical score to those risks, it is only a screening process; the information does not provide in-depth site characterization.

Site Listing on the NPL

Most sites are listed on the NPL because they pass through the HRS screening process. If the HRS site score is greater than or equal to 28.5, the site is eligible for placement on the NPL, and therefore potentially warrants Superfund remedial action. Concurrence by the state in which the site is located is also required.[3] An HRS score below the cut-off yields a "No Further Response Action Planned" (NFRAP) designation. The cutoff score of 28.5 was developed in 1982 in order to meet a mandate in CERCLA that at least 400 sites be placed on the NPL. Because it is used as a screening tool and is not intended as a means of risk characterization, the HRS process is often halted once a score of 28.5 is reached. This is a means of conserving resources in the management of the Superfund program, but makes HRS scores unreliable for use in evaluating and comparing different sites.[4]

Sites may also be included on the NPL regardless of their HRS score if designated as the top priority by their state or territory. This can happen only once per state/territory, so only 56 NPL sites can ever be created this way (state roles in Superfund are discussed in more detail later in this chapter.) In addition, a site can be placed on the NPL if it meets one or more of three criteria: ATSDR issues a health advisory for the site recommending disassociation of the residents from the site; EPA determines that there is a risk to human health and/or the

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[3] Initially required by appropriations language, this was institutionalized by EPA guidance in 1986.

[4] The truncation of HRS scores at 28.5 did not occur at the original set of 400 (approximately) NPL sites, which makes HRS values more meaningful for these sites.

environment; and EPA determines that a remedial action is more cost-effective than a removal action. EPA infrequently uses this last method for listing an NPL site.

The Removal Actions Pipeline

The NCP gives EPA the authority to respond rapidly to urgent problems associated with releases, such as chemical spills, human health threats that might cause harm from short term exposures (e.g., lead-contaminated residential soils), and situations that may cause a sudden release (e.g., leaking drums). A wide variety of response actions can be taken under this authority, such as waste treatment, excavation and disposal, or providing alternate water supplies. However, less permanent measures, such as erecting a fence to prevent access to the contaminated area and thus prevent exposure, are also common removal actions. In part, this is due to the limited monetary and temporal scope permitted for removal actions ($2 million and one year, with occasional exceptions), and in part due to the way EPA coordinates removal actions with larger, more complex remedial actions to ensure health and ecological risks are dealt with appropriately at all sites. In some cases (slightly less than 20% of the time) PRPs undertake removal actions with EPA or state supervision (Probst and Konisky 2001, 25).[5] In these cases, the limits on expenditures and duration do not apply.

There is extremely little quantitative risk assessment data about removal actions, but qualitative information can be found in several sources. Several researchers have documented significant reductions in exposure and risk from exposure during both remedial and removal actions (von Lindern et al. 2003; Sheldrake and Stifelman 2003; Khoury and Diamond 2003). This is the only quantitative evidence that removal actions may significantly reduce risk.

The qualitative evidence begins with the dramatic examples of removal actions provided in Table 3.1 and several of the case studies included here, such as LCP Chemicals on page 3-10 and RSR smelter on page 4-21. These examples suggest that for some removal actions, at least, significant hazards are being addressed.

It is useful to observe that the NCP authorizes EPA to use the same techniques in removal actions as in remedial actions, with the exception of permanent relocation of neighbors. This includes permanent remedies like incineration or other disposal, as well as simpler approaches such as erecting fences or otherwise limiting site access. Several of the case studies illustrate the sorts of techniques used in removal actions. However, some techniques used in remedial actions – such as the long-term treatment of contaminated ground water – are not used in removal actions. In a situation where ground water used for drinking was discovered to be contaminated by a release, a removal action might provide alternative drinking water on a temporary basis while a remedial action might treat the ground water so that it could eventually be used again as a drinking water source. Thus, in terms of techniques employed, removal actions are limited in comparability.

The other qualitative evidence comes from statements made in the literature. Essentially all analysts who have considered the question of whether removals mitigate significant real risks

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[5] Note that Probst and Konisky excluded federal facilities from most of their analyses, which may lead to differences in total cases they report versus those of other researchers.

have come to the conclusion that they do (Koshland 1991; Hird 1994; Wildavsky 1995; General Accounting Office 1995; Office of Management and Budget 2003). For instance, Hird notes removals prominently in his section on "Superfund's Overlooked Accomplishments" and goes on to say: "Indeed, much of Superfund's success lies with the removal action program, which has removed more than 2,600 immediate threats to heath and the environment since 1980 and has reduced substantial risks at many sites at relatively little cost. Thomas Grumbly, former Director of Clean Sites, Inc. and former U.S. Department of Energy Assistant Secretary for Environmental Management, stated that EPA's removal program, 'has probably eliminated most of the *immediate* health risks posed by abandoned hazardous waste sites'" (Hird 1994, 29-30, 112). There are some qualitative comparisons between removal and remedial actions: "… these emergency activities may operate in tandem with, *or as replacements for*, the remedial process…" (Hird 1994, 19 emphasis added). An OTA report noted that removal actions can resemble a remedial cleanup (Office of Technology Assessment 1989, 7, box). These comparisons are not quantitative, but they provide support for the idea that some removal actions result in significant health benefits.

EPA classifies removal actions into two types: time-critical, and non-time-critical.[6] To provide an example of typical removal actions, parts of a table from Probst and Konisky (2001, 20-21) are reproduced below in Table 3.1. In addition, several of the case studies contained in this report provide examples of removal actions. See, for instance, the LCP Chemicals case study on page 3-10. The other case studies are listed in Appendix B.

Table 3.1. Examples of Removal Actions

Type of Removal	Example Actions
Time-Critical	▪ Respond to truck accidents and train derailments involving chemical releases ▪ Temporarily provide bottled water to homes with contaminated water supplies ▪ Remove and dispose of chemicals abandoned by roadsides or in vehicles ▪ Respond to fires and explosions involving chemicals at operating or abandoned facilities, tire fires, and so forth ▪ Clean up and monitor mercury contamination at schools and private residences where children have played with metallic mercury ▪ Clean up and monitor chemical releases due to natural disasters (e.g., floods) ▪ Restrict access to and remove and dispose of chemicals at abandoned or bankrupt facilities or warehouses that may be subject to vandalism or fires (e.g., small electroplating shops, illegal drug production sites) ▪ Stabilize mining wastes to prevent releases to surface and ground waters
Non-Time-Critical	▪ Remove "hot spots" ▪ Install ground water treatment systems for contaminated ground water in conjunction with the remedial program

Source: (Probst and Konisky 2001 Table 2-3)

There is very little unified, systematic data characterizing the kinds of activities conducted during removal actions and the risk reduction associated with them. The most important information created through this process is included in the Action Memo for each removal (see Figure 3.1), but Action Memos do not include detailed risk information and are not readily accessible. As of the end of FY 2003, EPA had completed approximately 7,400 removal

6 Probst and Konisky (2001, 17) and others use a third category ('emergency' removals) but this is not an official EPA designation.

actions.[7] Over the last decade, an average of 430 removals has occurred annually. This is more than reported previously by Probst and Konisky (2001, Ch. 2), who did not include removal actions on federal facilities in their totals.

Based on records in CERCLIS,[8] 69% of removal actions were time-critical through the end of 2002. Removal actions are often responses to spills and other accidents (which are not sites in the usual sense of a long-standing contamination problem), so first responders discover many of these releases; others are reported by facility personnel to comply with statutory and NCP requirements. Other removal actions are taken at sites that EPA expects to eventually undergo remedial action on the NPL, but which could become significantly worse before the remedial action process reaches the action phase. As Figure 3.1 suggests, removal actions can take place at NPL sites (or sites that will eventually be placed on the NPL) at any time after discovery. Probst and Konisky report that most removal actions (76%) are taken at non-NPL sites, and the vast majority (>95%) are taken at sites that have only one or two removals (Probst and Konisky 2001, 17).

Because summary data on the size and scope of removal actions, or about the risk mitigation involved, are not available, estimates of the cost of removal actions can be used to provide some comparison to other Superfund responses. Of course, costs are not necessarily related to benefits, but this approach will at least provide some evidence that typical removal actions are not inconsequential. EPA's Office of Solid Waste and Emergency Response (OSWER) is in charge of conducting and supervising federal removal actions, which account for about one-fifth of federal Superfund expenditures (Probst and Konisky 2001, 12, 22). EPA's internal CERCLIS database contains expenditure information, which suggests that EPA expenditures averaged about $330,000 per removal action for 1999-2002. An alternative estimate can be calculated by dividing total EPA expenditures for removals in 1999 as reported by Probst and Konisky (2001, 12) ($317.8 million) by the number of removals accomplished that year (477) to obtain an average cost of about $660,000. This value would include some 'overhead' but not all.[9]

To partially adjust for the fact that these values do not include private PRP expenses, this calculation can be adjusted by the number of removals for which PRPs pay. Probst and Konisky (2001) indicate that PRPs lead approximately 18% of all removals. This suggests about 390 EPA-led removals in 1999, at an average cost of about $810,000.[10] This suggests that a rough estimate of the total federal cost of the average removal action, including overhead, is about $1 million. Unless private removals are systematically larger or more complex, which appears not to be the case, private costs would tend to be similar or lower.

[7] Data obtained from EPA's internal CERCLIS database on February 4, 2004. A small number (<3%) of the sites in this database are double-counted due to changing designations. The value above is 97% of the values reported in the database. Note: These values will be updated in the final version of the report.

[8] Not all CERCLIS data used in this study is available through the online CERCLIS query. Some CERCLIS data must be accessed through EPA.

[9] Using the number of removals in 1999 that Probst and Konisky found, 310, this average is about $1 million (2001, 22).

[10] This percentage may be inaccurate to apply to the larger internal CERCLIS count of removal actions. Adjusting the number of removals that Probst and Konisky found (310) by this percentage yields an average cost of about $1.3 million.

Case Study: LCP Chemicals Georgia

The LCP Chemicals Georgia NPL site is in the small city of Brunswick, Georgia, near the Turtle River Estuary.TP [1]PT The site comprises 550 acres, most of which is tidal marsh, and is contaminated with mercury, lead, polychlorinated biphenyls (PCBs), and semi-volatile organic compounds (SVOCs). The magnitude of the contamination at this site is evidenced by the fact that although EPA has recovered over 200 tons of mercury from the site, much more remains to be dealt with (Baker 1997). High mercury and PCB levels in the site's aquatic life have resulted in a ban on commercial fishing and a seafood consumption advisory for much of the estuary. Sampling of the water, sediment, and biota at and near the site confirmed that mercury and other hazardous substances were bio-available in species such as fish, fiddler crabs, and oysters, and that the conversion of mercury into the most harmful form (methyl mercury) was occurring (Matta, Gray, and Francendese 1998). Within four miles of the site, over 32,000 people rely on ground water for drinking and other uses (of which about 5,000 use private wells), and monitoring is beginning to show ground water contamination. Thus, without a Superfund response, many people would have been potentially exposed to hazardous substances from this site. In addition, the site was insecure; holes in a perimeter fence allowed relatively easy access to the site, making exposure more likely.

The site was originally operated as a petroleum refinery, and was subsequently used for various industrial processes, the most important of which was a chlor-alkali plant to manufacture products such as chlorine gas, sodium hydroxide, hydrogen gas, hydrochloric acid, and sodium hypochlorite (bleach). Allied Signal operated the facility from 1955 to 1979, during which time many hundred tons of mercury-contaminated sludge were dumped in surface impoundments next to the tidal marsh. LCP Chemicals operated the facility until 1994, when state and federal officials shut the plant down.

The managers of LCP Chemicals had little regard for worker health, the environment, or the law. When EPA arrived at the site in the mid-1990s, they found pools of mercury inside buildings and oil refinery wastes laced with PCBs seeping into the marsh in several places. In its 1999 case against three former LCP Chemicals managers, the U.S. government claimed that "[c]ompany officials had illegally blocked the windows and doors to a lower floor of a production building to store [caustic wastewater] because they knew the company's water treatment system was not adequate." The three LCP officials were convicted of endangering plant employees and conspiring to violate the Clean Water Act (CWA) as well as CERCLA. In 1999, several LCP managers were convicted and sentenced to prison terms, including the longest sentence handed down for environmental crimes up to that time (nine years).

TP[1]PT Sources:

Baker, S. (1997). *A Toxic Legacy*. UPublic HealthU. **Fall**. www.whsc.emory.edu/_pubs/ph/phfall97/toxic.html.

Matta, M., G. Gray, et al. (1998). ULCP Chemical Site Monitoring StudyU. Silver Spring, MD, NOAA National Ocean Service Office of Response and Restoration, August.

Scogin, G.E. (1994) Action Memorandum: Documentation for an Enforcement-lead Removal Action at the LCP Chemicals Site in Brunswick, Glynn County, GA. Atlanta, GA: U.S. Environmental Protection Agency Region IV. p. 11.

Various documents available on the Internet in August-September 2004. These sources include the following: EPA's Fact Sheet, updated 5-11-04, www.epa.gov/region4/waste/npl/nplga/lcpincga.htm; EPA's NPL Site Narrative, June 1996, www.epa.gov/superfund/sites/npl/nar1458.htm; T. Dickson, "Corporate Pollution Trial Begins," *Savannah NOW*, 1/13/99, www.savannahnow.com; EPA's Remedial Investigation Fact Sheet, June 2002, http://www.epa.gov/region4/waste/npl/nplga/lcpjune02fs.pdf; "Official Receives Record Prison Term for Environmental Law Violation," 6/18/99, www.edie.net/news/Archive/1305.html; and, "Guidelines for Eating Fish from Georgia Waters: 2004 Update," Georgia Department of Natural Resources, www.dnr.state.ga.us/dnr/environ/gaenviron_files/fishadvs_files/fcg_2004.pdf. Further information is also available at www.glynnenvironmental.org

Case Study: LCP Chemicals Georgia (cont.)

After the plant closed in 1994, the state of Georgia designated LCP as the state's highest priority site and requested that EPA take immediate action and place it on the NPL. The resulting sequence of events is a good illustration of how removal and remedial actions are often coordinated at NPL sites, how CERCLA and other laws act in concert to protect human health and the environment, and how considerable ecological damage can be reversed (without ever being measured) as an additional benefit to the health risk reductions that motivate the response actions.

The most pressing concerns at the site included the threat of chlorine gas release and the flow of contamination into the marsh inhabited by endangered species. In 1994, EPA determined that the site presented an imminent and substantial endangerment to public health, welfare, or the environment and ordered the parties responsible for the contamination to remove contaminated soils and sediments from the site and dispose of them appropriately. The removal action at the site was completed in 1999; it excavated the vast majority of on-site soils and waste piles. Over 132,000 tons of hazardous waste were removed from the site and disposed of appropriately. Thirteen acres of contaminated sediment were excavated from the marsh.

This rapid response greatly reduced the environmental and health risks at the LCP Chemicals Georgia site. The removal action carried out at the site resulted in lowered levels of PCBs and mercury in the site's aquatic species. For instance, before the removal action, the Georgia Department of Natural Resources advised against consuming some locally caught fish (e.g. red drum). Data collected after the removal action showed that it is now safe to eat fish once a week, although shellfish and some fish species are still unsafe for consumption.

Currently (in late 2004), EPA is assessing the need for further cleanup at the site. The Remedial Investigation / Feasibility Studies for the ground water operable unit and the upland soil and marsh operable unit are nearing completion, after which EPA will decide on final site remedies. Some of the data that would be needed to estimate risk reductions will become accessible at that time. This investigation is also exposing new concerns, such as a recently discovered pool of mercury beneath a sandstone layer at the site, as well as a caustic brine pool, both of which illustrate how complex many NPL sites are and why detailed investigation is often needed.

In this case, only CERCLA provided the legal authority to EPA to force the firms that polluted the site to clean it up; however, this had the effect of advancing the goals of numerous environmental laws, like the CWA. Without the existence of CERCLA (the policy case considered in the SBA), it might have been possible to shut LCP Chemicals down, but the hundreds of tons of contaminants on the site would have remained and continued to leak into the estuary and nearby ground water, increasing the risks to human health and the environment.

None of the ecological improvements at this site has been quantified or recorded, largely because there is no statutory or regulatory reason to do so. Thus, this case illustrates how the ecological benefits estimated in Chapter 5 may be a significant underestimate, because the data used in that chapter ignores reversals of injuries to natural resources (and the avoidance of future natural resource injuries) due to Superfund responses.

This site also illustrates some of the challenges left for the nation in dealing with uncontrolled releases of hazardous substances. Essentially the entire marsh, and possibly a significant portion of Turtle River, is contaminated with hazardous metals that will not degrade or disperse for many decades. Thus, the only ways to eliminate the contamination are to either clean an enormous amount of soil and sediment, or to replace it. Both options would essentially destroy the marsh in order to render it harmless, and would also be very expensive. Other alternatives, which would essentially cap the contaminants, would probably not permit the continued existence of marshlands at this location and could be quite unattractive. With such challenging problems, it is no surprise that sites like LCP Chemicals tend not to be resolved quickly and are accumulating on the NPL.

This case study also illustrates how the EPA responds to challenging problems of hazardous substance contamination with innovative approaches. An experimental phytoremediation project was approved by EPA in November 2003 that will locally suppress the ground water table and prevent seepage of contaminated ground water and staining of sediments.

<u>The Remedial Action Pipeline</u>

Overview

The NCP gives EPA the authority to undertake larger, more complex responses to actual or potential uncontrolled releases of hazardous substances through the remedial action program. Remedial actions also tend to fulfill the Congressional mandate in SARA to seek permanent solutions to releases at sites where both removal and remedial actions occur – this can be a major distinction. The removal action(s) may temporarily interrupt an exposure pathway, but leave the contamination in place or only remove some of the contamination. The remedial action then treats or isolates the hazardous substance, thereby providing a long-term solution. Often, soil or ground water contamination is dealt with through remedial actions because these pathways may not present an imminent risk (which would trigger a removal action) or are expensive and time-consuming to address (thus falling outside of the limitations of removal actions). The RSR Smelter case study on page 4-21, the Butterworth #2 case study on page 2-14, and the LCP Chemicals case study on page 3-10 all illustrate how removal and remedial actions are designed and implemented together at individual sites.

Sites must be on the NPL for EPA to have the authority to conduct a remedial action and for the liability scheme to be invoked against potentially responsible parties. Thus, NPL sites are the most well-known and most expensive part of the Superfund program, and are often what is being referred to when terms like “Superfund cleanups” and “Superfund sites” are used casually. In recent years, more than two-thirds of all remedial actions have been paid for by PRPs, who also pay for remedial action at VCP sites (Probst et al. 1995, 33). The cost of individual NPL remedial actions varies a great deal, but estimates of average costs for individual sites (excluding overhead) fall in a fairly narrow range of about $15-$30 million, with a best subjective estimate of about $25 million; this is around 25 times the cost of a removal (Probst et al. 1995, 33; Hamilton and Viscusi 1999, 111, 119). However, some individual remedial actions involve hundreds of millions of dollars of effort, so adequate preparation and design is often a complex task in itself. Understanding how the NPL pipeline (shown in the bottom right of Figure 3.1) works is important to understanding how remedial action creates benefits; therefore, the following sections go through each step.

Remedial Investigation/Feasibility Study (RI/FS)

In the Superfund program the remedial investigation (RI) serves as the mechanism for collecting data to characterize site conditions, determine the nature of the hazardous substances on the site, assess risk to human health and the environment, and conduct treatability testing to evaluate the potential performance and cost of the treatment technologies that are being considered. The feasibility study (FS) is the mechanism for the development, screening, and detailed evaluation of alternative remedial actions. Because the RI of the site informs the FS of potential remedies, and the FS affects the data needs of the RI, they are performed concurrently. The RI involves extensive data collection and analysis designed to characterize the scope of the problems and the potential threats to human health and the environment. Potential sources of contamination, the types of contaminants, affected media, release mechanisms, potential contaminant pathways, and actual and potential receptors are identified and modeled. During this phase a site may be broken into smaller segments called “operable units” (OUs). Each of these site segments may require a separate remedial action to mitigate the contamination at the site.

During the RI, the nature and extent of the contamination is defined, and the risks associated with human health and the environment are mapped out in the baseline risk assessment (BLRA). The BLRA is a crucial document in that it is the most complete statement of the risks associated with the site. While BLRAs are available publicly at regional EPA offices, they are typically not available electronically on the Internet and information from them is not compiled in any single database or other resource. Thus, BLRAs are not readily accessible to researchers, nor is detailed information in BLRAs available in any centralized location. The most accessible source for information from a BLRA is the Record of Decision (ROD) that is issued for each NPL site. In general, RODs are readily accessible (most are on the Internet); however, RODs only contain the summarized results of the BLRA. Some prior studies of the Superfund program have evaluated sites based on BLRA data, or on BLRA summaries from RODs (Walker, Sadowitz, and Graham 1995; Hamilton and Viscusi 1999).[11] However, a key issue, discussed further below, is that reduced risks or reduced exposures resulting from removal actions at NPL sites are often not represented in BLRAs, and practice appears to vary from site to site. Thus, the total risk reductions at NPL sites may be underestimated by studies based on BLRA or ROD data because risk reductions due to removal actions at these NPL sites are likely to be ignored.

The FS is used to compare the advantages and disadvantages of possible remedies developed for the site. The goals of the RI are refined through the FS process. Multiple remedy scenarios are studied through the FS to inform the selection of the remedy. Each remedial alternative is examined through the following criteria in order to select the best remedy:

- Protection of human health and the environment, based on site-specific risk assessment
- Compliance with applicable or relevant and appropriate requirements (ARARs), such as ground water standards
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume of hazardous substances
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

Selection of Remedy

The FS identifies the best response options; EPA then develops a proposed plan and solicits public input. With input from the public, EPA next selects a remedy and produces a Record of Decision (ROD). The ROD will document the remedy, support the decision, and develop performance standards or goals for the site (or OU) under consideration. The ROD will also provide a plan for the site's remedial action as well as document the risks to human health and the environment. Note that these risk assessments evaluate risks to the maximally exposed individual, not the mean risks or other more typical value that would be appropriate for calculating benefits (Viscusi 1997). Thus, even if it were available, this data would be of only

[11] Hamilton and Viscusi (1999) go beyond the information in the RODs they examine to conduct site-specific risk assessments, but their work still relies critically on the information contained in RODs.

limited use in a benefits study. However, many RODs are readily accessible in a single location on the EPA website (http://www.epa.gov/superfund/sites/rods/index.htm).

For some NPL sites, ARARs are the most stringent requirements and these largely determine the remedy (Walker, Sadowitz, and Graham 1995). In some cases ARARs are state standards. This is why they are shown separately in Figure 3.1. See the Butterworth #2 case study on page 2-14 for an example of how ARARs can play a role in the NPL remedial action process.

Remedial Design and Remedial Action

The remedial design (RD) phase is when the engineering plan for the site is determined. Specific technical requirements are designed to conduct the remedial action. This activity is very similar to conducting any technical engineering project: plans and specifications are prepared, permits and approvals are obtained, and cost estimates are prepared. In the remedial action (RA) phase, the plans developed during the RD are implemented (constructed) and the actual cleanup process of the remedial action begins. The remedy must conform to the specifications outlined in the ROD. Projects vary in complexity, including soil excavation, encapsulation, or the use of complex subsurface systems to extract or negate the effects of the contamination.

After the RA is complete, the site has been cleaned up – removal and remedial action(s) have eliminated immediate risks, although ongoing operation of remedial action technologies may be needed to deal with some long-term risks. In cases where this is true for all operable units at a site, the site may be designated as "construction complete" (CC).[12] In any case, there may still be important post-construction activities remaining.

Institutional controls are used to supplement Superfund remedies when residual contamination restricts the unimpeded use of a site or ground water aquifer. Examples include easements, zoning restrictions, use restrictions, and deed notices. Institutional controls are implemented during or immediately following remedy implementation, and they should be maintained as long as needed to prevent human or environmental exposure or to protect the remedy.

Post-Construction

Overview

Many sites on the NPL require long-term care after construction of the remedy is completed. The goal of the post-construction phase is to ensure that Superfund response actions provide for the long-term protection of human health and the environment. Specific activities include the following:

The operation and maintenance (O&M) phase includes actions taken to ensure that Superfund remedies perform as intended, including maintaining engineered containment structures (e.g., landfill covers), and operating ground water restoration systems. Ground water restoration generally requires active management over many years to ensure effective and efficient operations, and to ensure that cleanup goals are achieved. In addition, it may be necessary to

[12] Usually, the term "construction complete" refers to all NPL sites that have reached either this status or deletion, and will be used in this way here.

take actions after remedy construction has been completed to ensure that institutional controls continue to remain in place.

For many NPL sites, deletion from the NPL is the last stage in the pipeline. Sites can be deleted from the NPL once all response actions are completed, all cleanup goals are achieved, and no further response is needed. Some deleted NPL sites, however, may still have hazardous substances present in concentrations and locations beyond levels that would allow for unrestricted use and unrestricted exposure. These sites may require operation and maintenance actions and Five-Year Reviews for some period of time.

Provisions of CERCLA and EPA's policy require that Five-Year Reviews occur when hazardous substances remain on sites above levels that would allow for unrestricted use and unrestricted exposure. Five-Year Reviews provide an opportunity to evaluate the implementation and performance of the remedy to determine whether the site remains protective of human health and the environment. For instance, a site that has had a barrier installed, like a cap, may be reviewed to look for evidence that the barrier is still functioning. Reviews are completed every five years as long as future uses of the site are restricted.

Community Involvement

As part of the NPL process, EPA involves the public at various stages of the remedial process. The amount of information flow and public interaction depends greatly on the level of complexity of the site. Public comment periods and formal responses to public comments are conducted at all NPL sites and at many removals.

EPA also provides additional services to the public beyond those required for the administrative record. In 1986 Congress established the Technical Assistance Grant (TAG) program to help communities understand the technical aspects of hazardous substances (U.S. Environmental Protection Agency 2000; Office of Solid Waste and Emergency Response 1998a). The grant provides funds for a community affected by an NPL site to hire independent technical advisors who can help them understand the information and recommendations related to the site(s) in their community. TAGs are available to communities where there is a proposed or listed NPL site. TAGs are available only to community organizations (not governments), and recipients must live near the site and have their health, economic wellbeing, or enjoyment of the environment threatened.

State Roles

CERCLA provides for a substantial role for states in the Superfund program. Among the provisions involving states are requirements for a state to share costs for remedial actions (typically 10%), substantial and meaningful involvement in remedy selection, and the ability to carry out response actions. Specifically, CERCLA authorizes the federal government to enter into cooperative agreements with states and Indian tribes to carry out response activities consistent with the National Contingency Plan (CERCLA as amended by SARA, Section 104(d)(1)). EPA's regulations also authorize funding for building state programs to carry out those activities and to develop their own response programs. Since 1987, Superfund State Cooperative Agreements have totaled over $3 billion, including over $300 million for building and maintaining state programs. Consequently, states have performed a significant number of CERCLA site assessments, along with a much smaller number of RI/FSs, RDs, and RAs.[13]

State response programs have grown in scope, capability, and sophistication, particularly over the last decade, and have provided an alternative to Superfund for many sites. Some states have developed the legal and technical capacities to deal with complex sites similar to those that typically end up on the NPL (General Accounting Office 1998a). States have been especially active in developing VCPs and programs to support brownfields redevelopment. These developments have undoubtedly led to benefits associated with the cleanup and redevelopment of thousands of non-NPL sites across the country. In the context of analyzing Superfund benefits, federal funding to build and maintain state programs means that some of these benefits should be attributed to Superfund even though the majority of sites in response action programs fall under state authorities and programs. However, at this point, data are not available to support a definitive analysis of either those benefits or the portion that would be attributable to funding under CERCLA.[14] In addition, the problems associated with the type and accessibility of federal removal and remediation actions also occur in the state programs. In the context of attempting to understand the benefits of the national Superfund program through actions by the states, these data problems are compounded by the fact that state activities are not compiled in any single place. Although data are not available to support a definitive estimate of the magnitude of the benefits of state Superfund programs, the next section uses available data to estimate the fraction of these benefits that should be attributed to CERCLA and SARA.

Quantifying Responses

The current study present estimates of some of the benefits of remedial actions at NPL sites, omitting entirely the benefits of other Superfund responses (e.g., removals and state actions) due to the lack of relevant data (see Chapters 4 and 5). This approach will thus underestimate the benefits of the Superfund program as a whole. While it may not be possible to definitively know the magnitude of the resulting underestimate, it *is* possible to gain some insight into whether this underestimate is large or small by quantifying all of the response actions.

<u>Responses Associated with the Remedial Process</u>

EPA provides technical and oversight support for many non-NPL sites, which creates a potential benefit that is not quantified here. As of the end of FY 2003, EPA had performed preliminary assessments (PA) at almost 44,000 sites and proposed or finalized 1,572 of them on the NPL. Thus, about 3% of all sites that are listed in CERCLIS for possible evaluation under the Superfund program are placed on the NPL. Where the PA/SI indicated that no federal remedial action would be taken, the sites were placed in the Superfund archive list. Thus, there are over 40,000 sites in the nation that at one time or another were suspected of having hazardous substances on them where EPA has determined no Superfund remedial action is needed. This provides the benefit of reducing uncertainty for the community and potential developers in

[13] In most circumstances, funding for removals from the CERCLA trust fund is reserved to EPA.

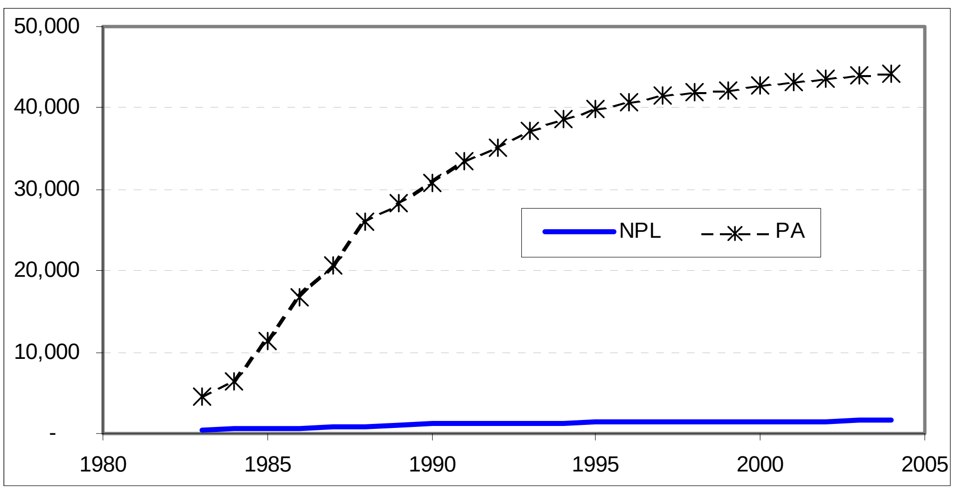
[14] The most detailed review of state response programs provides considerable discussion of the programs and quantifies the level of activity, but it does not provide sufficient information to develop a reliable estimate of the economic benefits or the amount leveraged by Superfund cooperative agreements (Environmental Law Institute 2002).

relation to those 40,000 sites. The latter effect can make previously used property available for use without concerns about liability, enabling new commercial or industrial activities to occur. This may lessen the need for additional conversion of agricultural or wild lands into developed property.

Figure 3.2 shows the cumulative number of NPL sites and PAs for 1980 – 2004. For this figure, and for most of the current study, "NPL sites" are defined as sites that have ever been on the NPL, or those that have been proposed or listed. This cumulative value is shown in the solid lower line in the figure. At the end of FY 2003, the total number of NPL sites on the NPL was 1,572. Twenty of these sites are in U.S. Territories (e.g., Puerto Rico and Guam) and essentially no data are available to describe them; therefore, these are not included in this analysis, which leaves a cumulative total of 1,552 NPL sites analyzed for calculating benefits. The results in Chapters 4 and 5 are based entirely on data for these 1,552 NPL sites.

This figure shows that more than half of all PAs were performed in the first ten years of the Superfund Program. Over the last several years an average of over 200 sites per year received PAs. To the degree that this work continues to reduce the uncertainty associated with potential releases, the Superfund program continues to provide a benefit by screening sites. This benefit might be placed in the *amenities* category (defined in Chapter 1) to the degree that perceived health risks decline with the reduced uncertainty, and in the *materials* category (defined in Chapter 1) to the degree that commercial property is made usable by the reduced uncertainty.

Figure 3.2. Cumulative NPL Sites and Preliminary Assessments



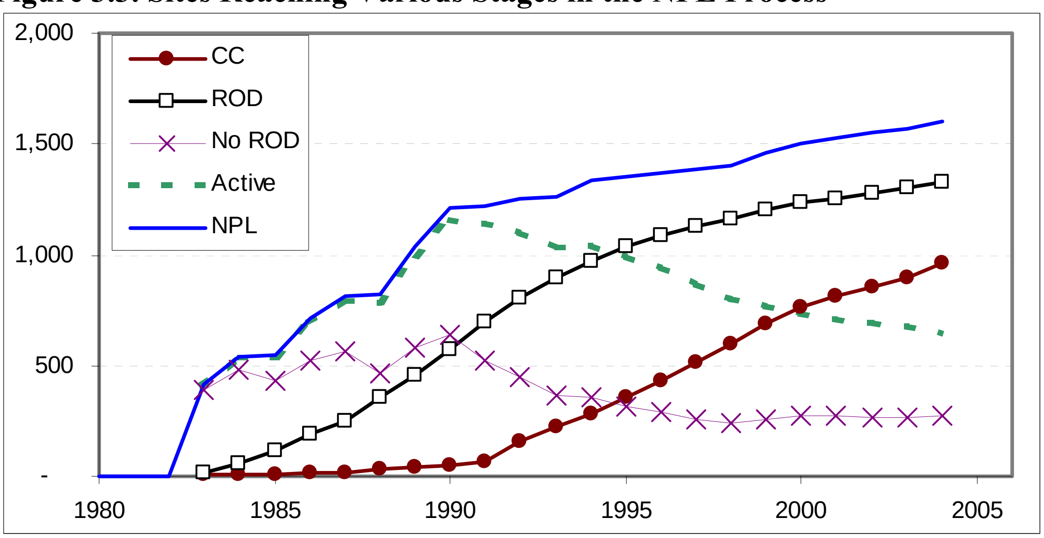
Note: "NPL" refers to all sites that have been proposed, final, and deleted from the NPL.
Source: CERCLIS

Progress with the NPL itself is described by Figure 3.3, which also shows the cumulative number of NPL sites, as well as the cumulative number of NPL sites for which RODs have been issued, and the number that have reached either construction complete or deleted status (CC). The plot of RODs issued shows how many NPL sites have plans for remedial action. The plot of CC sites shows how many have reached the final stages of the NPL process and for which the releases have been dealt with (except for ongoing O&M). A category of *active* sites is defined as those sites that have been proposed or listed on the NPL, but for which plans for remedial action have not yet been made. The number of *active* sites shown in Figure 3.3 is calculated by subtracting the number of CC sites from the total NPL.

Figure 3.3 shows that the NPL grew quickly during its first few years of existence. From zero sites in 1980 – 1982 (CERCLA was signed into law on December 31, 1980), the number of NPL sites grew suddenly to over 400 in 1983.[15] By 1987, more than half of the current NPL had already been proposed or made final. Over the last ten years, annual additions to the NPL averaged about 30 sites.

Through the early 1990s, over 1,000 sites had RODs issued.[16] This pace slowed down around 1995, and over the last ten years, approximately 40 RODs have been issued annually. At the end of FY2003, 83% of all sites on the NPL have at least one ROD issued. Sites with more than one OU may have different RODs issued for each one. The values for RODs in Figure 3.3 ignores multiple OUs and represents the number of NPL sites for which RODs have been issued, not the total number of RODs (which is higher). The annual values for ROD sites in Figure 3.3 are used in Chapter 4 to determine the dates at which benefits are assumed to occur. Chapter 4 also contains the discussion of why these dates are used.

Figure 3.3. Sites Reaching Various Stages in the NPL Process



Note: "NPL" refers to all sites that have been proposed, final, and deleted from the NPL. "ROD" values are the number of sites for which a Record of Decision has been issued. CC values are the number of sites that have reached construction complete or deleted status. 'Active' sites are those that are proposed or final only, not those that have reached construction complete or deleted status. "NO ROD" sites are those that have been proposed or listed, but for which a ROD has not yet been issued.
Source: CERCLIS

[15] Technically, the first group of NPL sites were identified on December 30, 1982, but for consistency of record-keeping, they are shown in 1983. In addition, there were a number of sites that were discovered before 1980 that were later added to the NPL, e.g. Love Canal.

[16] Because the NPL process is long and complex, deciding how to count Superfund responses at NPL sites is difficult. RODs are chosen because they are usually issued approximately halfway through the NPL pipeline (Probst and Konisky 2001, 51). In addition, RODs are a good approximation of the point at which much of the difference between perceived and actual risk at an NPL site is eliminated (see Chapter 5).

The pace of deletion was slow throughout the 1980s, due to several factors. First, technologies to address releases of contaminated substances were not well established, and it took some time for both EPA and industry to develop the capability to deal with the complex and often large contamination problems found at many NPL sites. Second, many NPL sites have significant ground water contamination, which can take a long time to deal with because of the massive volumes of contaminated media and the slow rate of effectiveness of some underground remedial action technologies.

For convenience, *deleted* and *construction complete* designations are combined in the designation "CC" shown in Figure 3.3. The start of the *construction complete* designation in 1993 is evident in the rise in the rate of sites reaching CC status. The annual increase in the number of sites reaching CC status has been fairly constant since then, averaging about 65 sites per year over the last decade. Because this is about twice the rate of sites entering the NPL, Figure 3.2 shows the NPL and CC curves have been converging for over a decade. At the end of FY 2003, 60% of all NPL sites had reached either *construction complete* or *deleted* status.

This progress is also evident in the *active* data. This includes Proposed or Final NPL sites, but excludes sites that have reached *construction complete* or *deleted* status.[17] They are *active* in the sense that there are on-site activities associated with risk assessment, remedy planning or remedy implementation. Through the early 1990s, the number of *active* sites is very close to the number of NPL sites, since few had been deleted. The number of *active* NPL sites peaked in 1990 at 1,162 sites, and has declined steadily since then (except for 1994). At the end of FY 2003, 643 NPL sites were *active*.

Sites that have been *proposed* or *listed*, but for which no ROD has been issued are labeled "No ROD" on Figure 3.3. The number of *No ROD* is approximately equal to the number of NPL sites in 1983 – 1984, but as plans for remedial action were developed, this value tended to become smaller than the total number of NPL sites after that. The number of *No ROD* sites peaked in1990 at about 638, or about half the number of NPL sites at the time. Since then, the number of *No ROD* sites has declined to under 300, or less than 20% of all sites that have ever been placed on the NPL. The meaning of these values is discussed in Chapter 4.

<u>Responses Associated with the Removal Process</u>

In order to understand whether the underestimate of the benefits of Superfund as a whole due to ignoring removal actions is large or small, it is necessary to understand how many response actions there have been, and when they occurred. Because CERCLA and SARA authorize response activities, all federal responses are assumed to be attributable to Superfund.

Information is available about each removal action in the Removal Site Evaluation (RSE) or Engineering Evaluation/Cost Analysis (EECA) prepared for each site. These documents are summarized in the Action Memorandum (AM) that serves as the official written record of the decision to conduct a removal action. However, these documents are not readily accessible to

[17] Important activities still continue at sites that have reached construction complete and deleted status, including operation & maintenance of remedial technologies and Five-Year Reviews.

researchers as they are not transferred into a centralized database and typically exist only as paper records stored at the various Regional EPA offices (Office of Emergency and Remedial Response 1990; Office of Solid Waste and Emergency Response 1990; Traceski 1994).

Data on removal actions were obtained from the CERCLIS database on November 26, 2003 for the fiscal years (FY) 1980 – 2002.[18] Very little information about removals is readily accessible. However, the total number of removals performed each year is available, and some cost information is available. By the end of 2003, EPA had undertaken 8,860 removal actions, averaging slightly over 435 annually during the last ten years.

Based on prior research and an evaluation of the CERCLIS database, most removal actions (between one-half and three-quarters) occur at non-NPL sites (Probst and Konisky 2001, 16-17).[19] Of those that do occur at non-federal NPL sites, 87% occur at sites where only one removal occurs, and about 10% occur at sites with two or three removals. A few NPL sites experience many removals (some sites have over ten) but these amount to a relatively small fraction (<3%).

Guidance on risk assessment and on conducting removal actions is silent on how removals should be represented in BLRAs (Office of Emergency and Remedial Response 1989; Office of Solid Waste and Emergency Response 1990, 1998; RCRA/CERCLA Division 1993; Traceski 1994, 1995). In practice, removal actions at NPL sites can be treated in different ways.[20] Removals that temporarily interrupt exposure pathways (e.g., fences) tend to be ignored because the statutory intent behind SARA for permanent solutions to uncontrolled releases of hazardous substances results in a remedy that will not necessarily make use of that temporary removal action. These removal actions are ignored when the baseline risk assessment (BLRA) is performed for the site as part of the RI/FS. If the number of these removal actions is added to the number of remedial actions, double-counting would occur.

However, some removal actions at NPL sites are more significant and may involve such steps as taking contaminated soil off-site to a disposal or incineration facility, which permanently and significantly changes the characteristics of the site. When BLRAs are performed for these sites, the post-removal condition of the site is evaluated in the BLRA, and the risks that the remedial action addresses are treated separately. For instance, a removal might take away and treat drums that are leaking, or are about to begin leaking hazardous substances, while a remedial action of the site would clean up the soil and ground water from the hazardous substances that had already leaked out. Thus, these two responses address two different goals of CERCLA and reduce two different types of risks. If the number of these removal actions were added to the number of remedial actions, double-counting would not occur.

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[18] Data for 2003 – 2004 are projected and estimated currently. In the final version of this report, actual values will be used.

[19] Probst and Konisky estimate the number of removal actions (non-federal sites only) in 1992 – 1999 as 2,053, of which about 495 (24%) occurred at non-federal NPL sites.

[20] The Superfund program has changed significantly since it was started, and the number of removal actions began to increase dramatically around 1990. This description is accurate for the program as it has existed for the last few years, but may be less accurate for removal actions that occurred before the mid-1990s.

Unfortunately, there are no quantitative data at present to distinguish between these scenarios. This is a limitation, but it does not affect the results in Chapters 4 and 5 because these chapters ignore removal actions entirely. The uncertainty associated with not knowing how to treat removal actions that occur at NPL sites affects only the consideration of the underestimate caused by ignoring removal actions in Chapters 4 and 5. The calculation of the number of Superfund responses given below assumes that all removal actions are not included in the BLRA. Therefore, each removal action is considered a separate response.

Quantifying State Responses
In order to understand if the underestimate of the benefits of Superfund as a whole due to ignoring state Superfund actions is large or small, it is necessary to understand how many state response actions there have been, when they occurred, and how many of them can be attributed to CERCLA and SARA. In general, fewer data are available for state activities than for federal activities, and the data that exist are less complete. Therefore the estimates in this section are likely to be more uncertain that those in the previous sections.

The number of response actions taken by state Superfund programs is considered first. Detailed data for multiple states are available from two sources that have conducted several studies of state Superfund programs.

The most recent study by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) involved a survey sent to all states and territories, and received replies from 33 of them (Association of State and Territorial Solid Waste Management Officials 1998). Responses that summarized state programs were not accepted for data quality reasons, and instead only responses that documented each site individually were included. Some of the excluded states have large state Superfund programs, such as Michigan and Pennsylvania (Environmental Law Institute 2002). For 1993 – 1997, the ASTSWMO study reported that 33 states averaged 485 removals annually, and 1,597 remedial actions (all RA Completions) annually. This level of effort represents an 80% and 670% increase, respectively, over the levels found in a previous ASTSWMO study for 1980 – 1992 (271 and 207, respectively). The cumulative number of state removals for 1993 – 1997 was 2,303, and the total for state remedial actions was 7,584.[21] These values are for 33 states, excluding those that did not respond to the survey or did not provide sufficiently detailed data.

The Environmental Law Institute (ELI) has conducted several studies, also using a survey technique (Environmental Law Institute 1998, 2002). The results reported here are from the most recent study, which evaluated forty-four states. This study reported that state Superfund programs completed 4,5000 "cleanups" at non-NPL sites in 2000 (the total since these programs were begun is about 29,000. A further 15,700 cleanups were reported as being underway in 2000. These numbers are approximately the same as found in 1997.

However, since the early 1990s, many states have developed much more active state remedial action programs as well as voluntary cleanup programs (VCPs) to encourage and oversee private

[21] The reporting period actually covers only 4 years and 9 months.

remedial action of releases. Enforcement actions (e.g., lawsuits against PRPs) also increase the spending on "state Superfund" sites. The 2002 ELI study finds that VCP cleanups account for almost half (45%) of state Superfund responses, but private spending is not estimated.

The number of cleanups reported by the ELI studies is greater than those reported by the ASTSWMO report. This difference may be partly explained by the larger number of states included in the ELI study. However, another factor is the difference in survey technique – the ASTSWMO study required respondents to provide data for each site and did not accept totals. The ELI study notes that definitions of "cleanup" vary from state to state and have changed over time for individual states (2002, 16). The ASTSWMO study methodology may have partially controlled for this effect. As a result, the number of state responses calculated below relies on the ASTSWMO estimates.

The ELI study also notes that states report a large number of sites that may require response actions in the future (2002, 15-16).[22] States reported about 23,000 sites "in need of attention," although there is no information about the level of risk presented by these sites. Nonetheless, this large number suggests that although there may be a finite number of sites with uncontrolled releases (actual or potential) of hazardous substances, current levels of response activity could continue, or even increase, for some time.

The 2002 ELI study notes that the number of state cleanups reported in 2001 was approximately equal to the number in 1997, suggesting that it is reasonable to extrapolate the number of cleanups found by ASTSWMO for 1997 forward. There is no evidence that the number of state Superfund activities have declined significantly in the last few years, so the ASTSWMO estimates are extrapolated to 2004.

Budget information provides some insight into the size of state Superfund programs, and provides one basis of determining how many state response actions to attribute to CERCLA and SARA. The states are crucial to environmental protection in the United States. Combined, states spend about the same amount on environmental protection as the federal EPA's budget; however, states also receive considerable federal grants and distinguishing the source of state expenditures is not always straightforward.[23] One study found that total state spending in 2000 to "develop and maintain a comprehensive hazardous waste management program (which could include remedial action of Superfund sites and addressing underground storage tanks)" was $1.4 billion (Brown 2001 table 3). Comparing these values with other data suggests that less than one percent of this amount is actually devoted to remedial actions at NPL sites, which seems reasonable given that the NPL is a federal program (Congressional Budget Office 1994). Probst and Konisky (2001, 96) document an ongoing commitment of state resources (that is, funds other

[22] Probst and Konsisky (2001, 28-30) make a similar observation about the EPA's removal actions, their number appears to be limited by resources to deal with them, not the number that could use attention.

[23] Brown (2001) gives a higher value in his text, but this calculation includes expenditures associated with activities that are the responsibility of agencies other than the state analogs for the EPA (e.g. forestry, and fish and wildlife). The sum of state expenditures given by Brown for state activities in 2000 is similar to those EPA is responsible for (Table 3: Drinking Water, Water Quality, Hazardous Waste, Pesticides Control, Solid Waste, and Air Quality), and is approximately $6.6 billion. This amount includes all sources of state expenditures, including EPA grants and other federal monies.

than those from the federal government) to address uncontrolled releases of less than $200 million annually for nine states with significant numbers of releases and almost half the nation's population (CA, FL, MA, MO, NJ, NY, OH, PA, TX). This value can be compared with the estimates of total state Superfund expenditures reported by ELI, which average about $500 million annually for 1992 – 2000, although it is not clear how much of this money comes from the federal government (Environmental Law Institute 2002, 18-28). States report highly varied levels of federal support for their Superfund activities, from 2%-90% (18).

Overall, however, approximately one quarter of state environmental expenditures come from the federal government (Brown 2001). Lacking any more definitive value, this study will attribute 25% of state Superfund responses on the basis of funding. This approach ignores the potential that Superfund has any role in causing privately financed responses under state VCP programs because private expenditures are *not* included in the state budget figures discussed above.

In addition to funding support, Superfund supports state activities in other ways. The Superfund statutes, CERLA and SARA, provide the states with authority and credibility in managing releases (King 2002; National Governor's Association 2003; National Conference of State Legislatures 2004). The New Hampshire Commissioner of the Department of Environmental Services, representing the Environmental Council of the States, recently testified: "…with respect to sites not on the NPL … comprising a universe far greater than the NPL, … the success of many state programs in addressing these sites has been reliant on the present federal liability structure" (2000). State responses also benefit from the research and development activities sponsored by the Superfund program to improve the technologies and practices for the management of hazardous substances. Thus, the number of state Superfund responses that can be attributable to CERCLA and SARA may be higher than would be indicated by the amount of funding support alone (Science Advisory Board 1990). However, there is no obvious method to quantify this effect, so it is ignored.

Comparing Superfund Responses

The analysis discussed above permits a calculation of the total number of response activities that can be attributed to the Superfund program. This value can be used to help consider whether estimates of benefits in Chapters 4 and 5, which ignore some classes of Superfund response actions, are underestimates by small or large margins.

Table 3.2 presents the number of total responses to uncontrolled releases of hazardous substances in the United States for the period 1980 – 2004, and the number that can be attributed to CERLCA and SARA (i.e. Superfund). As discussed above, the number of EPA remedial actions is equal to the number of RODs found in the CERCLIS database. This amounts to 1,326 actions. The number of EPA removal actions is equal to the number of response actions found in the CERCLIS database. This amounts to 7,798 actions. The total number of state actions (both removal and remedial actions) is taken from the ASTSWMO studies for 1980-1997, which reports only on 33 states. The 2002 ELI report contains data that shows no significant change in the number of state response from 1997 to 2001, and there is no more recent data to suggest significant changes in state-level response activity. Therefore, the trend reported by ASTSWMO for 1992 – 1997 is extrapolated through 2004, yielding 9,345 state removal actions and 21,649 state remedial actions for 1980 – 2004. These values do *not* address the risk addressed by any of these response actions, only the number of actions.

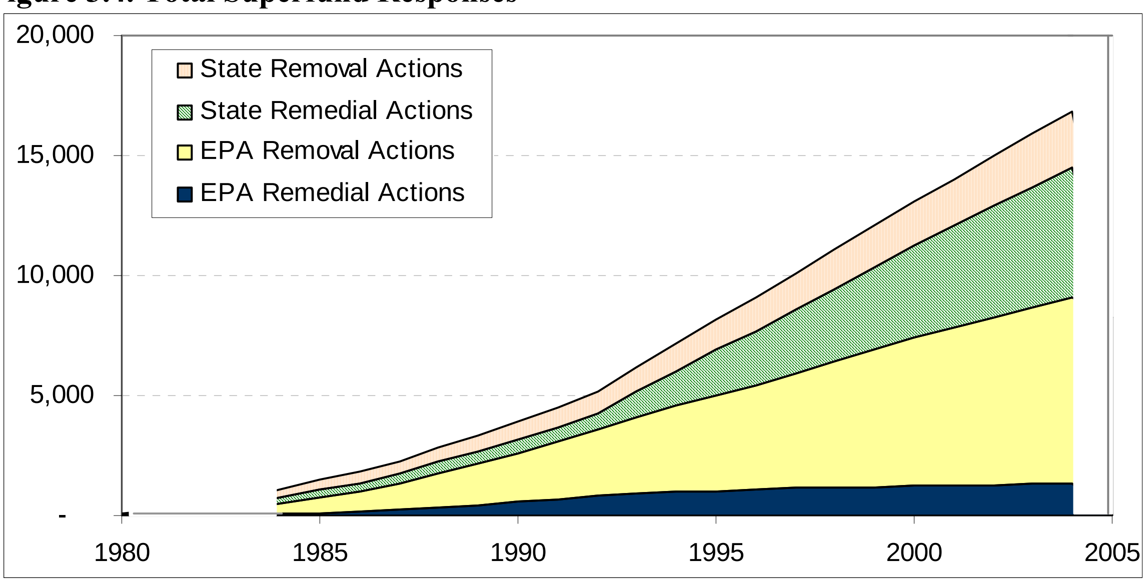
The EPA response actions are obviously attributable to CERCLA and SARA, but there is no clear, objective method to determine how many state response actions should be attributed. Based on the discussion above concerning the average percentage of state environmental expenditures provided by federal sources, 25% of state actions are attributed to CERCLA and SARA in Table 3.2. Thus, the total number of state responses that are attributable to Superfund for 1980 – 2004 is 7,748. These values are presented graphically in Figure 3.4. These values address the number of actions, *not* the risk addressed by any of these response actions. These values are *not* used in any of the subsequent chapters to calculate benefits.

Table 3.2. Total Responses and Total Superfund Responses, 1980 – 2004

Response type	Total Responses	Attributable to Superfund**	Superfund Responses
EPA remedial action	1,326	1.0	1,326 (8%)
EPA removal	7,798	1.0	7,798 (46%)
State remedial action*	9,345	0.25	2,336 (14%%)
State removal*	21,649	0.25	5,412 (32%)
TOTAL	40,118		16,872

* Uses data for 33 states and assumes no state response actions for 1998 – 2004.
** Assumes only 25% of state actions are attributable to Superfund, based on federal funding to states.
Sources: See text.

Figure 3.4. Total Superfund Responses



Note: See Table 3.2.

This analysis suggests that of all Superfund responses for 1980 – 2004, remedial actions at NPL sites represent only 10% of the total, assuming no state response actions after 1997. The alternative assumption implies that remedial actions at NPL sites represent only about 8% of all Superfund response actions. If data for state response actions in all 50 states were available, these percentages would likely be even lower.

Thus, remedial actions at NPL sites make up only a small fraction of all Superfund response actions. This suggests that the estimates of benefits in Chapters 4 and 5, which are based on analyses of only the NPL, may be non-trivial. Of course, the size of any underestimate depends on the risk reduction (or other benefits, like amenities improvement) that non-NPL response actions create, about which there is very little data.

Characterizing NPL Sites

The third part of this chapter characterizes NPL sites. Due to a lack of data accessibility, it is not feasible to characterize NPL sites according to risk. However, several other important features of NPL sites are available to characterize NPL sites, including area, nearby population, the number of homes nearby, duration of time from proposal to CC, and location within or outside of a Metropolitan Statistical Area (MSA). These features are important to the analysis presented in Chapters 4 and 5. For the purposes of this study, and based on the existing literature, a distance of 2.5 miles from the boundary of the site will be used to define "nearby." Chapter 4 contains a discussion of this assumption and includes a sensitivity analysis of it. The designation of within or outside an MSA allows a rough division between urban/suburban sites and rural sites.

In order to know whether the benefits transfer analyses in Chapters 4 and 5 are reliable, several groupings of NPL sites are created in order to compare the "study case" (the subject of a prior valuation study) with the "policy case" (the subject of the current study). For the analysis in Chapter 4, the policy case will be all the NPL sites that have had a ROD issued by the end of FY 2004; this group is labeled ROD. The analysis of these sites is aided by creating a group, MROD, consisting of those ROD sites that are located within an MSA. The analysis in Chapter 4 is based on a set of prior studies that examined the changes in home prices near a total of 24 NPL sites and 16 non-NPL hazardous waste sites. These 24 NPL sites are placed into a group labeled "Property" in Table 3.3.[24]

The policy cases for the different sections of Chapter 5 vary from effect to effect. For instance, for cancer, the study cases are the 150 NPL "risk sites" that Hamilton and Viscusi (1999) examined, and this group of NPL sites is labeled "HV" in Table 3.3.[25]

Finally, federally-owned NPL sites (e.g., former military bases and Department of Energy sites) are often analyzed separately from others; these may be different from other sites in terms of size and population, which are important in this analysis. To study these sites, a group "Federal" is designated in Table 3.3.

[24] For a list of these sites, see Table 4.3.

[25] NOTE: By agreement with EPA's Science Advisory Board Staff, the health effect-by-effect analysis has *not* been conducted for this draft, only proposed. This discussion of the cancer benefits transfer analysis and the related study and policy cases is meant to be illustrative only. If it and the other health effect-by-effect analyses are approved, several other NPL site groups will likely be designated.

Table 3.3. Definitions of NPL Site Groups

Group name	Definition
NPL	All sites that are proposed, final, or deleted from the NPL through the end of FY 2004
ROD	All NPL sites for which a ROD has been issued through the end of FY 2004
MROD	ROD sites that are located within a Metropolitan Statistical Area (MSA)
Property	All NPL sites that are included in the property value studies used in Chapter 5
HV	The 150 "risk sites" used in Hamilton and Viscusi (1999).
Federal	All federal NPL sites

<u>Data</u>
Data with which to characterize these sites were collected from CERCLIS and from the U.S. Census for 1980, 1990, and 2000. ESRI's ArcView 3.2 geographic information system (GIS) software and its programming language, Avenue, were used to create algorithms to process the census data. These estimates were only calculated for the 50 U.S. states and the District of Columbia; sites in the U.S. territories were excluded. This section describes how these data were handled.

Census data on population and residences are available at several levels of detail, the most highly resolved (spatially) being the census block. Census blocks are combined first into larger census block groups and then into even larger census tracts. Census tracts contain approximately 4000 people. The differences in the sizes of these areas are shown in Table 3.4, which gives the mean and median values for all census blocks, census block groups, and census tracts that contain NPL sites. These area data are highly skewed – the data is bounded on the left by zero but includes some very large areas located in places with sparse population. The mean area of census blocks that contain NPL sites is more than an order of magnitude smaller than the mean area of census tracts that contain NPL sites. The difference between medians is larger, by a factor of fifty.

Table 3.4. Census areas with NPL sites (square miles)

Census Area Definition	Mean Area	Median Area
Block	2.0	0.24
Block Group	36	4.3
Tract	74	10

Census 1990 and 2000 population data were obtained at the block level and housing data at the block group level. 1980 data were queried at the county level, which is even larger than the census tract level.[26] Blocks and block groups are polygons that are often bounded by streets and other physical features, but do not have any relationship to NPL site boundaries or the distance rings of interest for this study.

Defining the site boundary is an important issue in this analysis. The boundaries for NPL sites (i.e., the extent of the releases) do *not* generally correspond to property boundaries, and some mining or ground water sites can cover very large areas. Most of the area included within the boundaries of a ground water site generally does not have hazardous substances at or near the

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[26] The 1980 data was used for establishing population growth trends only. See Chapter 4.

ground surface, but there may be a plume of contamination in the ground water underlying the property. Similarly, mining areas and former military bases may have several "hot spots" that contain significant concentrations of contamination but cover only a small percentage of the entire area of the site as it is defined by EPA. Some mining sites, though, especially those where smelters operated, do have extensive areas of surface level contamination. These larger site types can have residences or even entire towns located within them.

The CERCLIS database contains a set of coordinates (latitude and longitude) that defines the location of each NPL site.[27] Site boundary data is not available. Those coordinates are assumed to be at the centroid of the site, and an 'equivalent radius' (r_{eq}) is defined such that a circle with that radius has the same area as given in CERCLIS, the ROD (for sites with no area given in the CERCLIS database), the Envirofacts database, site fact sheets, or site listing narratives. This creates a pseudo-site. Sites with no area data given and those shown with zero area are treated as points. The equivalent area circle is centered on the geographical coordinates given in CERCLIS, and then a set of circles is created, centered on the same point, having radii or r_{eq} +0.5, r_{eq} +1.0, r_{eq} +1.5, r_{eq} +2.0, r_{eq} +2.5, and r_{eq} +4.0 miles. Bins for population and housing data are created based on these circles. The reasons for choosing these distances for bins is to match previous work in the literature in order to make the benefits transfer analysis in Chapters 4 and 5 more reliable (Lybarger et al. 1998; Gayer, Hamilton, and Viscusi 2000; Kiel and Zabel 2001). The area with the circle of equivalent radius (r_{eq},) is considered 'on site' and each of the rings created by adjacent pairs of circles is designated by the distance of the outer circle from the edge of the onsite circle we have defined. Thus the smallest ring is the 0.5-mile ring and extends from the edge of the onsite area to 0.5 miles away. The largest ring has an inner boundary r_{eq}+2.5 miles from the CERCLIS location and an outer boundary r_{eq}+4.0 miles away.

Figure 3.5 shows a schematic of how the equivalent radius circle might look for a hypothetical site. In this figure, the area of the site is less than 100 acres, so r_{eq} is under a quarter-mile. Only the first two radii are shown.

[27] Hamilton and Viscusi were able to obtain precise boundaries for NPL sites by using the RELAI database, which is no longer maintained by the USEPA (Hamilton and Viscusi 1999, 253).

Figure 3.5. Construction of Equivalent Area and Radii for Population Estimation

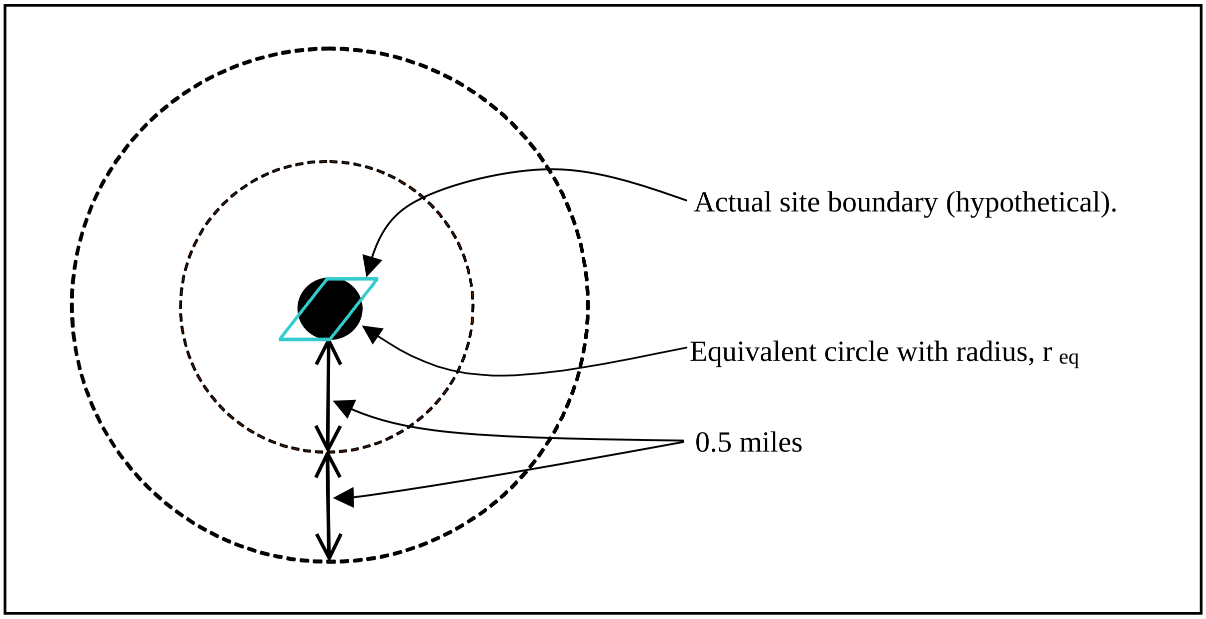
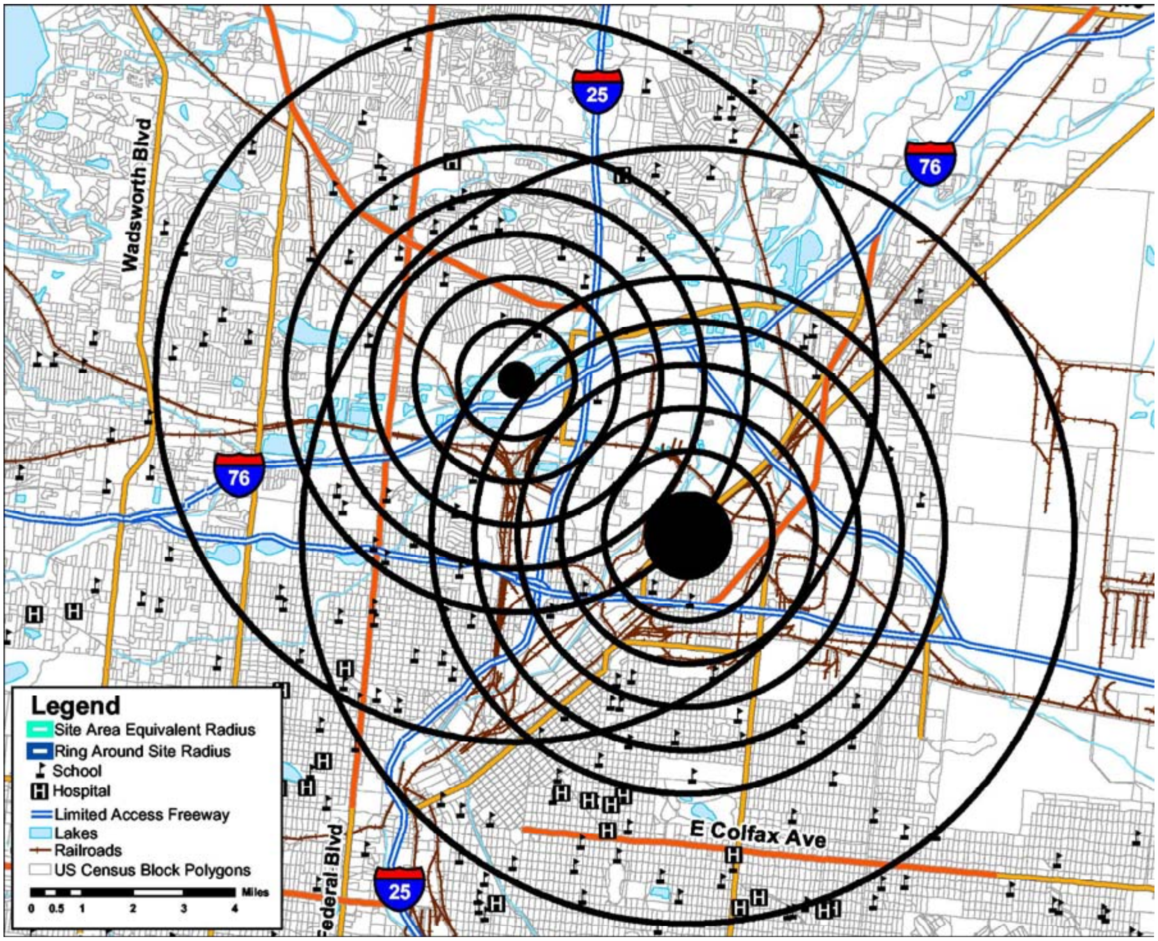


Figure 3.6 illustrates the results of this procedure for two sites in Denver, Colorado. This figure also shows how the population data are arranged. The site areas are shown as solid black circles, and the distance rings are shown as thick black circles. Distance rings are shown for all of the half-mile rings out to 2.5 miles, as well as the 4-mile ring. The boundaries of the census blocks are shown in gray. For reference, major roads and water bodies are also shown. The geographic rings shown in Figure 3.6 correspond to the bins into which the population and housing data are placed.

The smaller of the two sites (to the northwest), Broderick Wood Products, encompasses 64 acres; the larger site, Vasques Boulevard, encompasses 456 acres. These sites are larger than most; the median site size for all NPL sites is 30 acres. However, the size of the area within 2.5 miles of these sites is much larger than the site areas themselves. The nearby area would be larger than the on-site area by an even greater margin for most NPL sites. This suggests that differences between the actual site boundaries and pseudo-site boundaries may not be very important in estimating population size or number of residences. Spot checks at NPL sites for which boundaries were known indicated this approach introduced only small (<2%) errors in estimates of the number of residences near NPL sites up to the 2.5-mile distance.

Figure 3.6 also shows that some locations are close to more than one NPL site, which raises the question of how best to count populations and residences near NPL sites. This problem can be more severe in locations with many NPL sites, such as the Grand Rapids, Michigan, area, as shown in Figure 3.7. This figure shows the pseudo-site areas and 2.5-mile rings for eight NPL sites, many of which overlap. Thus, many locations that are near one NPL site are also near several others.

Figure 3.6. Site Areas, Distance Rings, and Population Data for Two NPL Sites in Denver, Colorado



Populations in places near more than one NPL site may have greater potential exposure to hazardous substances, and they may be affected by multiple disamenities, but it is not clear how to treat such multiple exposures. It is unclear if the impact of each individual disamenity would be the same at places near multiple sites as the impact of the same disamenity at a place near only one NPL site. It is also not clear if the impacts (or exposures) would be additive, or more or less than additive; the result could well vary with the specifics at each site. The literature generally ignores the issue of multiple sites, and assumes locations (or receptors) are affected by only a single NPL site.

Figure 3.8 illustrates that the problem of proximity to multiple NPL sites is common nationwide. This figure shows the location of all of the places near NPL sites in the contiguous United States, including site areas plus areas within 2.5 miles of the boundary of the pseudo-sites. Note that this figure shows places near sites, not just the site areas themselves. The smallest circles seen are five miles in diameter and are associated with sites having either zero area or no area data in CERCLIS or related EPA documents. Spot checks of this figure, comparing circular areas to geographic features of known size, and to Figures 3.6 and 3.7, show that the figure is to scale. There are many concentrations of sites, as well as large individual sites, which create significant overlaps between areas. For instance, Long Island, New Jersey and eastern Pennsylvania have many overlapping circles, as do the areas near Boston, Salt Lake City, Minneapolis, Houston, and Los Angeles.

Figure 3.7. Site Areas, 2.5-Mile Distance Rings, and Population Data for NPL Sites in Grand Rapids, Michigan

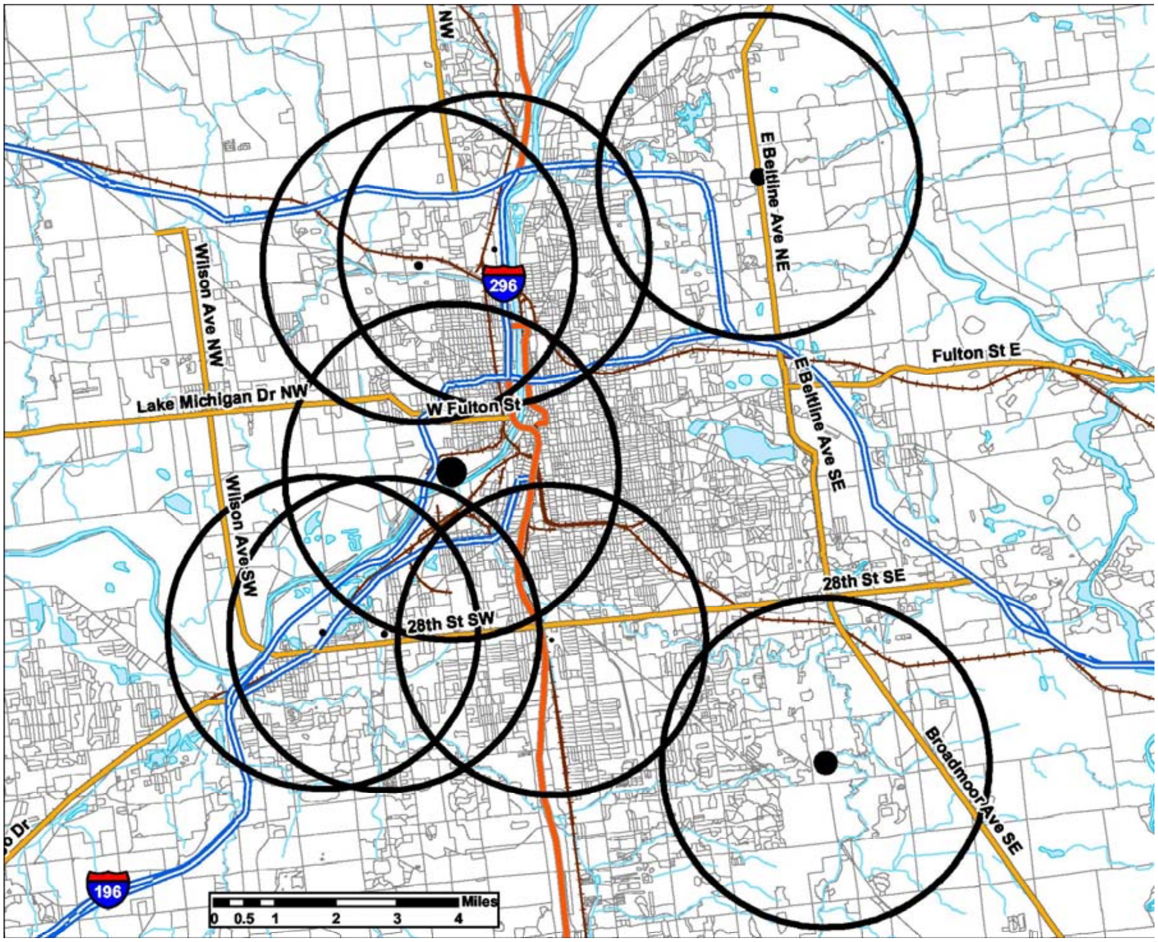
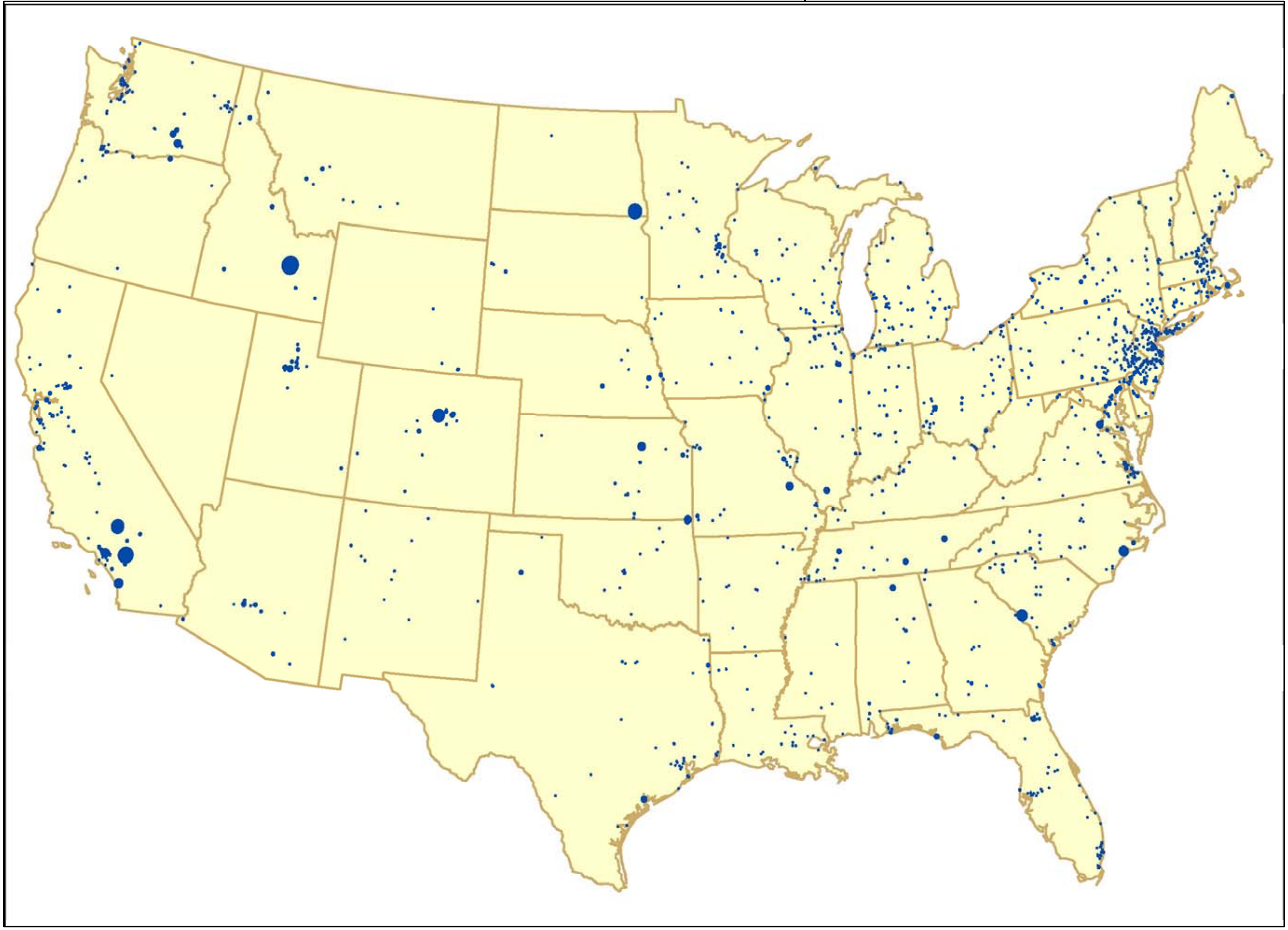


Figure 3.8. Places Near NPL Sites in the Coterminous United States (area plus r_{eq} = 2.5 mile circles)



Two approaches were used to count the number of residences and populations around sites: the multi-count approach, and the full-count approach. The multi-count approach is the simpler of the two and provides a non-arbitrary count of the number of people living near each site, making it useful for describing these sites individually. In the multi-count site population ($PS_{i,k}$), the number of people near each individual site are counted, irregardless of any other sites, for each bin. The number of people in each bin is determined by the fractional area of each census block that is within the ring corresponding to that bin, assuming uniform population distribution across the census block. In the multi-count total (PM_i), each person is counted once for every NPL site they are near and are put into the bins corresponding to the distance to each of the relevant boundaries, as shown in Equation 3.2. Six bins (i= 1 to 6) for this data are created using the equivalent area circle and the rings with radii or r_{eq} +0.5, r_{eq} +1.0, r_{eq} +1.5, r_{eq} +2.0, r_{eq} +2.5, and r_{eq} +4.0 miles.[28] To generate the multi-count of population, a census block (or block group) area fraction $\text{CBAF}_{i,j,k}$ was defined for each census block by NPL site and ring by the GIS software and applied as shown:

$$PS_{i,k} = \sum_{j=1}^{n} \left(CBP_{i,j,k} \cdot CBAF_{i,j,k} \right) \qquad \text{(Equation 3.1)}$$

$PS_{i,k}$ = the site population at site k in bin i, irrespective of other sites.

$CBP_{i,j,k}$ = the population in the j census block of bin i for site k.

$CBAF_{i,j,k}$ = the fractional area of the j census block within the i ring for site k.

n = the number of census block groups that intersect with the ring associated with bin i.

$$PM_k = \sum_{i=1}^{m} PS_{i,k} \qquad \text{(Equation 3.2, Multi-Count)}$$

PM_k = the multi-count population in all bins for site k.

$PS_{i,k}$ = the multi-count population in bin i for site k.

m = the number of bins (6).

However, the multi-count approach obviously has the potential for double-counting (or worse, as shown in the figures above) and so would not be appropriate when a sum of all people who live near NPL sites is needed. For this purpose, a full-count value is defined, (PF_i) in equation 3.3. In the full-count estimates, every person living within 2.5 miles of the boundary of an NPL pseudo-site is counted once, and he/she is placed in the bin corresponding to the distance from

[28] For simplicity, this report only contains the 2.5-mile values, except in sections on sensitivity analysis.

the closest boundary (residences are counted in the same way). Note that this is a set of six values, one for each bin.

In this approach, a census block (or block group) area fraction $CBAF_{i,j,k}$ was defined for each census block (or block group) by an area made up of the union of all *i* rings, excluding those areas already accounted for. The approach is described below:

$$PF_i = \sum_{j=1}^{n} \left(CBP_{i,j} \cdot CBAF_{i,j} \right) \quad \text{(Equation 3.3 Full Count)}$$

PF_i = the full-count population in bin *i* for all sites.

$CBP_{i,j}$ = the population in the *j* census block of bin *i*.

$CBAF_{i,j}$ = the fractional area of the *j* census block within the area made up of the union of all *i* bins for all NPL sites.

n = the number of census block groups that intersects with a given bin.

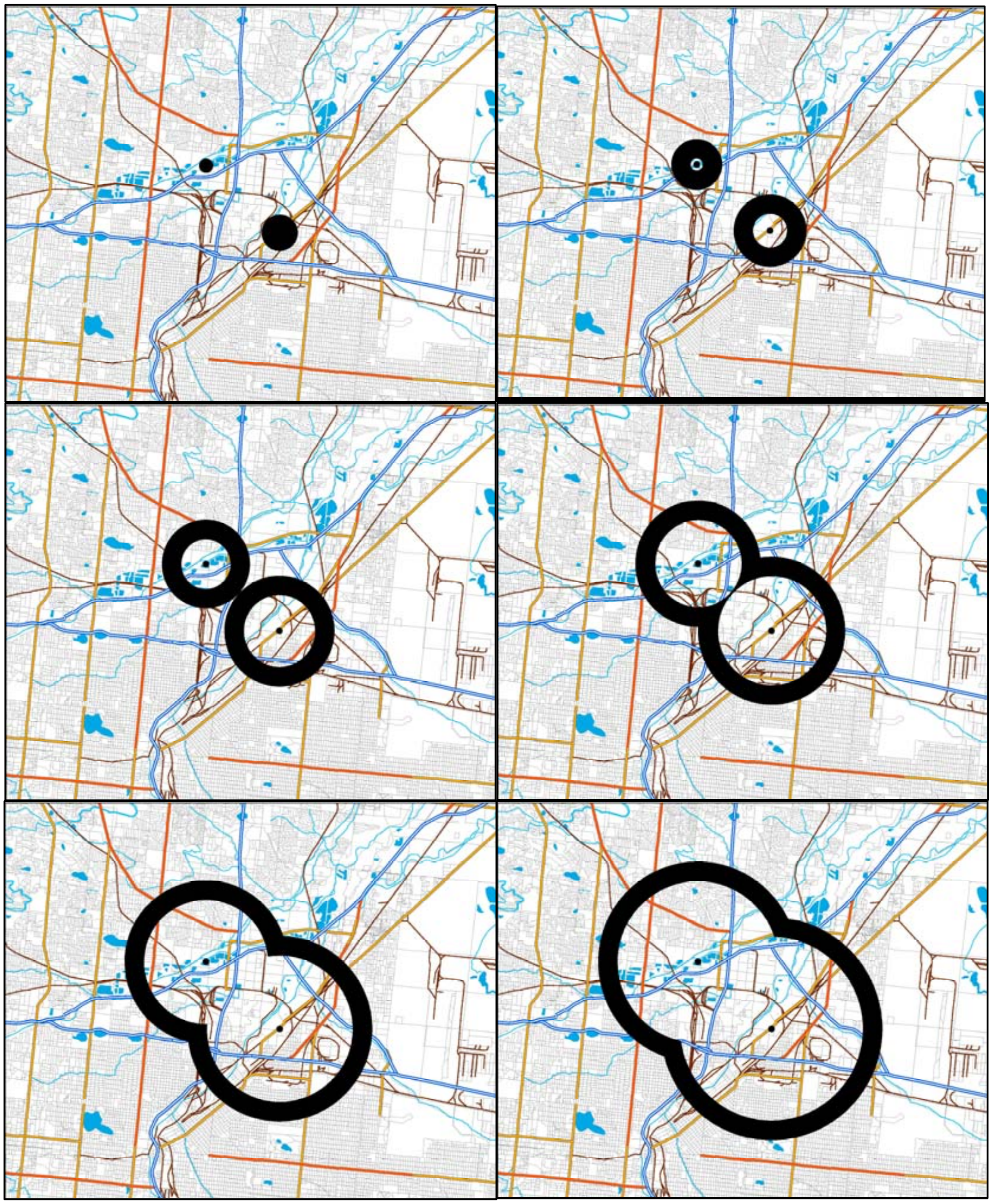
For example, in the full-count estimate, a person living close to the intersection of highways 25 and 76 in Figure 3.6 would be placed in the 0.5-1.0 mile bin because of proximity to the Broderick Wood Products site. In the multi-count estimate he/she would be counted twice, and would be placed in the 2.0-2.5 mile bin for Vasques Boulevard site as well as in the 0.5-1.0 mile bin for the Broderick Wood Products site.

The full-count procedure is illustrated in Figure 3.9 for the two Denver sites. The six panels of the figure indicate the area that is considered for each of the six bins. The first is made up of the two circular pseudo-sites; the second and third by two rings each; and the fourth, fifth, and sixth by figure eight-like shapes that avoid double counting. A similar plot of the six areas in the Grand Rapids area that correspond to the six data bins would produce a set of complex, discontinuous shapes.

Thus, the full-count procedure creates one value for each bin for the entire NPL or subset (e.g., the ROD group as defined in Table 3.3), for a total of seven values (the population on the site, plus each of the six rings). The multi-count procedure produces an array of values: seven for each site in the group being evaluated. For the entire NPL, this is (7 *x* 1,552 =) 10,864 values.

The full-count values are used in Chapters 4 and 5 to estimate benefits while avoiding double counting. The multi-count arrays are used below to characterize NPL sites. An important feature of the multi-count approach is that it does *not* preserve the association between population and individual NPL sites; only six values are calculated for population, which is the total number in each bin. This is acceptable because for the analysis conducted in Chapters 4 and 5, preserving the distance information is necessary, while preserving the site-specificity is not.

Figure 3.9. Full Count Procedure



The Character of Sites

This section discusses the *character* of NPL sites, using the groupings given in Table 3.3.

This analysis is based on insights from prior analysis, discussions with EPA staff and other experts, and the data available in CERCLIS. Parameters of interest include: location; dates that RODs are issued; dates of listing and construction completion (if applicable); the population living near the site; the size of the site (acres); whether the site is located in a Metropolitan Statistical Area (MSA); whether the site is a federal facility; and whether the site appears to be a "new" site type.

A distinction is often made between federal and non-federal sites, where the latter are hazardous waste facilities, industrial facilities (abandoned and active), and so forth, and the former might include those as well as military facilities, national laboratories, and the facilities uniquely found on them. For an example of this, see the Hanford case study on page 3-50. The distinction of federal and non-federal is usually made because of important differences in liability, response roles, and availability of the Trust Fund to pay for response. Moreover, federal facilities often are geographically large installations with numerous releases or potential releases that are somewhat separated and distinct from one another. However, it is not clear if there are significant differences in benefits from federal and non-federal sites, so this distinction is examined. Through FY 2003, a total of 175 federal sites were on the NPL, representing 11.3% of all sites.

Tables 3.4 through 3.7 provide descriptive statistics for these various characteristic features. Population and residence totals are based on full-count data, while the other values and statistics rely on site-specific data from the multi-count arrays.[29]

The most important parameters in the tables above are population and number of residences, since these are used as inputs to some of the calculation of benefits in Chapters 4 and 5. Another important issue is time from proposal to CC (construction completion or deletion), which gives an indication of the difficulty in remediating the site. The size is of interest as well.

Table 3.5 contains data that begin to describe the NPL and the groups defined in Table 3.3. Sites with RODs include most (81%) of all sites on the NPL (proposed, final, or deleted). Sites with RODS that are also in MSAs are a smaller number, but still include most (67%) of NPL sites. The study sites in the Property and HV groups are much smaller subsets (1% and 10% of NPL sites, respectively). Federal sites make up a relatively small subset of the NPL (11%).

A large majority (83%) of all NPL sites are within MSAs. Similar proportions of the ROD, HV, and Federal groups are within MSAs. By contrast, all of the NPL sites in the Property and MROD groups are within MSAs (the latter by definition).

A chi-squared statistical test can be applied to this data to test hypotheses about the differences in these sets. This statistic is calculated first to compare all the groups to the NPL and then to compare the other groups to the ROD group. In this case, there is one degree of freedom, so the critical value at the five percent level is 5.024. Thus, the data in Table 3.5 indicate that the hypothesis that the likelihood of a site being located inside an MSA is the same for the NPL, ROD, Property, HV, and Federal groups cannot be rejected at the five percent level. Similarly, the hypothesis that the likelihood of a site being located inside an MSA is the same for the ROD, Property, HV, and Federal groups cannot be rejected at the five percent level. This suggests that in terms of location relative to large numbers of people, all of these groups are similar, except for MROD, which by definition contains sites near population centers.

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[29] When percentages of residences and/or populations are discussed, these percentages are based on totals from the full-count data.

Table 3.5. Characteristics of NPL Sites

Group	Total	MSA	%	χ^2 NPL	χ^2 ROD	CC	%	χ^2 NPL	χ^2 ROD
NPL	1,552	1,264	81%	-	-	873	56%	-	-
ROD	1,263	1,044	83%	0.70	-	833	66%	1.04	-
MROD	1,044	1,044	100%	218	-	675	65%	-0.97	-2.19
Property	16	16	100%	3.64	3.35	7	44%	1.00	3.47
HV	150	125	83%	0.33	0.04	123	82%	37	15.7
Federal	175	154	88%	4.60	3.17	39	22%	73	123

Only a little more than half (56%) of all NPL sites have reached CC status, and Table 3.5 shows that there is more variation in this percentage for the other groups. The ROD, MROD, and HV groups have higher percentages of CC sites, while the Property and Federal groups have lower percentages. Using the chi-squared statistic to test the hypothesis that the likelihood of a site having reached CC status is the same for the NPL and other groups shows that only the Property group passes this test. Therefore the differences between the HV and ROD and the Federal and ROD groups are statistically significant at the 5% level.

The population data presented in Table 3.5 include both full-count and multi-count information, as appropriate. Totals for the larger groups (NPL, ROD, and MROD) are given using the full-count procedure, and avoid double counting. Totals for the smaller groups (Property, HV, and Federal) are sums of the individual site values created by using the multi-count procedure, and are accurate because there is little or no double counting among the sites in these groups. Thus, approximately 40 million people live near an NPL site, equaling 13% of the U.S. population; 11 million residences are near an NPL site, which equals about 14% of the national total. A distance of 2.5 miles is used to define "near," as discussed in Chapter 4.

Table 3.6 presents population data for places near NPL sites. The most striking feature of this data is that the mean population near Property sites is much larger (about twice as big) as the mean populations near NPL and ROD sites. Part of this difference can be explained by the fact that all of the Property sites are near population centers. However, the mean population near Property sites is still 80% larger than the mean population near MROD sites. A similar pattern is observed for the number of residences near sites, as shown in Table 3.6.

For this data, the *t* statistic can be used to test hypotheses, and because the number of observations is large, the critical value for the 0.05 percent level is 1.96. Thus, only for the Property group can the hypothesis that the mean of nearby populations is the same as the mean of nearby populations for all NPL sites be rejected. When compared to the ROD group, the hypothesis that the mean of nearby populations is the same as the mean of nearby populations for ROD sites can be rejected for the MROD, Property, and Federal groups.

Table 3.6. Populations Within 2.5 Miles of NPL Sites (thousands)

Group	Total	Mean	S.Dev	Median	Min	Max	*t* stat. NPL	*t* stat. ROD
NPL	40,000	37	83	17	0	2,200	-	-
ROD	32,000	34	58	17	0	1,200	1.09	-
MROD	30,000	40	62	23	0	1,200	-0.91	-2.18
Property	1,600	72	47	61	21	203	-2.99	-3.25
HV	4,900	33	40	15	0	205	1.16	0.43
Federal	7,500	43	49	27	0	323	-1.33	-2.12

Table 3.7 presents similar data for residences near NPL sites. The results of statistical hypothesis testing for the number of residences is similar to that discussed above, except that when compared to the ROD group, the hypothesis that the mean of nearby populations is the same as the mean of nearby populations for ROD sites can*not* be rejected for the Federal group.

The implications of the data in Tables 3.5 and 3.6 are that the Property sites have larger populations and larger numbers of residences near them than the other site groups and that these differences are statistically significant. These differences do not affect the estimates in Chapters 4 and 5, however, because mean populations and mean numbers of residences do not enter the calculations.

Table 3.7. Residences Within 2.5 Miles of NPL Sites (thousands)

Group	Total	Mean	S.Dev	Median	Min	Max	*t* stat. NPL	*t* stat. ROD
NPL	14,000	13	27	6.0	0	670	-	-
ROD	11,000	12	20	5.5	0	340	1.06	-
MROD	11,000	14	21	7.8	0	340	-1.11	-2.31
Property	420	26	15	23	7.3	58	-3.48	-3.75
HV	1,700	12	14	5.3	0	72	1.02	0.34
Federal	2,500	15	17	8.4	0	96	-1.07	-1.78

The time it takes a site to go from being proposed for inclusion on the NPL to reaching the status of CC is shown in Table 3.8. The only significant difference among the groups is for the Property group, which has a statistically significant longer mean time from Proposed to CC. This difference is smaller than the differences in population and number of residences, however, amounting to only a 25% increase. By looking at the medians and ranges for this value reported for the groups, it appears that the difference is due to the exclusion of sites with quicker (less than 7-year-long) remedial action processes from the Property group. However, as discussed in Chapter 5, it is not clear that this difference has any impact on the estimate of the benefits associated with NPL remedial actions.

Statistics describing the area of NPL sites are given in Table 3.9. As discussed below, these data are different from the nearby population and nearby residence data in that a few large sites dominate the area of NPL sites. Thus, the standard deviations are larger than the mean values for all the groups. The median values are therefore more informative. The median area for the NPL, ROD, and MROD sites is 30 acres; the median area for the Property sites is 33 acres. The HV sites tend to be smaller, with a median of only 17 acres. In this table, it is the Federal sites that stand out; these 175 sites account for most (67%) of the area of all NPL sites, and, naturally, have much larger mean and median areas.

Table 3.8. Time from Proposed NPL Listing to CC (years)

Group	Mean	S.Dev	Median	Min	Max	*t* stat. NPL	*t* stat. ROD
NPL	12	4	11	0	21	-	-
ROD	12	4	11	2	21	-0.44	-
MROD	12	4	12	2	21	-0.95	-0.54
Property	15	4	15	8	21	-2.05	-1.99
HV	12	4	12	4	21	-0.46	-0.25
Federal	12	4	11	4	20	-0.03	0.10

Table 3.9. Area of NPL Sites (thousands of acres)

Group	Total	Mean	S.Dev	Median	Min	Max	*t* stat. NPL	*t* stat. ROD
NPL	5,400	3.5	34	0.030	0	910	-	-
ROD	4,600	3.7	36	0.030	0	910	-0.14	-
MROD	2,300	2.2	19	0.030	0	450	1.24	1.25
Property	1.5	0.093	0.111	0.033	0	0.33	3.93	3.48
HV	17	0.113	0.439	0.017	0	3.2	3.91	3.46
Federal	3,600	21	86	3.6	0	910	-2.61	-2.57

The population and area data for all NPL sites are presented below in Figures 3.10 through 3.13 in order to provide a better characterization. Figure 3.10 shows the cumulative distribution of nearby populations for all NPL sites, sorted in two ways: by population, and by area.

The data in Figures 3.10 through 3.13 show that the size distribution of NPL sites is dominated by a small number of sites, but that these sites have relatively few people near them. Only six sites (0.4% of the NPL) make up 53% of the total area of all NPL sites. Table 3.10 gives the name, state, and size of all NPL sites larger than 100,000 acres. Of these ten sites, four are military bases, two are associated with the Department of Energy's nuclear weapons infrastructure, two are large ground water contamination sites, and two are former mining sites. Although these sites are very large, relatively few people are near them (only about 2.2 million, or 7% of the total population near NPL sites.) Of this total, about half are associated with a single site (Newmark). The ten largest sites in the coterminous United States are identified in Figure 3.14. Of the largest NPL sites, only Ft. Wainwright in Alaska is missed. The dominance of large sites is further seen in the fact that only 66 sites (4% of all NPL sites) make up 90% of the area of all NPL sites. However, only 11% of population near NPL sites is near these large sites. In addition, only two of these large sites are in the eastern part of the United States, while four of them are in southern California.

Figures 3.10 through 3.13 also show that there is little correlation between NPL site size and the population near NPL sites. The 170 NPL sites with the greatest nearby populations (11% of the total) have 50% of the total nearby population, while these sites represent 22% of the area of all sites. Similarly, 90% of the nearby population is associated with only 725 sites (47% of all NPL sites), but these sites have only 63% of area of all NPL sites.

Figure 3.10. Cumulative Population Distribution Near All NPL Sites

Figure 3.11. Distribution of Populations Near All NPL Sites (note logarithmic scale)

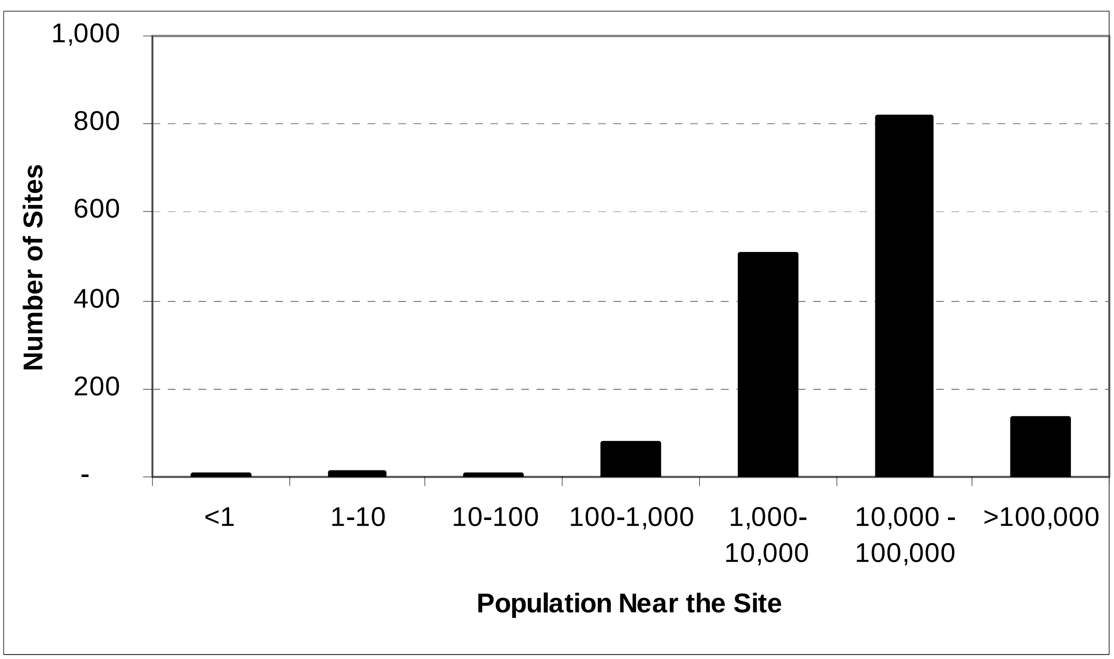


Figure 3.12. Cumulative Distribution of the Area of All NPL Sites

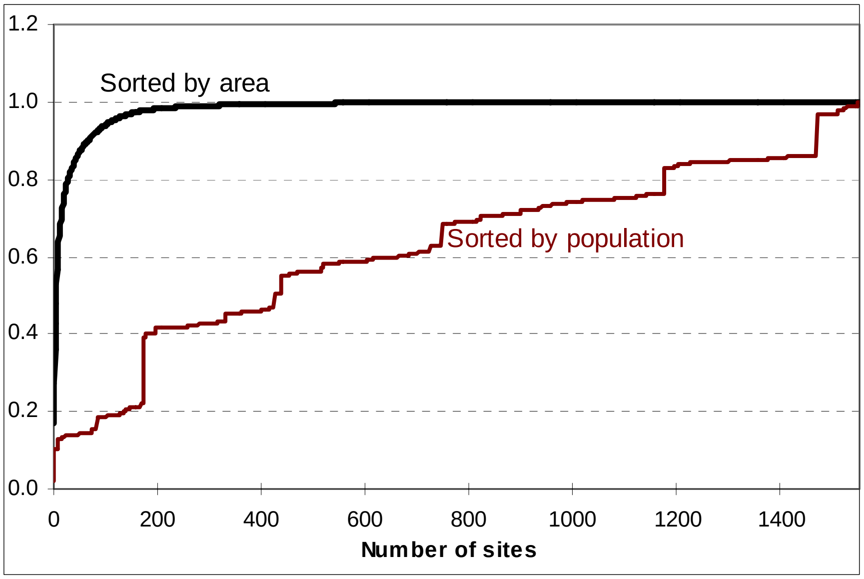
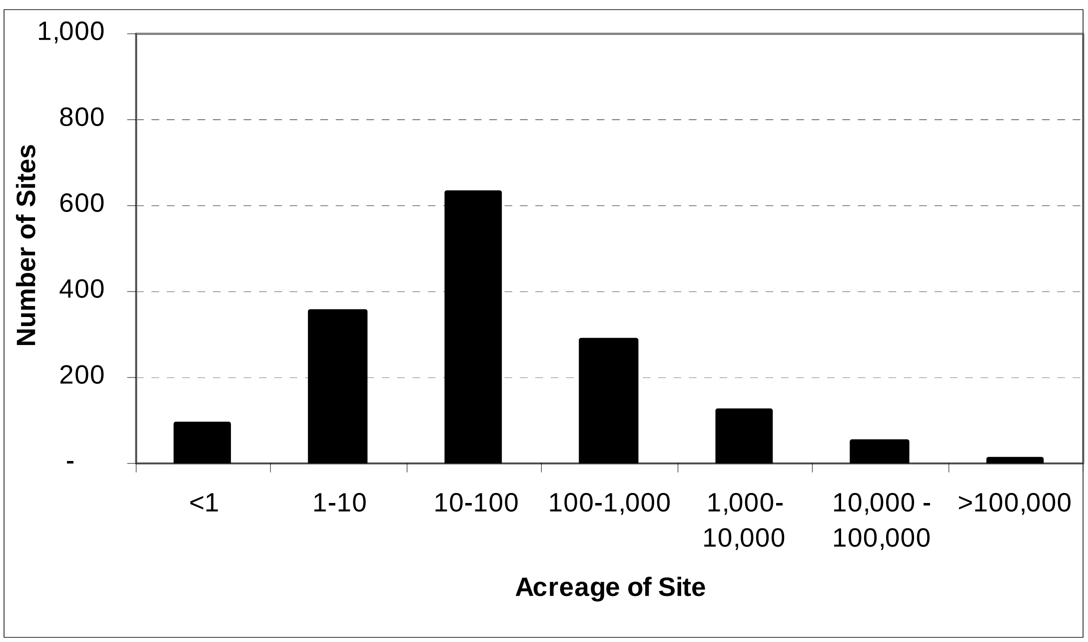


Figure 3.13. Distribution of NPL Site Areas (acres, note logarithmic scale)



These figures show that most NPL sites (824, or 53% of all NPL sites) have nearby populations of 10,000 to 100,000 and almost all (1,420, or 91% of all sites) have nearby populations of less than 100,000.

Those NPL sites with nearby populations of more than 250,000 are shown in Table 3.11. These sixteen sites account for about fifteen percent of the total population near all NPL sites. Three sites appear on both Tables 3.10 and 3.11: Newmark Ground Water, San Gabriel Valley (Area 3), and Camp Pendleton Marine Corps Base. All three of these sites are in southern California, and ten of the sixteen sites in Table 3.11 are in southern California.

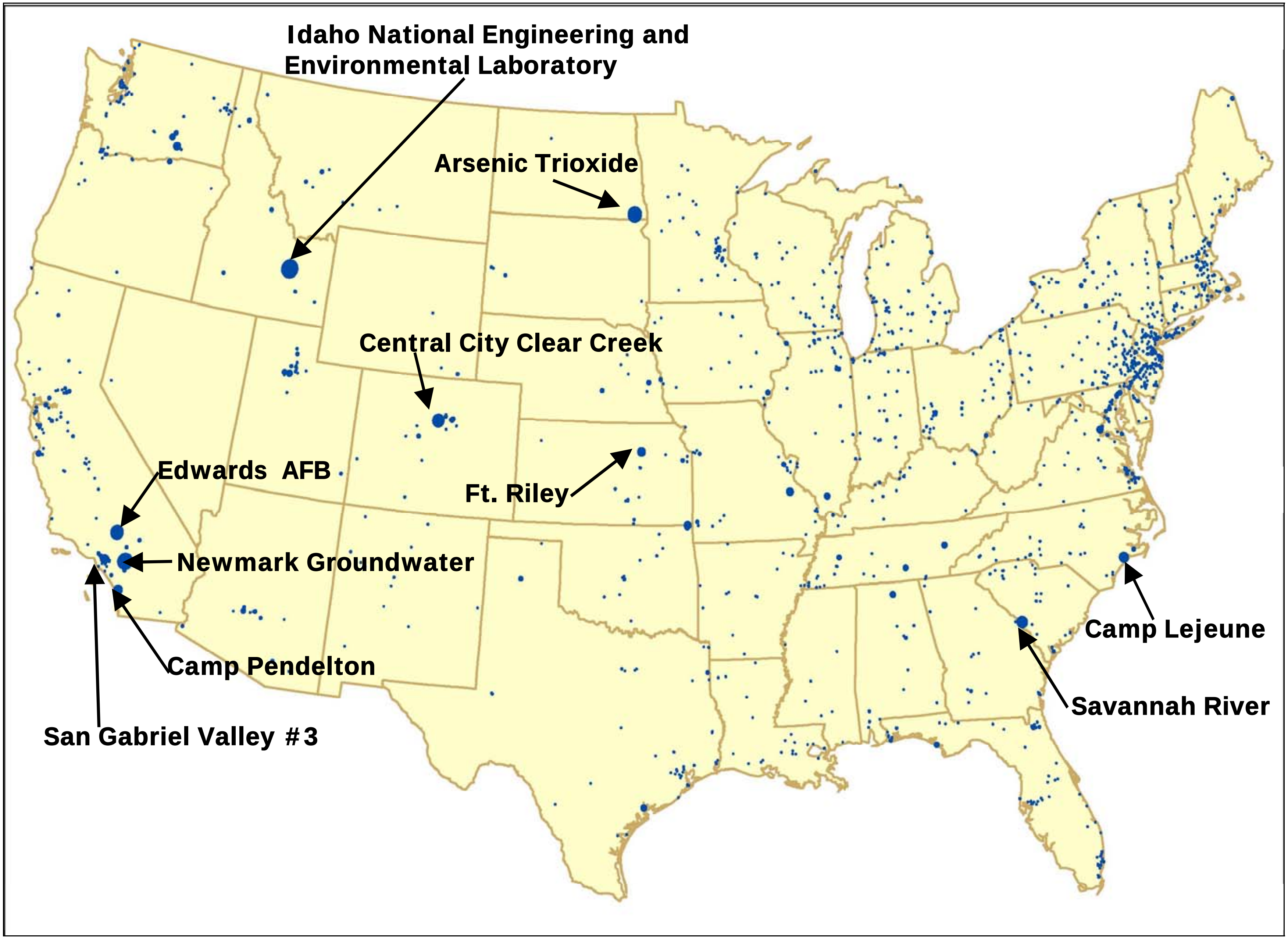
Table 3.10. NPL Sites Larger than 100,000 Acres

Name	**State**	**Size (acres)**
Fort Wainwright	AK	911,604
Idaho National Engineering Laboratory	ID	569,598
Newmark Ground Water	CA	447,998
Arsenic Trioxide Site	ND	363,520
Edwards Air Force Base	CA	301,000
Central City, Clear Creek	CO	255,999
Savannah River Site	SC	198,399
Camp Lejeune Military Reservation	NC	151,039
Camp Pendleton Marine Corps Base	CA	125,000
San Gabriel Valley (Area 3)	CA	108,800

Table 3.11. NPL Sites with Nearby Populations Over 250,000

Name	**State**	**Nearby Population**
San Gabriel Valley (Area 3)	CA	2,227,129
Newmark Ground Water	CA	1,168,434
San Fernando Valley (Area 4)	CA	712,205
Quanta Resources	NJ	634,671
Radium Chemical Co., Inc.	NY	630,826
San Fernando Valley (Area 3)	CA	492,427
Grand Street Mercury	NJ	434,146
San Fernando Valley (Area 2)	CA	355,919
San Gabriel Valley (Area 2)	CA	336,839
Camp Pendleton Marine Corps Base	CA	322,880
San Fernando Valley (Area 1)	CA	316,778
Cooper Drum Co.	CA	282,343
Austin Avenue Radiation Site	PA	277,236
Lansdowne Radiation Site	PA	256,287
Glen Ridge Radium Site	NJ	255,001
San Gabriel Valley (Area 1)	CA	252,404

Figure 3.14. Areas Near NPL Sites and the Ten Largest NPL Sites in the Coterminous U.S. States



The data presented in Figures 3.10 and 3.11 are reproduced below for each of the groups listed in Table 3.3. In general, the figures below illustrate the insights of the statistical tests discussed above (that they are all similar with the exception of the Property group).

Figure 3.15. Cumulative Population Distribution Near ROD Sites

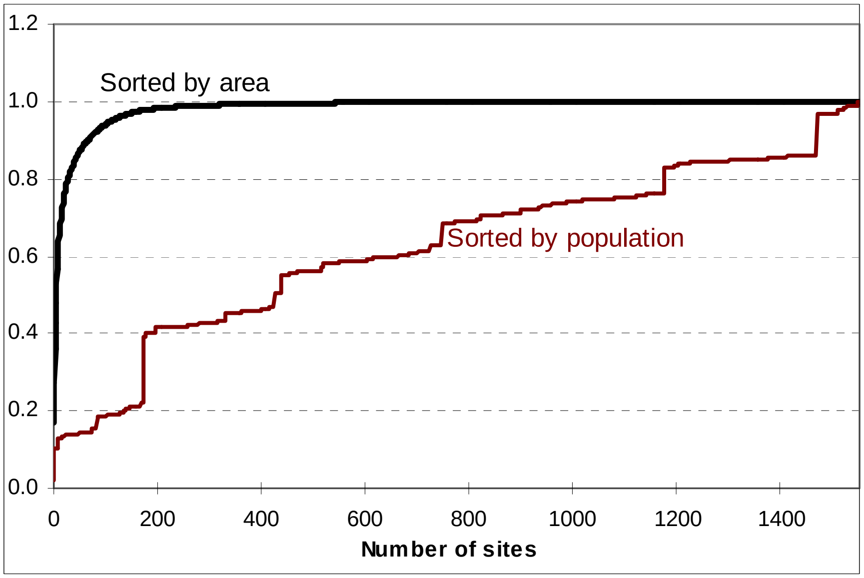


Figure 3.16. Distribution of Populations Near ROD Sites (note logarithmic scale)

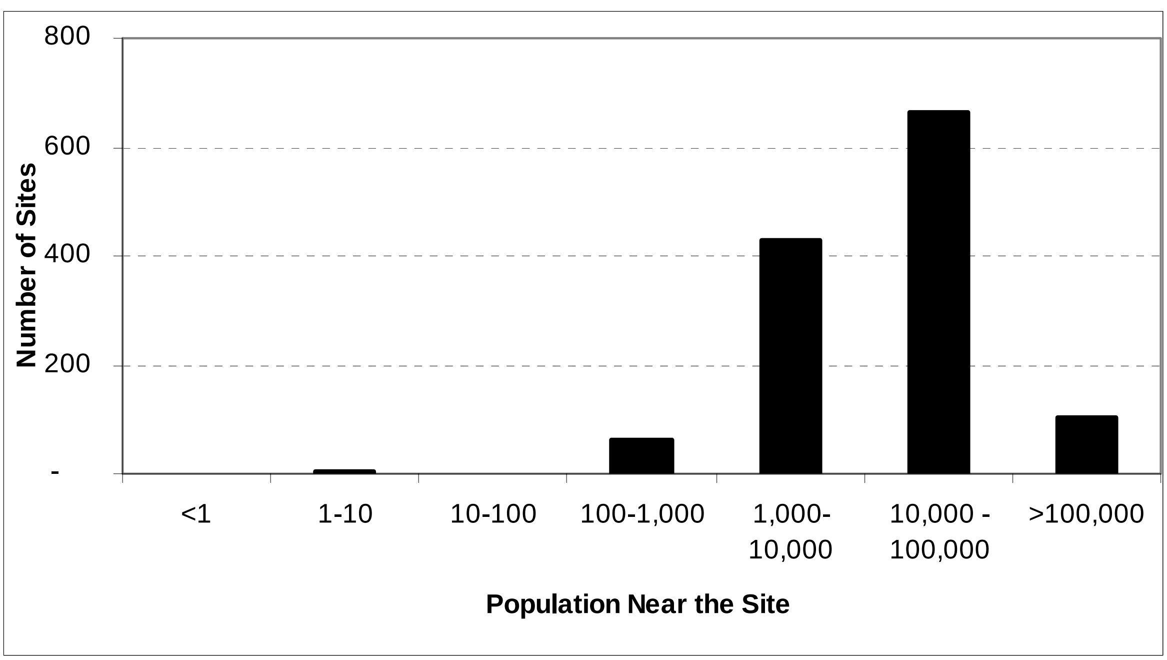


Figure 3.17. Cumulative Population Distribution Near MROD Sites

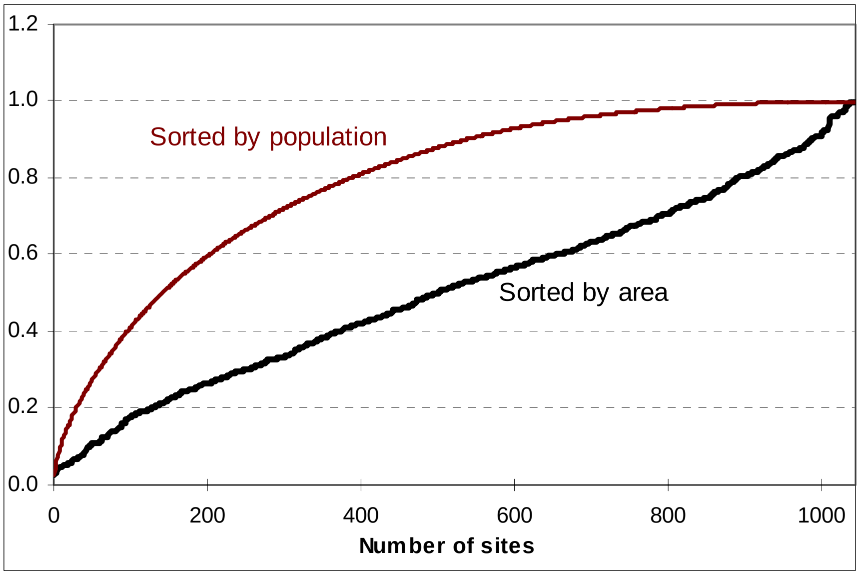


Figure 3.18. Distribution of Populations Near MROD Sites (note logarithmic scale)

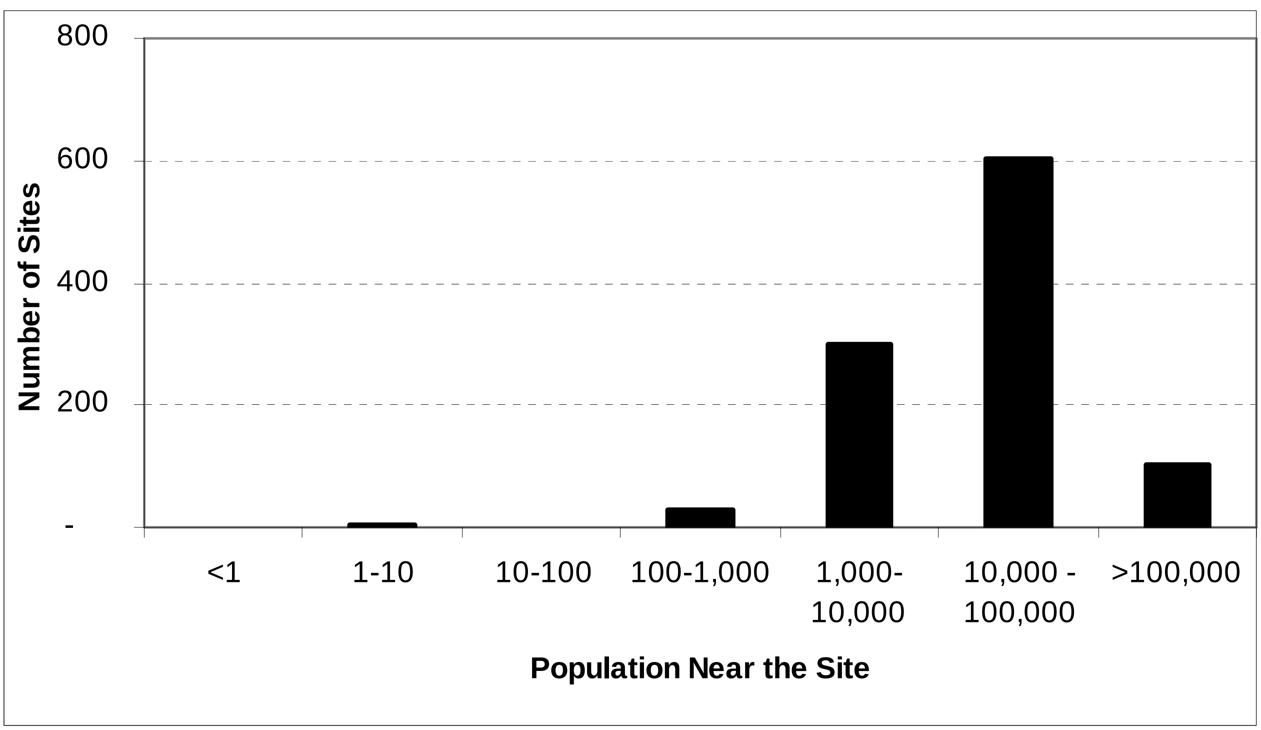


Figure 3.19. Cumulative Population Distribution Near Property Sites

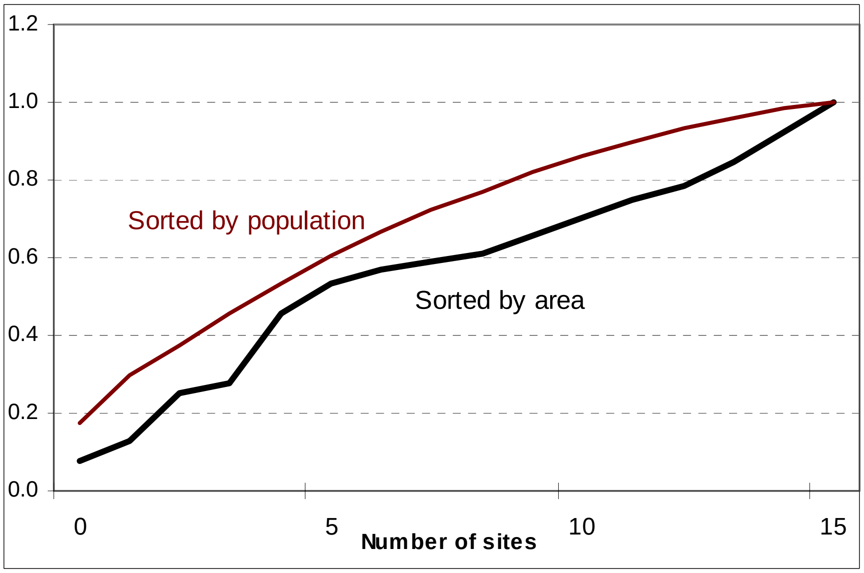


Figure 3.20. Distribution of Populations Near Property Sites (note logarithmic scale)

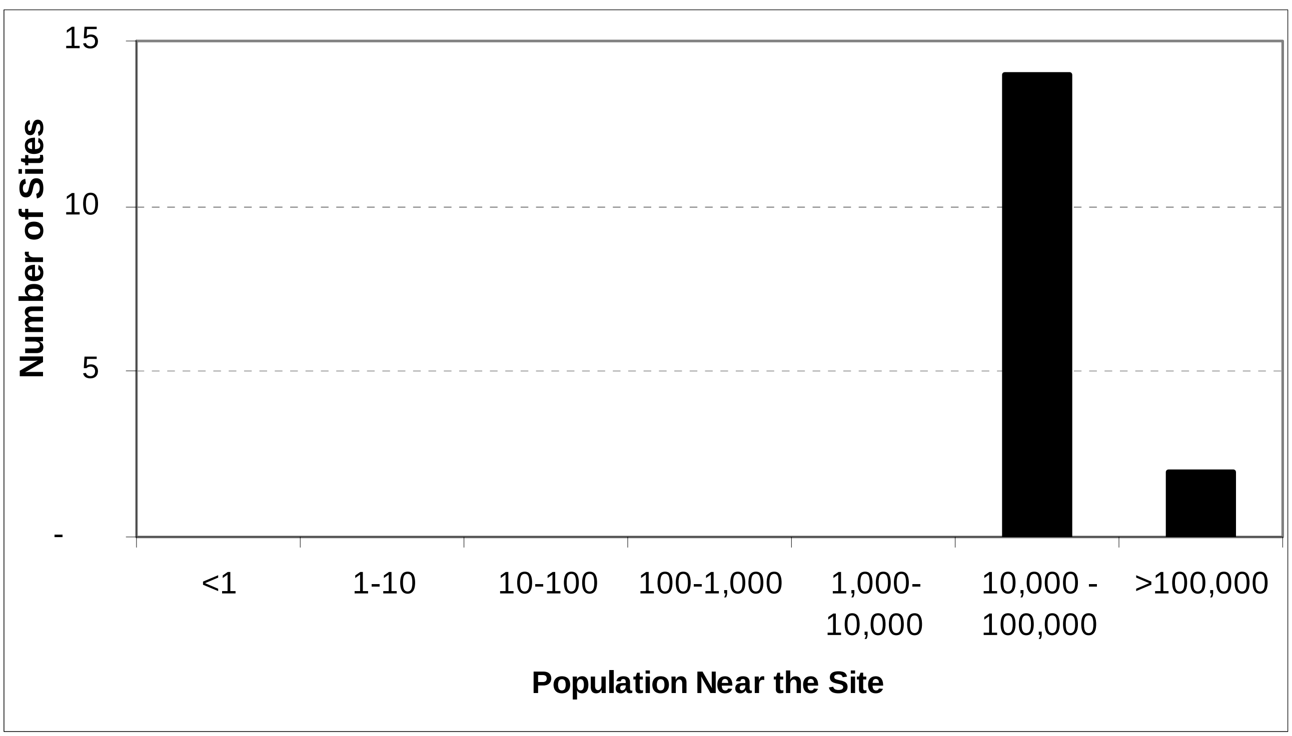


Figure 3.21. Cumulative Population Distribution Near HV Sites

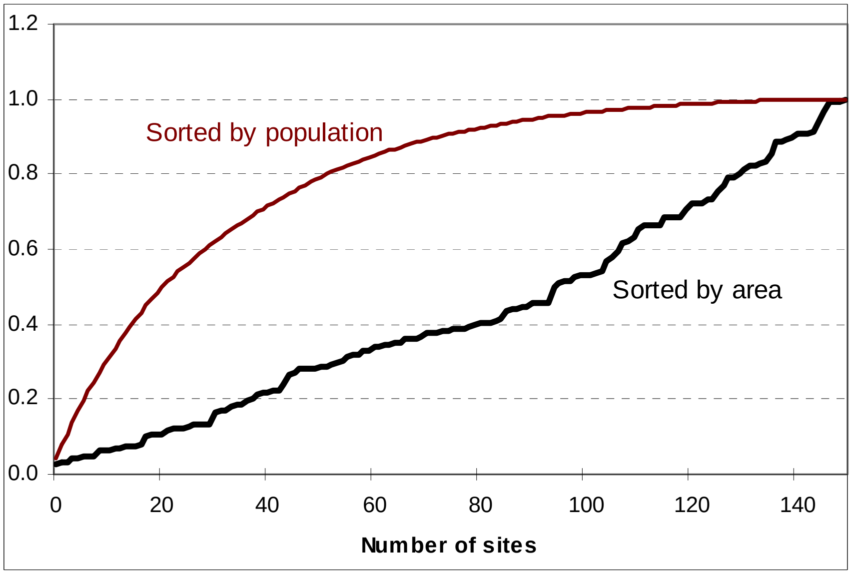


Figure 3.22. Distribution of Populations Near HV Sites (note logarithmic scale)

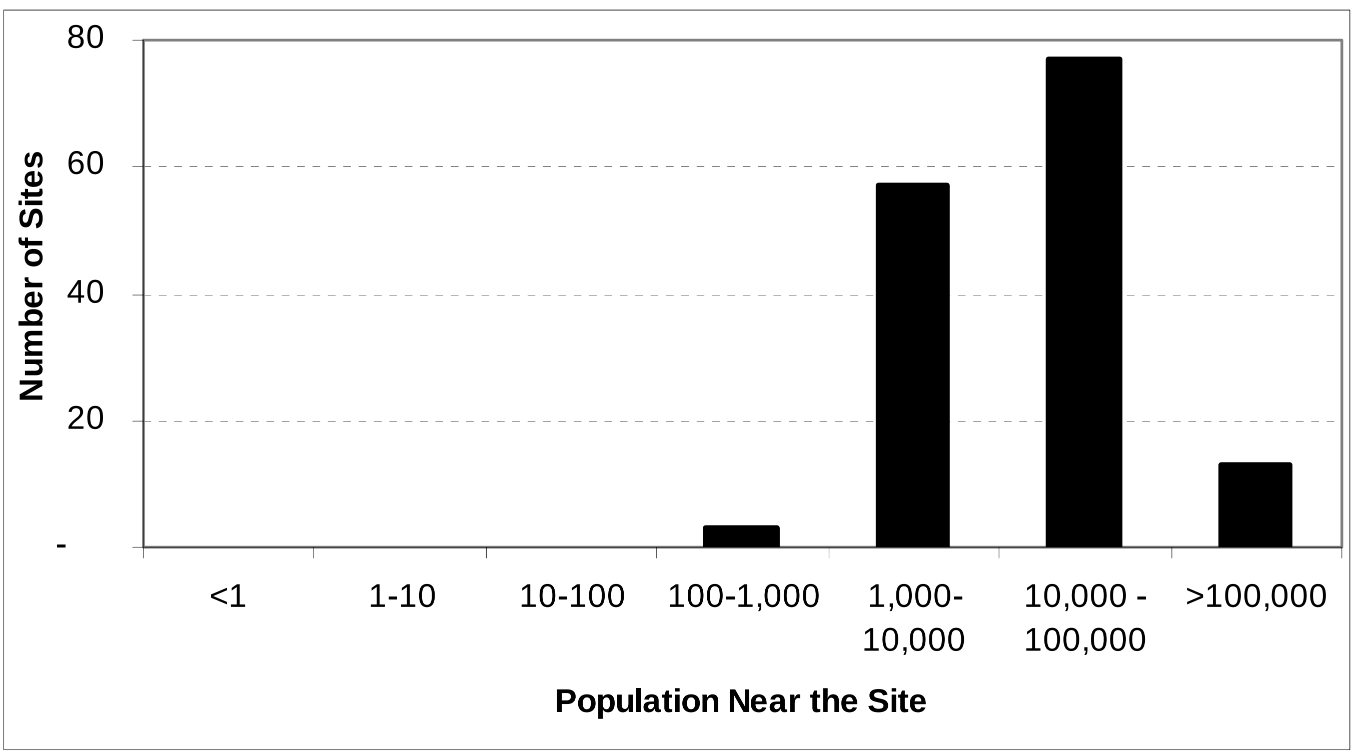
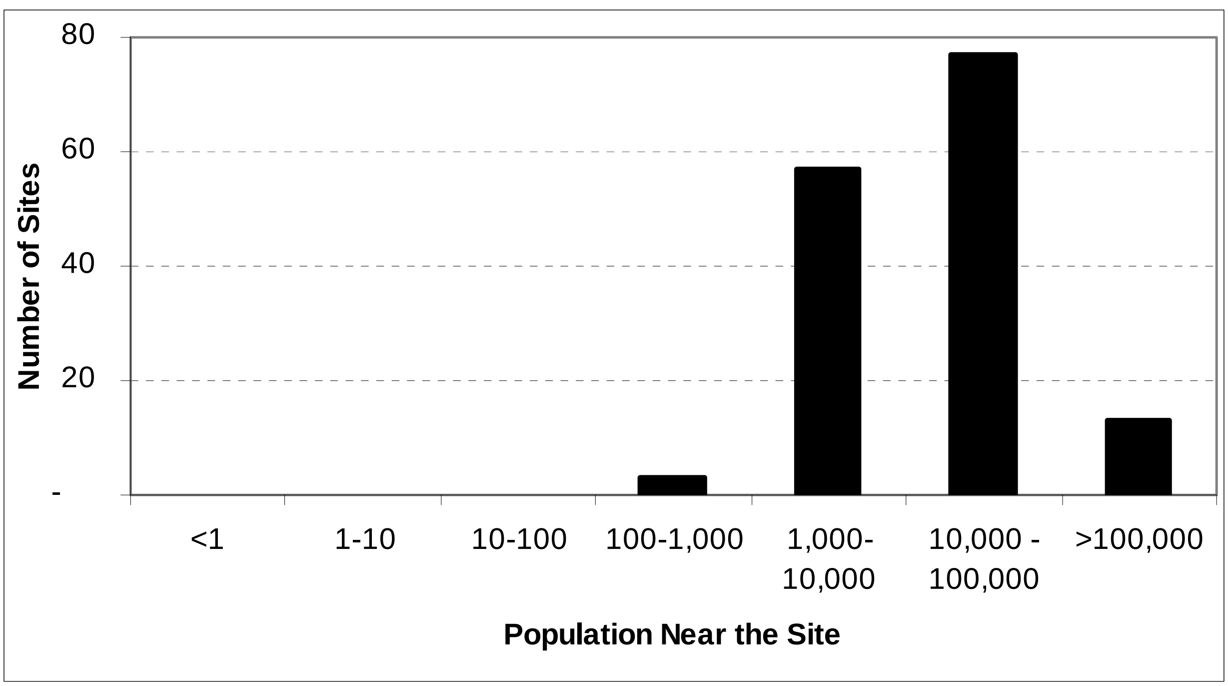


Figure 3.23. Cumulative Population Distribution Near Federal Sites

Figure 3.24. Distribution of Populations Near Federal Sites (note logarithmic scale)



Case Study: Hanford

Many of the largest and most challenging NPL sites are associated with current and former military bases and nuclear weapons facilities, such as the Hanford Nuclear Reservation in southeastern Washington State.TP[1]PT During World War II, the U.S. government created this and other research and manufacturing operations for the Manhattan Project. The 586-square-mile site continued to play an important role in the nation's defense for more than 40 years during the Cold War. The Atomic Energy Commission was in charge of Hanford from the 1940s until 1977 when Congress created the U.S. Department of Energy (DOE), which then took over Hanford's management. Today, the site is undergoing the world's largest environmental cleanup, involving both chemically toxic materials and radionuclides.

The problems being addressed at Hanford include more than 50 million gallons of high-level liquid waste, 2,300 tons of spent nuclear fuel, 12 tons of plutonium, 25 million cubic feet of solid waste, and 270 billion gallons of contaminated ground water. The problems are spread out over about 80 square miles and are located at more than 1,700 waste sites and 500 contaminated facilities. Sixty percent of the nation's high-level radioactive wastes are stored at Hanford in aging, deteriorating tanks. If they are not cleaned up, these wastes are a threat to the Columbia River, which flows next to the Hanford site. Over half a million people live within 50 miles of Hanford, and over two million people live downstream, many in or near Portland, Oregon. In May 1989, the Environmental Protection Agency (EPA), the Washington State Department of Ecology, and DOE signed an agreement providing a framework for Hanford's cleanup. In October of the same year, an area totaling 208 square miles was listed on Superfund's National Priorities List (NPL). The enormous task of cleaning up contamination at Hanford was made more manageable by dividing the contaminated property into four NPL sites known as Areas 100, 200, 300, and 1100.

The 26-square-mile 100 Area was contaminated by nine nuclear reactors, the last of which shut down in 1988. Cooling water contaminated with radioactive and hazardous chemicals was discharged to both the Columbia River and infiltration trenches. As a result, 11 square miles of ground water are contaminated with hexavalent chromium, radioactive strontium-90, carbon-14, and tritium (radioactive hydrogen). Though the ground water is not directly used for drinking, it discharges into the Columbia, which provides drinking water to the 100,000 residents of Richland, Pasco, and Kennewick just downstream of Hanford. The ground water is being cleaned by three pump-and-treat systems, two of which are removing hexavalent chromium, and one of which is removing strontium-90. An in-situ barrier has been installed to contain the hexavalent chromium-contaminated ground water. Contaminated solid wastes buried on the site are also being removed as part of the remediation; over 2 million tons of contaminated soil and debris have been removed.

The Hanford 200 Area covers approximately 60 square miles of land and over 120 square miles of contaminated ground water. It contains the former chemical processing plants and waste management facilities used to process, finish, and manage nuclear materials, including plutonium. About one billion cubic yards of wastes were disposed of in more than 800 locations in the 200 Area. This resulted in the contamination of soil and ground water with tritium, uranium, cyanide, carbon tetrachloride, and technetium. Since 1992, a soil vapor extraction system has removed 168,000 pounds of carbon tetrachloride. Ground water systems have removed 10,000 pounds of carbon tetrachloride, 220 pounds of uranium, and one pound of technetium-99. Nonetheless, some exposure may be ongoing due to this site. For instance, the City of Richland's surface water intakes on the Columbia River contain low levels of tritium.

TP[1]PT Most of the information used to create this case study was obtained from various documents available on the Internet in August 2004. These sources include: www.hanford.gov/history/0435/0435-1st.htm; EPA's Site Summary for the Hanford 100, 200, 300, and 1100 Areas, http://yosemite.epa.gov/r10/nplpad.nsf/; TUwww.hanford.gov/ORPreporter/index.cfmTU; EPA's Hanford 1100 Area Case Study, February 2000, www.epa.gov/superfund/programs/recycle/success/casestud/hanfcsi.htm. In addition, please see Gephart 2003; Washington State Department of Ecology 1997; Washington State Department of Health 1997.

Case Study: Hanford (cont.)

The 1.5-square-mile Hanford 300 Area was an industrial complex and disposal area. The Department of Energy fabricated fuel for nuclear reactors and conducted research and development in the 300 Area. The 300 Area also received 27 million cubic yards of wastes. The liquid wastes percolated down through the highly permeable sand and gravel aquifer, contaminating the ground water and the Columbia River and endangering the drinking water intakes downstream. Ground water and soil contaminants include uranium, volatile organic compounds (VOCs), strontium-90, tritium, cobalt-60, copper, polychlorinated biphenyls (PCBs), and chromium. Soil contamination is being addressed via excavation and removal; 530,000 tons of contaminated soil and debris had been removed as of June 2000, with more excavation planned. The ground water contamination is being addressed by monitored natural attenuation.

The Hanford 1100 Area covers 120 square miles, approximately one mile north of Richland, Washington. The 1100 Area provides maintenance services to other areas of Hanford. The Yakama Nation has exclusive fishing rights to the Yakima River, which borders the 1100 Area. Wells near the 1100 Area are contaminated with VOCs, including trichloroethylene. The soil was contaminated with asbestos, heavy metals, and PCBs. This contamination was addressed by excavating 295 cubic yards of contaminated soil and disposing of it at a permitted facility. Ground water will be monitored until natural processes clean it over time. The 1100 Area was deleted from the NPL in September 1996. Since that time, new enterprises have begun operating at the 1100 Area; these include a rail hub and a locomotive maintenance and repair facility.

The cleanup at Hanford demonstrates how EPA can work with state and federal agencies to address widespread contamination at huge federal facilities even when high-level radioactive waste is involved. EPA, DOE, and the Washington State Department of Ecology are pooling resources and using techniques developed at other Superfund sites to protect the Columbia River and the health of populations surrounding Hanford. In some cases, decisions about remediation at the Hanford site will be guided by Washington state standards, as part of the applicable or relevant and appropriate requirements (ARARs) provisions of the Superfund Amendments and Reauthorization Act (SARA). This case also illustrates large-scale examples of the use of institutional controls (i.e. access restrictions) to prevent exposure while remedial actions are designed and implemented. Due to the magnitude of the contamination at this site, the operation and maintenance phase of the remedial actions is likely to continue for a lengthy period.

References

Association of State and Territorial Solid Waste Management Officials. 1998. State Cleanup Accomplishments for the Period 1993-1997. Washington, DC: ASTSWMO.

Baker, S. 1997. A Toxic Legacy. *Public Health*. Available at http://www.whsc.emory.edu/_pubs/ph/phfall97/toxic.html

Brown, R. S. 2001. States Put Their Money Where Their Environment Is. Washington, DC: Environmental Council Of the States (ECOS). Available at http://www.sso.org/ecos/ECOStatesArticles/rsbrown.pdfT

Congressional Budget Office. 1994. The Total Costs of Cleaning Up Nonfederal Superfund Sites. Washington, DC.

Environmental Law Institute. 1998. An Analysis of State Superfund Programs: 50 State Study, 1998 Update. Washington, DC.

———. 2002. An Analysis of State Superfund Programs: 50 State Study, 2001 Update. Washington, DC.

Gayer, T., J. T. Hamilton, and W. K. Viscusi. 2000. Private values of risk tradeoffs at superfund sites: Housing market evidence on learning about risk. *Review of Economics and Statistics* 82 (3):439-451.

General Accounting Office. 1995. Superfund: Information on Current Health Risks. Washington, DC: General Accounting Office,.

———. 1998a. Hazardous Waste Sites: State Cleanup Practices. Washington DC.

———. 1998b. Hazardous Waste: Unaddressed Risks at Many Potential Superfund Sites. Washington, DC.

———. 1999. Superfund: Progress, Problems, and Future Outlook. Washington, DC.

Hamilton, J. T., and W. K. Viscusi. 1999. *Calculating Risks? The Spatial and Political Dimensions of Hazardous Waste Policy*. Edited by N. L. Rose and R. Schmalensee, *Regulation of Economic Activity*. Cambridge, MA: MIT Press.

Hird, J. A. 1994. *Superfund : the political economy of environmental risk*. Baltimore: Johns Hopkins University Press.

Khoury, G. A., and G. L. Diamond. 2003. Risks to children from exposure to lead in air during remedial or removal activities at Superfund sites: A case study of the RSR lead smelter Superfund site. *Journal of Exposure Analysis and Environmental Epidemiology* 13 (1):51-65.

Kiel, K., and J. Zabel. 2001. Estimating the economic benefits of cleaning up Superfund sites: The case of Woburn, Massachusetts. *Journal of Real Estate Finance and Economics* 22 (2-3):163-184.

King, G. 2002. Letter to Michael B. Cook, Director of the Office of Emergency and Remedial Response. Washington, DC: Association of State and Territorial Solid Waste Management Officials.

Koshland, D. E. 1991. Toxic-Chemicals and Toxic Laws. *Science* 253 (5023):949-949.

Lybarger, J. A., R. Lee, D. P. Vogt, R. M. Perhac, R. F. Spengler, and D. R. Brown. 1998. Medical costs and lost productivity from health conditions at volatile organic compound-contaminated superfund sites. *Environmental Research* 79 (1):9-19.

Matta, M., G. Gray, and L. Francendese. 1998. LCP Chemical Site Monitoring Study. Silver Spring, MD: NOAA National Ociean Service Office of Response and Restoration.

Office of Emergency and Remedial Response. 1989. Risk Assessment Guidance for Superfund. Volume I Human Health Evaluation Manual (Part A). Washington, DC: U.S. Environmental Protection Agency.

———. 1990. National Contingency Plan.

Office of Management and Budget. 2003. Performance and Management Assessments. Washington, DC.

Office of Solid Waste and Emergency Response. 1990. Superfund Removal Procedures Action Memorandum Guidance. Washington, DC: U.S. Environmental Protection Agency.

———. 1998. RCRA, Superfund & EPCRA Hotline Training Module: Introduction to Superfund Accelerated Cleanup Model. Washington, DC: U.S. Environmental Protection Agency.

Office of Technology Assessment. 1989. Coming Clean: Superfund Problems Can Be Solved. Washington, DC: U.S. Congress.

Probst, K. N., D. Fullerton, R. E. Litan, and P. R. Portney. 1995. *Footing the Bill for Superfund Cleanup: Who Pays and How?* Washington, DC: Brookings Institution and RFF Press.

Probst, K. N., and D. M. Konisky. 2001. *Superfund's Future: What Will It Cost?* Washington, DC: RFF Press.

RCRA/CERCLA Division. 1993. Remedial Investigation/Feasibility Study (RI/FS): Process, Elements and Techniques, edited by Office of Environmental Guidance. Washington, DC: U.S. Department of Energy.

Science Advisory Board. 1990. Review of the Superfund Innovative Technology Evaluation (SITE) Program. Washington, DC: US EPA.

Scogin, G.E. (1994) Action Memorandum: Documentation for an Enforcement-lead Removal Action at the LCP Chemicals Site in Brunswick, Glynn County, GA. Atlanta, GA: U.S. Environmental Protection Agency Region IV.

Sheldrake, S., and M. Stifelman. 2003. A case study of lead contamination cleanup effectiveness at Bunker Hill. *Science of the Total Environment* 303 (1-2):105-123.

Traceski, T. T. 1994. Environmental Guidance on CERCLA Removal Actions, edited by U. S. D. o. Energy. Washington, DC: Office of Environmental Guidance.

———. 1995. Baseline Risk Assessment: Toxicity and Exposure Assessment and Risk Characterization, edited by U. S. D. o. Energy. Washington, DC: Office of Environmental Policy and Assistance.

U.S. Environmental Protection Agency. 2000. Technical Assistance Grant Program: Final Rule. 65 *FR* 191: 58850-58868. October 2.

Varney, Robert W. (2000) Statement of the Commissioner of the New Hampshire Department of Environmental Services on Superfund on behalf of the Environmental Council of the States. Senate Committee on Environment and Public Works, Washington, DC. March 21.

Viscusi, W. K., J. T. Hamilton, and P. C. Dockins. 1997. Conservative versus mean risk assessments: Implications for superfund policies. *Journal of Environmental Economics and Management* 34 (3):187-206

von Lindern, I., S. Spalinger, V. Petroysan, and M. von Braun. 2003. Assessing remedial effectiveness through the blood lead : soil/dust lead relationship at the Bunker Hill Superfund Site in the Silver Valley of Idaho. *Science of the Total Environment* 303 (1-2):139-170.

Walker, K. D., M. Sadowitz, and J. D. Graham. 1995. Confronting Superfund Mythology: The Case of Risk Assessment and Management. In *Analyzing Superfund: Economics, Science and Law*, edited by R. L. Revesz and R. B. Stewart. Washington, DC: RFF Press.

Wildavsky, A. 1995. *But Is It True? A Citizen's Guide to Environmental Health and Safety Issues*. Cambridge: Harvard University Press.

CHAPTER 4: PROPERTY - BASED VALUATION

Introduction

This chapter presents a benefits-transfer analysis that applies data from hedonic valuation studies to data on housing units near NPL sites to estimate the benefits of all NPL remedial actions for which a Record of Decision (ROD) has been issued through 2004. Hedonic valuation studies are indirect measures in that the values for the environmental (dis)amenity are inferred from data on commodities with many relevant properties (U.S. Environmental Protection Agency 2000, 71, 75, 77-79). In a recent review of a similar analysis, an EPA Science Advisory Board (SAB) review panel noted:

> If this approach is utilized, the issues of property value changes and welfare, amenity effects on property values, and benefits transfer need to be addressed. But given the problems with the other approaches proposed, this approach may be a relatively simple way to get obtain [sic] a 'ball park' or order-of-magnitude estimate of benefits. (EPA Science Advisory Board 2002, 3)

This chapter thus addresses the theoretical issues identified by the EPA Science Advisory Board and others, evaluates and applies the current peer-reviewed economics literature, and develops an order of magnitude estimate of the benefits of NPL site remedial actions. The next section provides an introduction to the use a benefit-transfer analysis for estimation of Superfund benefits. The third section of the chapter discusses theoretical concerns associated with the analysis. The fourth section presents the methods and data used in both the meta-analysis and benefits transfer. The fifth section presents and discusses the results.

Use of hedonic analysis for estimation of Superfund benefits

The economic benefits of public investments can be approached by focusing on measures of individual satisfaction or well-being, referred to as measures of welfare or utility. Economic theory assumes that individuals can maintain the same level of utility while trading-off different "bundles" of goods, services, and money. The willingness to trade off compensation for goods or services can be measured either as *willingness to pay* (WTP) or as *willingness to accept compensation* (WTA). Economists generally express WTP and WTA in monetary terms. In the case of an environmental policy, willingness to pay is the maximum amount of money an individual would voluntarily exchange to obtain an improvement in the relevant environmental effects. Conversely, willingness to accept compensation is the least amount of money an individual would accept to forego the improvement.

A challenge in analyzing the benefits of the Superfund program is that there are no markets for any of the approaches that the Superfund Program takes. Economists have developed other methods for eliciting values for these types of effects. These methods rely either on information from the markets for related goods (revealed preference methods) or on direct information on people's preferences (stated preference methods). The hedonic property model (HPM) is a revealed preference methodology that has been applied to sites with hazardous substances on them (U.S. Environmental Protection Agency 2000, 71, 75, 77-79).

Hedonic price theory assumes that consumers value heterogeneous goods (such as houses) based on characteristics that are both intrinsic to the items themselves and external to the item.[1] In this sense, individuals view housing units as bundles of attributes and derive different levels of utility from different combinations of these attributes. Relevant characteristics may include structural attributes (e.g., number of bedrooms and age of house), neighborhood attributes (e.g., population demographics, crime, and school quality), and environmental attributes (e.g., air quality and proximity to hazardous waste sites). According to hedonic price theory, when decisions to buy and sell are made, individuals make tradeoffs between money and these attributes. Observing the buying and selling behaviors of individuals reveals the marginal values of these attributes and is central to hedonic property value studies.

Thus, differences in the prices for heterogeneous goods can be used to estimate the implicit value that markets place on the characteristics of those goods. Relevant characteristics include proximity to NPL sites. Because actual behaviors (i.e., home purchases) are used for data, such revealed preference methods are less vulnerable to strategic manipulation and study design problems than stated preference methods, which rely on surveys and questionnaires. Hedonic property value studies use statistical regression methods and data from real estate markets to examine the increments in property values associated with different attributes. One of the attributes that has been investigated in the literature is proximity to NPL sites.

Although data on home sales near NPL sites is available, it would be prohibitively expensive to purchase for any large number of sites. One approach to solving the problem of sparse data is to conduct a benefits transfer analysis, in which the results of previous research are applied to a new context (Rosenberger and Loomis 2003). Rather than collecting primary data, the benefits transfer approach relies on information from existing studies that have used a primary approach, such as a hedonic property study. In the current study, this approach is taken.

Four major caveats apply to this analysis. First, the current analysis includes perceived risks and uncertainty. Second, it ignores many benefits, including any benefits to non-neighbors or benefits that consumers do not include in home purchasing decisions. Third, the hedonic studies upon which the current study is based are themselves only partial estimates of benefits because non-use values are excluded (Boyle 2003). Finally, the current study ignores all Superfund activities other than NPL site remedial actions. For instance, the removals program is ignored in the analysis of this chapter, even though it may be responsible for a non-trivial part of short-term risk mitigation associated with Superfund and is much larger (by number of actions) than the NPL (Hird 1994, 31-32, 112; Probst and Konisky 2001, chapter 2).

The next section of the chapter discusses theoretical concerns associated with the benefits transfer analysis. The third section presents the methods and data used in both the meta-analysis and benefits transfer. The fourth section presents and discusses the results.

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[1] Heterogeneous goods, such as automobiles and houses, are sold within a single market but can vary in characteristics. They can be contrasted to commodity goods, such as minerals and basic foodstuffs, which are sold in a single market but do not vary much.

Theoretical concerns with hedonic valuation

Overview

The theory of hedonic valuation begins with the observation that some products can be differentiated by the quantities of various features they possess (Rosen 1974; Freeman 1993). For residential real estate, these features include size, number and type of rooms, age, neighborhood characteristics and environmental amenities. The consumers of different types of the product (e.g., new, detached single family homes or condominiums in a refurbished factory) derive utility from the characteristics of the product, while producers or sellers incur costs that are dependent on the type of product they provide (Palmquist 1992a; McConnell 1993). Market prices are set by the interaction of the supply and demand schedules.

Rosen (1974) first modeled the interactions of consumers and producers in such a market. He developed the hedonic price function (sometimes called the hedonic model), P = P(**z**), where vector $\mathbf{z} = (z_1, z_2, \ldots z_n)$ represents the characteristics of the product. Rosen also developed a hedonic production function in which each producer chooses the variety of products he will produce and the number of each type. He then examined the equilibrium properties of such a market. His analysis improved the practice and interpretation of analyses in which the observed prices of the differentiated product are regressed on relevant attributes (including environmental amenities) in order to obtain estimates of the contribution of each attribute to the total price (Boyle and Kiel 2001).

An example of a relevant hedonic model is shown in Equation 4.1 (Kiel and Zabel 2001). In this specification, the price for house *i* at time *t* (P_{it}) is a log-linear function of home characteristics (H_{it}), neighborhood characteristics (N_{it}), and characteristics of the closest NPL site (S). The home and neighborhood characteristics examined by Kiel and Zabel include finished area (sq. ft.), age (date constructed), style (ranch, split, Cape Cod, colonial), unemployment at the census tract level, and median household income at the census tract level. The function that models the effect of an NPL site, $S(D_i;\theta_t)$, is more sophisticated than most other models in the literature, accounting both for distance (D_i) and for phases in the remedial process (θ_t). Otherwise this sort of specification is quite typical in the literature, with minor differences such as functional form or the inclusion of different home and neighborhood characteristics (e.g., number of bedrooms, racial makeup).

$$\ln P_{it} = \beta_{0t} + H_{it}\beta_{1t} + N_{it}\beta_{2t} + S(D_i;\theta_t) + u_{it} \quad \text{(Equation 4.1)}$$

In a hedonic analysis, the data are the price and characteristics of each home, and the results are the estimates for the parameter values, especially *S*. In a benefits transfer analysis, these results are the data. That is, this study will use estimates of the effect of proximity to NPL sites found in prior research and apply them to a larger set of NPL sites.

Several sources provide guidance on how to conduct a benefits transfer analysis with hedonic data. Bartik and Palmquist discuss theoretical issues of hedonic valuation theory as applied to amenity improvements (Bartik 1988; Palmquist 1991; Palmquist 1992a; Palmquist 1992b). Several recent references summarize good practices in benefits transfer (U.S. Environmental Protection Agency 2000, 85-87; Rosenberger and Loomis 2003). In a review of a study much like the one mentioned above, the EPA's Science Advisory Board (SAB) raised six theoretical concerns, each of which is discussed below (EPA Science Advisory Board 2002).

Market Size

The first theoretical concern involves the fraction of the housing market that homes near NPL sites make up. Palmquist, who focused on hedonic production functions and market equilibria, first raised questions about the size of the market relative to the environmental (dis)amenity thought to affect prices (Palmquist 1991). At the time Palmquist was writing, air pollution studies dominated the literature on hedonic price studies of environment and home prices. As a relatively large-scale phenomenon (city-wide or larger), air pollution is challenging for hedonic studies since, as Palmquist noted, "the prevalent view ... is that the housing market within a city is a single entity, whereas the housing markets in cities that are separated by significant distances are separate entities" (Palmquist 1991, 89). This "market size condition" suggests that hedonic price studies attempting to evaluate environmental disamenities should evaluate markets in which consumers have options that include housing not affected by the environmental disamenity. Although NPL sites have much more localized effects than air pollution, this problem can still arise because some areas have many NPL sites, thus affecting a large fraction of the housing market. For instance, the SAB expressed concern about the proposed study of underground storage tanks because data from New York State indicated that 23% of residences are located near the sites proposed for analysis (EPA Science Advisory Board 2002, 21).[2] Although concern was raised, no specific acceptable threshold was established.

To examine the importance of the market share problem for this analysis, the fraction of residences near NPL sites was calculated for several relevant counties and metropolitan statistical areas (MSAs), as well as for the nation as a whole. Actual site boundaries for NPL sites are not generally available in a database, but latitude and longitude and site area are typically given for each NPL site. Using GIS software, a circular area for each NPL site was created, centered on the given point and with an area equal to that of the site. Areas within 1, 2.5, and 4 miles of the sites' circular pseudo boundaries were delineated. Using U.S. Census data at the block level, the number of residences within these areas was counted, assuming uniform density across each block. (See Chapter 3 for the relevant details.) Spot checks at NPL sites for which boundaries were known indicated this approach introduced only small (<2%) errors in estimates of the number of residences near NPL sites up to the 2.5-mile distance. Following the practice in the literature, residences are counted only once, even if they are near two or more NPL sites.

By comparing the number of residences within these areas with the total number of homes available to consumers, it is possible to assess how well the market size condition is met. The results vary greatly with the geographic extent used to define the market. However, it is important to define the market carefully because different specifications of what makes up a housing market can strongly influence whether or not the market size condition is met. This definition must include both “where” the market is, and “when” it is.

[2] Note that the market size condition is only a test that indicates if the HPM is appropriate or not; market size does not enter into hedonic models directly.

For instance, consider the housing market relevant to the two NPL sites in Woburn, Massachusetts, a suburban town located in Middlesex County and in the Boston MSA, as illustrated in Figure 4.1. This figure shows the location of places near NPL sites (site area plus a 2.5-mile ring), state and census tract boundaries, and the area of the Boston MSA.[3] First, consider the "where" question. Potential buyers in 2004 looking for homes in Middlesex County would find a market in which 40% of all residences are within 2.5 miles of any NPL site that has ever existed. But if they were willing to consider homes anywhere in the Boston MSA, then only 25% of homes are near NPL sites. And, if they were willing to look for homes in Worcester County, which borders Middlesex County to the west, is partly within the Boston MSA, and is about 20 miles from Woburn, they would face a housing market in which only 5% of all homes are near NPL sites.

Thus, how well the market size condition is met depends in part on how large an area potential homebuyers and renters search for homes, which relates to commute lengths. Housing data suggest that the mean commute trip length for first-time homeowners and recent movers who live in MSAs is 15.6 miles nationwide, while even higher values are observed in densely crowded places like Boston (Anonymous 2000, Exhibit 48). These data suggest that households may be willing to move ten miles or more and still have acceptable commute lengths, especially if the move is not directly away from the workplace. Thus, a move from near the Woburn NPL sites in 1984 to Worcester County seems at least plausible. This conclusion is in agreement with Palmquist: "for real estate markets, a majority of researchers seem to favor urban area markets" (Palmquist 1991, 120). That is, housing markets are not national, but neither are they generally limited to a single city, county, or even MSA. This analysis suggests that even for the Boston area, which has a major concentration of NPL sites, the market size condition is met.

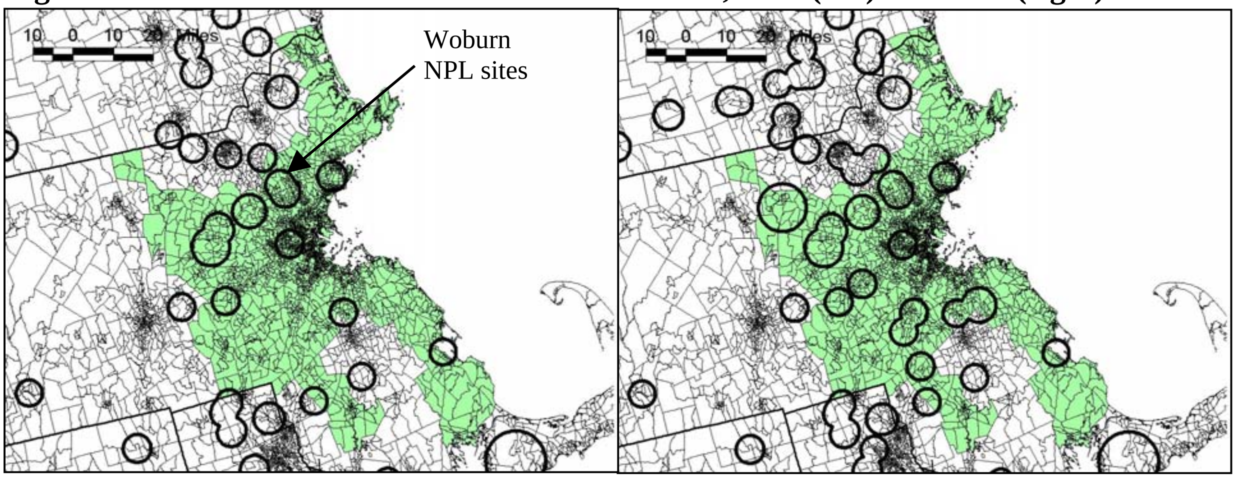
Now consider the "when" question, which is also illustrated in Figure 4.1. This figure shows areas near all NPL sites (proposed listed, and deleted) in 1983 and 2004, on the left and right, respectively. Because the NPL was created in 1983 and no sites had yet been deleted from it, all of the areas in the left map are near either proposed or listed NPL sites. These would have affected housing markets in 1983. However, sites that were proposed for, or added to, the NPL subsequently (those additional sites on the right-hand side of Figure 4.1) would not have been known in 1983 and thus could not have affected the housing market at that time. Accounting for this difference significantly affects the market size calculation above. For instance, if the 1983 data are used then only 18% of homes in the Boston MSA (not 25%) are near NPL sites.

There is a further aspect to the "when" question: NPL sites that receive remedial actions and are cleaned up should not cause a disamenity. All the calculations of market size above are based on the cumulative number of sites that have ever been on the NPL for a given area. A more accurate estimate would be based on the number of NPL sites perceived as disamenities at any given time, which, for reasons discussed below, is defined as those that were discovered but for which no remedy had yet been determined. This is the number of sites on a national basis that have been discovered but for which no ROD has yet been issued. Using this definition, the number of sites that would be considered disamenities by potential home buyers was approximately equal to the number of NPL sites for 1983-1984, but as plans for cleanup began to

[3] Because census tracts all contain approximately the same number of people, their size (or the density of their boundary lines) is an indication of population density.

be determined, tended to become smaller after that.[4] The number of such sites peaked in1990 at about 638, or about half the number of NPL sites at the time. Since then, the number of NPL sites presenting disamenties to housing markets has declined to under 300, or less than 20% of all sites that have ever been placed on the NPL.

Figure 4.1. Areas Near NPL Sites in the Boston Area, 1982 (left) and 2004 (right).



NOTE: Boston MSA is shaded. Includes all sites proposed to, on, or deleted from the NPL. State and census tract boundaries are shown.

The image on the right side of Figure 4.1 shows all sites that have ever been placed on the NPL in the Boston area, so it, shows a greater fraction of the land area as near NPL sites than would have been perceived as such by the housing market in either 1982 or 2004. Similarly, the percentages calculated above all overestimate the fraction of the housing market with NPL-related disamenities because they are based on the cumulative number of sites that have ever been proposed for or placed on the NPL. Nonetheless, these images show the general pattern of population and NPL sites in the area. Analysis of other parts of the country shows a similar pattern.

These values seem less important than the observation that in all cases, there appear to be significant numbers of homes not near NPL sites that would keep commute lengths close to the mean distances observed in urban areas in the United States. Therefore, while the number of homes that are near historical NPL sites may be high enough to raise concerns about the market size condition, the current analysis suggest that these concerns are not significant for this study because of spatial and temporal variations, along with the willingness of Americans to accept long commutes. As shown in the Woburn example above, the market size condition appears to be met, although by what margin it is met is dependent on how the homebuyers' housing markets are defined.

Ex Ante Data

The SAB's second theoretical concern was articulated by Bartik (1988), who argued that, "the property value increases due to amenity improvements predicted by the original hedonic property value function will generally overestimate benefits," because the adjustments by buyers and

[4] See Figure 3.3 for a graphic representation of the trend of these “No ROD” sites.

sellers are not taken into account (p. 173). However, this market adjustment problem applies only to the application of ex ante hedonic studies to consider ex post conditions, which is not the case here. The hedonic studies upon which the benefits transfer analysis in this study are based all utilize observations of ex post data, not estimates based on ex ante hedonic price functions. In some cases both ex post and ex ante data are used, but in no cases are only ex ante data used.

Relationship

The SAB's third theoretical concern is about the strength and character of the relationship between the amenity improvement and the change in real estate prices. That is how well established is the causal linkage between the amenity improvement and the change in home prices? One possible weakness with this causal linkage relates to the possibility that perceived and actual risks may differ. Expert and popular views of the likelihood and magnitude of risks are often different, and in the case of hazardous waste the popular opinion rates risks higher (Slovic, Fischhoff et al. 1979; U.S. Environmental Protection Agency 1987). However, it is not clear that only the risks of negative health outcomes (actual risk) motivate changes in real estate prices. Perceived risk and uncertainty have been found to have a significant influence on home prices (McClelland, Schulze et al. 1990; McCluskey and Rausser 2001; Gayer and Viscusi 2002). However, the problem of differences in perceived and actual health risks may not matter for this study because the HPM studies used here are not designed to distinguish between perceived and actual risk, and no claim is made here that they do. This issue is analyzed in more depth later in this chapter, in the section on observations of the reversal of the negative price effect.

A related but somewhat different effect is called stigma - the rejection of people, places, or objects as fundamentally discredited, flawed, or spoiled (Gregory, Flynn et al. 1995; Kasperson, Jhaveri et al. 2001). Potential hazards possessing psychologically powerful characteristics that tend to raise perceived risk above actual risk are good candidates for stigmatization. These characteristics include dread consequences (e.g., cancer), violations of rights or standards, inequitable distribution of impacts (e.g., if most of the risk is to children), and involuntary exposure. All of these characteristics might apply to an NPL site. But not all risks become stigmatized. A critical feature of stigmatization is that "a standard of what is right and natural has been violated or overturned because of the abnormal nature of the precipitating event...or the discrediting nature of the consequences" (Gregory, Flynn et al. 1995). When this happens, there has typically been an initiating event that signals a new or different risk. Then, "extensive media coverage interprets the meaning and projects risk signals, imputing blame, trustworthiness, vulnerability, and victimization" (Kasperson, Jhaveri et al. 2001, 16). This leads to a social amplification of the risk and tightly identifies the person, place, or object with the negative, threatening characteristics of the hazard, even if the actual risk declines. There is some evidence, discussed below, that this has occurred at some NPL sites but not others.

In addition, uncertainty may play a significant role. The data needed to adequately assess the actual risk associated with NPL sites is typically not available even after lengthy study, and is certainly not available when a site is first placed on the NPL (Viscusi, Hamilton et al. 1997; Johnson 1999; Harrison 2003). Homebuyers are thus faced with a choice that may entail significant risk that they cannot assess very well. In the face of such uncertainty, homebuyers may well be risk averse. Gayer et al. examined this effect in detail and found a significant change in the disamenity associated with NPL sites as more information became available about them (Gayer, Hamilton et al. 2002). In this sense, the Superfund program reduces uncertainty, which should improve the efficiency of housing markets.

Therefore part of the causal linkage is as follows. The discovery of an uncontrolled release of hazardous substances creates concern about human health risks. Due to a lack of data about the site, this concern includes considerable uncertainty. The process of investigating the site, developing a plan for remedial action, and documenting it in a ROD significantly reduces these uncertainties. There is evidence that the release of the ROD seems to have a positive effect on home prices (see the discussion below in the Meta-analysis: Reversal section).

An additional part of this third theoretical concern is the problem that there may be health, ecological or other benefits that accrue to people other than those who buy houses close to NPL sites or that are not part of home buying decisions, which hedonic analysis systematically excludes. This is clearly an important effect. Reviews of RODs indicate that benefits do occur that are unrelated to home purchasing decisions and relevant to many people who do not participate in housing markets near NPL sites (Walker, Sadowitz et al. 1995; EPA Science Advisory Board 2002). For instance the value of leaving clean ground water for future generations to use motivates many decisions at NPL sites. While these people might value the availability of uncontaminated drinking water, most of them will not be neighbors of former NPL sites and thus their WTP would not be included in data from housing markets near NPL sites. Furthermore, the WTP for future neighbors of former NPL sites would be discounted in private decisions about home prices. While this is appropriate for individual decision-making, it is not appropriate when considering the societal value of those preferences (U.S. Environmental Protection Agency 2000, 71, 75, 77-79). Thus, it would be incorrect to assume that a valuation estimate based on changes in home prices alone would be complete.

The timing of changes in property values near NPL sites is also an important part of this concern. At issue is whether housing markets adjust quickly or slowly to new information. It is clear that at least some of the effect of a disamenity can be capitalized into housing markets fairly rapidly. For instance, Kiel and McClain looked at how house prices responded to an ultimately unsuccessful attempt to site a new incinerator in Woburn, Massachusetts (Kiel and McClain 1996). Housing prices declined when the incinerator was proposed and then fully recovered when plans were canceled. However, other studies have found that the adjustment period until the market returns to equilibrium can be quite long (McMillen and Thorsnes 2000; McCluskey and Rausser 2001; McCluskey and Rausser 2003a). Similarly, Kiel and Zabel noted that research on the capitalization of public goods shows that their values are often not fully capitalized in home prices (Kiel and Zabel 2001, 181). Thus, they suggested that hedonic property valuations are likely to be underestimates of the health benefits of remedial actions at NPL sites.

Another factor that may influence the magnitude and timing of changes in housing prices near NPL sites, and therefore the causal linkage between amenity improvement and price changes, is demographic change (Cameron and Crawford 2003; McCluskey and Rausser 2003a). This phenomenon starts with the discovery of an environmental risk, which reduces the value of housing stock near the site, inducing high-income families to move out and permitting low-income families to move in. If a sufficiently large change occurs, then the neighborhood itself changes in ways unrelated to the health risk posed by the NPL site but associated with lower average income: declines may occur in school quality, police attention, social status, and owner-occupancy rates. Moreover, because race and income are related, racial makeup may change. These changes will remain even if the original factor, increased health risk posed by the NPL site, is mitigated, creating a long-term effect. McCluskey and Rausser present anecdotal arguments and some econometric analysis to support this idea, while Cameron and Crawford, using a larger data set covering more sites find no consistent pattern (Cameron and Crawford 2003; McCluskey and Rausser 2003a; McCluskey and Rausser 2003b). Because the literature on neighborhood change is inconclusive, this effect is ignored.

Comparability

The SAB's fourth theoretical concern is the need for comparability between the study sites and the policy sites, the appropriate distance to select, and the use of non-peer-reviewed data. The HPM studies used in this analysis include data on a total of 40 hazardous waste sites, of which 24 are NPL sites. Of these sites, six NPL sites and all sixteen non-NPL sites are located in the Northeast; of the remaining NPL sites eight are in the Midwest, one is in Texas, and two are on the West Coast. This very roughly approximates the regional distribution of NPL sites in the country, with the exception that there are no study sites in the rural West or the Southeast. The sites include waste dumps, former manufacturing facilities, and smelters, common types of NPL sites. All are located in MSAs and because 80% of all NPL sites are in MSAs and over 95% of homes near NPL sites are in MSAs, this seems representative as well. (See also Chapter 3)

Pooled Data

The SAB's fifth theoretical concern is how the housing data are pooled. Michaels and Smith segmented the housing market into various categories ("Average," "Premium," etc.) and showed that the estimated effects of a hazardous waste site depended on whether the estimate was performed on an average basis or on a segmented basis (Michaels and Smith 1990). For more expensive categories, the price effect tended to be a larger fraction of home price (and thus much larger in absolute magnitude). More recent studies have found the same effect (Nelson, Genereux et al. 1997; McCluskey and Rausser 2003). These studies show that differences in how real estate markets are pooled in hedonic studies can create differences in estimated effects, and single pools are likely to be underestimates. The studies used here for data (see Table 4.2) generally pool the markets they examine into a single category, suggesting the resulting estimates of the price effect are underestimated.

Equilibrium Conditions

The last of the SAB's theoretical concerns is that hedonic valuation assumes equilibrium in a perfectly competitive market with no transaction costs and perfect information (Freeman 1993; McConnell 1993). These conditions rarely apply to housing markets since search and moving costs are so high, possibly several percentage points of home price. The problem of transaction costs has received little or no treatment in the literature. Because transaction costs tend to create a wedge between equilibrium housing prices and consumers' WTP for avoiding NPL sites, they can cause estimates using observed prices to be underestimates of the actual change in value.

McConnell noted that one of the principal problems associated with assessing the impacts of NPL sites is that hazardous substances may injure in ways that are not directly perceptible by individuals (McConnell 1993). Therefore, people must rely on secondary sources of information. The dominant source of information for most people is the news media, which can amplify the perceived level of risk (Kasperson, Jhaveri et al. 2001; Gregory and Satterfield 2002). On the other hand, Lipscomb et al. have shown that knowledge about health risk assessments can fade, and Hite found evidence that homebuyers may be poorly informed about locally undesirable land uses (LULUs) such as landfills (Lipscomb, Goldman et al. 1992; Hite 1998). Thus, while imperfect information and uncertainties about risks due to proximity to NPL sites may be common features in real estate markets, it is not clear in which direction this effect will tend to bias the result.

The potential biases in this analysis are summarized in Table 4.1, which suggests that overall, the methods used here may be subject to biases both up and down, with more biases that would produce an underestimate. The review above also supports the idea that a HPM-based benefits transfer analysis is likely to produce an estimate applicable only for the NPL program as a whole, and the results are not transferable to any specific site. That is, the analysis contained in the remainder of this chapter applies only to the NPL in aggregate, not individual NPL sites.

Table 4.1. Potential Biases in the Hedonics-Based Analysis

Type of bias	Perfect competition and no transaction costs	Perfect information	Pooled data	Not in market
Direction of estimate	Underestimate	Not clear	Underestimate	Underestimate

Method

Overview

A benefits transfer analysis is used to apply information from previous HPM studies to places near NPL sites that are expected to have experienced a reversal of a negative price effect. A complete reversal of the negative price effect is assumed. The value being transferred is the effect of proximity to an NPL site on home prices. Using estimates of central tendency, two estimates are calibrated for distance and thus use non-linear price effect estimates developed below. The procedures outlined in Rosenberger and Loomis (2003, Tables 3 and 7) are used. For the purposes of this analysis, three specific questions addressed by the literature applying HPM to NPL and other hazardous waste sites are most important. How large an effect do NPL and other hazardous waste sites have on residential home prices? What events cause a decline in prices to occur? And what, if any, events reverse the negative price effect? This section first examines several aspects of the meta-analysis, the magnitude of the effect, the cause of the effect, and cause of reversals of the effect. Then the benefits transfer analysis is discussed.

Meta-analysis: Magnitude

The policy context is the NPL from its creation in 1982 through 2004, limited to sites within the 50 states because sufficient data on sites in U.S. territories were not available. Data for 1,572 sites on the NPL through the end of fiscal year (FY) 2003 are available in CERCLIS. Benefits are transferred only to those sites that are expected to have their values restored, which, as discussed below, are those sites for which a record of decision (ROD) has been issued.[5] This amounts to 1,326 sites by the end of FY2004, using EPA estimates of the number of sites for which a ROD will be issued in FY2004. Thus, this analysis is retrospective only and requires no assumptions about future NPL sites.

A literature search was conducted using EconLit, Web of Science, several electronic catalogs from the University of California library, and email and personal queries to experts to seek out gray literature.[6] This yielded over 30 reports, book chapters and peer-reviewed papers on hedonic analysis relating to Superfund or hazardous substances. These studies were evaluated for relevance (including reporting data usable in this study), originality (i.e., no review articles), and quality (e.g., only studies published in peer-reviewed, archival journals). This literature search resulted in nine studies that presented original data suitable for use in this benefits transfer analysis.[7] Using language from the EPA's *Guidelines for Preparing Economic Analyses*, these nine HPM papers are the policy studies for this chapter and the sites they evaluate make up the "Property" group defined in Chapter 3.

Key characteristics of these studies are shown in Table 4.2. The 2.5-mile areas associated with these sites are shown in Figure 4.2. They are distributed around the country, although somewhat concentrated in the Northeast and Midwest. All price information is given in 2000 dollars, adjusted by the Bureau of Labor Statistics' Consumer Price Index for all goods for all urban consumers per Boyle and Kiel (2001).

A number of studies did not provide price effect data usable for this study or reported on the same data set, but were otherwise informative in terms of the distance from the site that they found an effect, or other insights (Smith and Desvousges 1986; Kohlhase 1991; Gayer, Hamilton et al. 2000; McMillen and Thorsnes 2000; Gayer and Viscusi 2002; McCluskey and Rausser 2003; McCluskey and Rausser 2003; McMillen 2003).

Some of the studies in Table 4.2 (those labeled 'C') use only cross-sectional data. They examine home sales over a relatively short, fixed period (usually several years) and compare homes that are near NPL sites with those that are more distant. That is, they do not look at prices before or after any specific event. Most of the studies in Table 4.2 (labeled 'P') use panel data sets that include both longitudinal and cross-sectional information. These examine home sales over a longer period, grouping sales by changes in site status or available information. Longitudinal studies may rely on repeat sales of the same home, which avoids the problem of potentially omitted variables. In some longitudinal hedonic studies, data may be collected for the period

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[5] Although some sites have multiple RODs, for the sake of simplicity this study used the first ROD issued for each site.

[6] Gray literature is a term used to describe unpublished studies, dissertations, and papers that if not uncovered may introduce bias into a meta-analysis since published studies are typically ones that find positive results.

[7] There is some disagreement between the EPA *Guidelines for Preparing Economic Analyses* and some of the most recent literature on meta-analysis (Stanley 2001) regarding the issue of inclusivity (all studies) versus selectivity (peer-reviewed studies only). There is controversy within the literature as well (see the subsequent commentary on Stanley in 61(3) of the same journal). One suggested problem is double counting datasets used in multiple studies, which is more likely to be a problem in non-peer-reviewed studies. McClelland and Schulze et al. (1990) and Hurd (2002) share some data, but really represent different data sets, and so avoid this potential problem.

before the site is proposed for listing on the NPL, while the facility is operating, after it is listed, and then after the remedial action.

Table 4.2. Hedonic Price Method Studies of Homes Near Hazardous Waste Sites

Study	Absolute effect (2000$)	Percent effect	Number of sites	Number of observa-tions	Cross-sectional or Panel	Period	Maximum Distance
(McClelland, Schulze et al. 1990)	$16,264	7.3%	1	178	C	83-85	-
(Michaels and Smith 1990)	$352	-	11	2,182	C	77-81	6.2 mi
(Mendelsohn, Hellerstein et al. 1992)	$11,804	7.5%	1	1,916	P	69-88	2 mi.
(Thayer, Albers et al. 1991)	-	-	16 non-NPL	2,323	C	85-86	4 mi
(Reichert 1997)	$9,156	7.1%	1	1,586	P	77-94	2.5 mi
(Dale, Murdoch et al. 1999)	$24,745	16%	1	203,353	P	79-95	2 mi
(Kiel and Zabel 2001)	-	-	2	2,209	P	75-92	2.5 mi
(Gayer, Hamilton et al. 2002)	$3,134	3.4%	7	1,883	P	88-93	4 mi
(Hurd 2002)	$6,664	3.1%	1	not given	P	83-85 94-97	3,000 ft

Note: Absolute values are per home. Percentages based on study-specific mean prices, where available.

The nine studies in Table 4.2 all report results from different data sets, although the data used by Hurd (2000) includes that used by McClelland, Schulze et al. (1990). All the policy studies evaluate NPL sites except Thayer et al., which evaluates other sites with hazardous waste on them (Thayer, Albers et al. 1991). Most of the policy studies use about two thousand observations; McClelland, Schulze et al. (1990) use an unusually small set and Dale, Murdoch et al. (1999) employ a very large data set. The maximum distance at which an effect is detected ranges from 0.57 miles to 6.2 miles, with a mean of 3.0 miles. Five studies find an effect at or beyond 2.5 miles and only two do not.

Table 4.3 presents information on the dates of key events at the study sites and when the data used in each study were gathered. No data is shown for Thayer et al. (1991) because it is not available. Table 4.3 also contains information on the study by Kohlhase (1991) because of its relevance to the question of the timing of the price effect. Numbers are given on the left to identify the studies, next to the names of the NPL sites. The table is filled in with letters representing different events. The keys for the numbers and letters appear at the bottom of the table. The grid squares in the table are colored to show the years for which the data were gathered for each study. If the study is cross-sectional, different periods are shown with different shades. For simplicity only two shades are used, even if more than two periods were defined in the study, which was the case for peer-reviewed papers (Dale, Murdoch et al. 1999; and Kiel and Zabel 2001).

Figure 4.2. Places Near NPL Sites in the Coterminous United States (Site Area Plus 2.5 Mile Circles) and Location of Study Sites

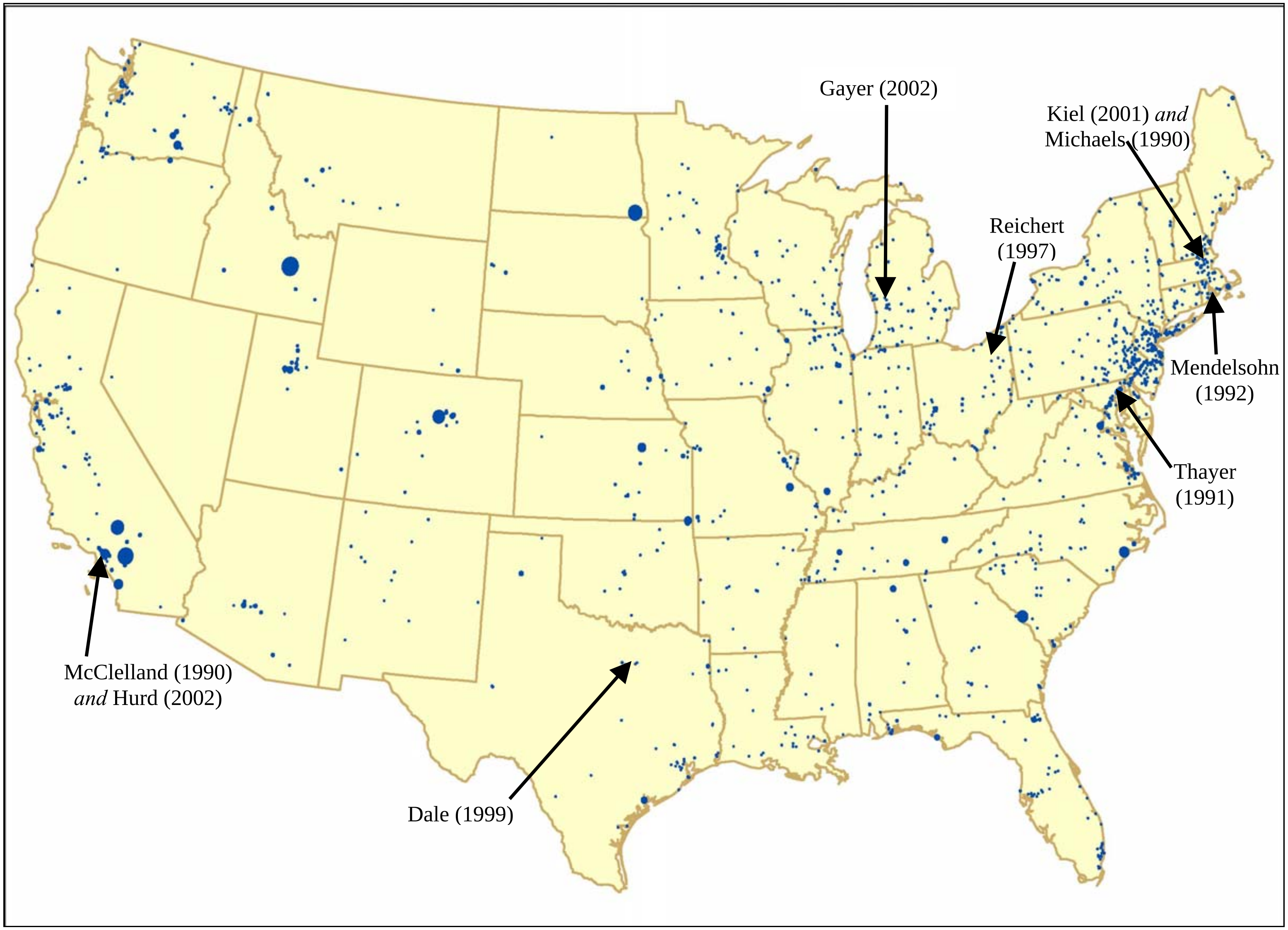


Table 4.3. Events and Data Collection for HPM Study Sites

Study	Site Name	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
1, 9	Operating Indust.					D					P		L	ERS															E		
2	Industri-Plex					D			P	L			ER		E				S												
	Nyanza Chem.						D		P	L		R		SE	E	E			E												
	Salem Acres						D				P		L		E		E			R	S					C		X			
	W.R. Grace					D			P	L						R				S											
	Wells G&H					D			P	L			E	E	E	R			S												
3	Brio Refining								D		P	E			R	LS															C
	Crystal Chem.						D		P	LE					E		R	E				S								C	
	Geneva Indust.							D		PE	LE		R	S						C											
	Harris (Farley)								DP	L		R	S		CX																
	N. Cavalcade St.										DP		L		R			S													
	Sol Lynn										DP				R	LE		S		C									E		
	S. Cavalcade St.									D	P		L		R							S					C				
4	New Bedford	(Data from 1969)				D			P E	L	E	E					R	S													
5	Indust. Excess						D				P		L	R	E	S				E											
6	RSR Smelter							D												P		LER					S		E		
7	Industriplex					D			P	L			ER		E				S												
	Wells G&H					D			P	L			E	E	E	R			S												
8	Butterworth #2					D			P	L						E	E		R						S		C				
	Chem Central				D				P	L								R			S	C									
	Folkertsma Refuse							D					P			L		R		S	C		X								
	H. Brown Co.						D					P	L						ER							S	C				
	Kentwood	(Data from 1971						P	L								R			S	C										
	Organic Chemicals					D			P	L								R			S									C	
	Spartan Chemical					D			P	L										R						S					

Legend:
Site: 1-McClelland 1990; 2-Michaels 1990; 3-Kohlhase 1991; 4-Mendelsohn 1992; 5-Reichert 1997; 6-Dale 1999; 7-Kiel 2001; 8-Gayer 2002; 9-Hurd 2002.
Events: D-Discovery; P-Proposed to NPL; L-Final on NPL; E-Removal Action; R-ROD; S-Start of Remedial Action; C-Construction complete; X-Deleted
Colors: Different shades indicate how panel data were divided longitudinally.

HPM studies of places near NPL sites evaluate only single-family, owner-occupied, detached (SOD) homes, and so provide no information on other types of residences or any benefits to the owners of commercial real estate near NPL sites. Palmquist suggested these differences are minor (1991,, 93-95), but this issue is investigated nonetheless. The Census data show that SOD homes are the largest residence type near NPL sites, representing 47% of all residences, and that single-family detached rentals accounted for another 8%. Other owner-occupied residences (duplexes, condominiums, etc.) account for 11%, and multi-family rental housing for 33%. Some studies include condominiums in their data, and the effect on prices for these properties are similar to those for other types (Hite, Chern et al. 2001; Ihlanfeldt and Taylor 2004). This suggests that for rental single-family detached homes and non-SOD owner-occupied dwellings, an SOD-based estimate may be reasonable, although possibly an overestimate since SOD home prices are typically higher than those for other residence types. Most studies ignore any differences and typically just scale the SOD-based estimate linearly with population (Gayer, Hamilton et al. 2000; Kiel and Zabel 2001). This convention assumes that the price effect is identical for all types of homes. The approach used here improves on a population-based approach by scaling the SOD-based estimate with the number of homes, and by conducting a sensitivity analysis for different kinds of residences.

Of the nine studies in Table 4.2, six provide only point estimates of the magnitude of the effect of proximity to NPL sites on home prices (called linear estimates because the value does not change with distance), two provide estimates that vary with distance from the site (called non-linear estimates), and two (Reichert 1997; Hurd 2002) provide both types of estimates. All point estimates reported here are *per home*, rather than *per home per mile*.

The linear estimates are shown in Table 4.4. The absolute estimates range from about $350 per home to almost $25,000. The mean value is $10,303 and the standard error is $3,129. The 95% confidence interval for the effect of proximity to NPL sites on SOD home prices is $7,173-$13,432. The percentage values range from 3.1% to 16%, with a mean of 7.4%. The standard error is 2.3 percentage points, so the 95% confidence interval for the effect of proximity to NPL sites on SOD home prices is 5.1%-9.7%. Figure 4.3 illustrates these data while Figure 4.4 illustrates the data for the non-linear estimates.

Table 4.4. Summary of Linear Price Effect Estimates Per Home (2000$)

	Absolute	Percentage
Minimum	$352	3.1%
Maximum	$24,745	16%
Mean	$10,303	7.4%
Std. Error	$3,129	2.3%

Figure 4.3. Linear Price Effect Estimates (2000$)

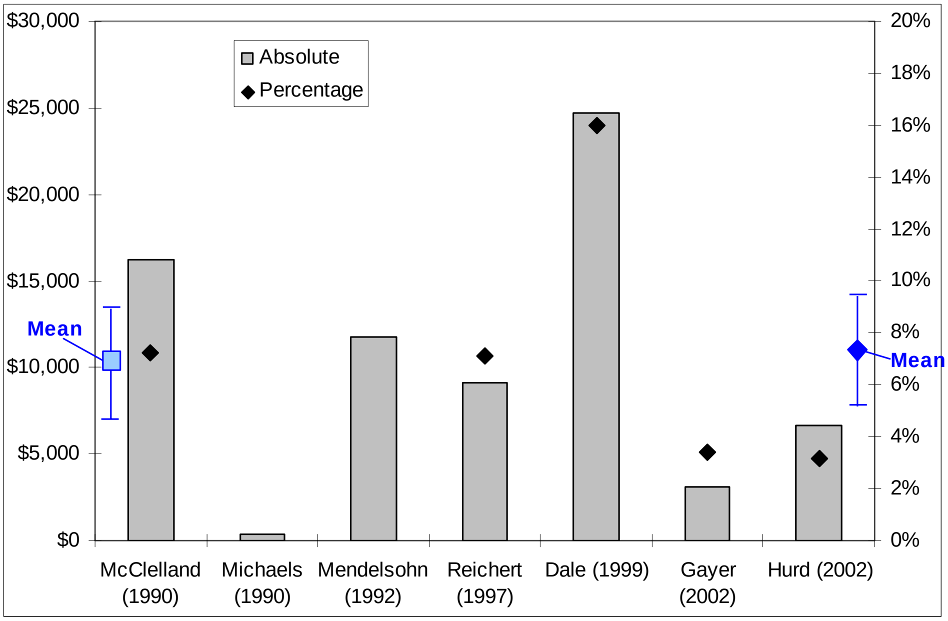
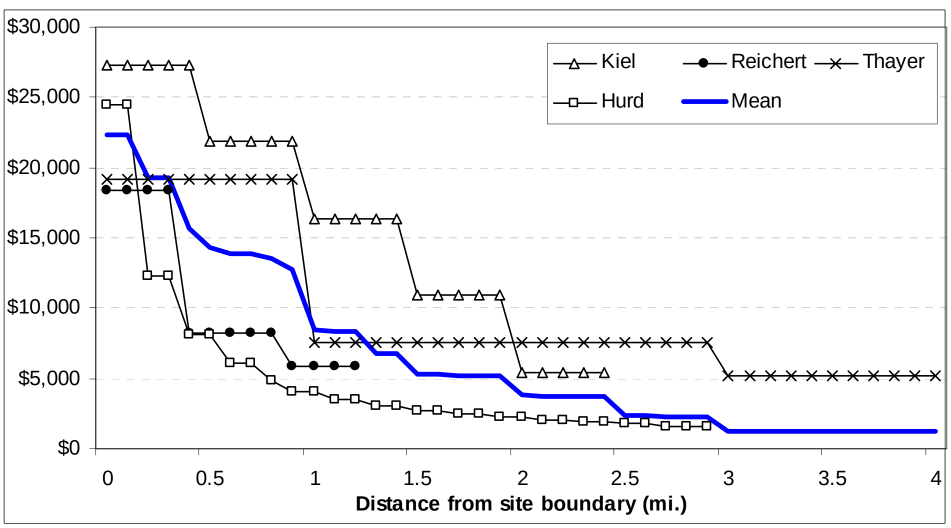


Figure 4.4. Non-linear Price Effect Estimates (2000$)



The mean estimates of the non-linear price effect (both absolute and percentage) are given in Table 4.5 as discrete values for various distances from the boundary of the NPL site; Figures 4.5 and 4.6 present this information graphically. For computational purposes, the mean values shown in Figure 4.5 are converted to mean values for each 0.5 mile increment. Of these studies only two, Kiel and Zabel (2001) and Reichert (1997) provided mean home price data that permitted us to calculate a non-linear percentage effect. Both the non-linear effect estimates at specified distances from the site, absolute and percentage, are shown in Table 4.5.

These curves can be considered measures of central tendency values for the benefits transfer analysis, with the non-linear estimate being calibrated for distance. In addition to curves for the four studies that report non-linear results, lines showing the mean values of the linear estimates (calculated at 0.1 mile increments) are given. These figures also show the 95% confidence intervals. The lower bound of 95% confidence interval for the non-linear percentage estimate changes from 3.8% to -1.6% from 1.2 to 1.3 miles (Figure 4.6). This is because the number of data points in the sample goes from four to three at that point. Because negative values are implausible, this implies that due to data limitations the estimate based on non-linear percentage effect (NLP) should be given less weight than the other effect estimates.

Table 4.5. Mean Estimates of Non-Linear Price Effect Estimates for Residences at Specified Distances (2000$)

Distance	Absolute	Percentage
r < 0.5	$41,194	14.5%
r = 1.0	$33,086	11.2%
r = 1.5	$26,613	8.7%
r = 2.0	$22,357	6.2%
r = 2.5	$19,411	3.1%

Figure 4.5. Mean Absolute Price Effect Estimates and 95% Confidence Intervals (2000$)

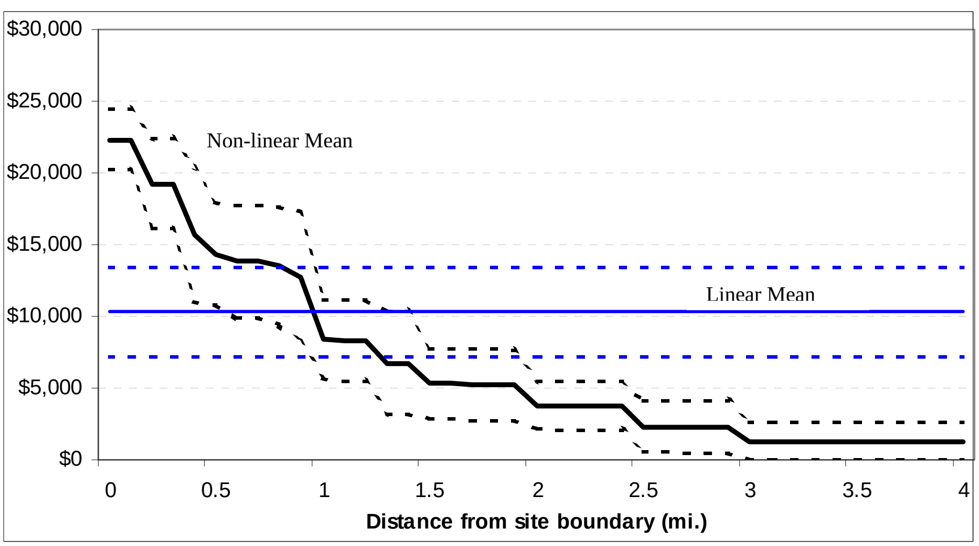
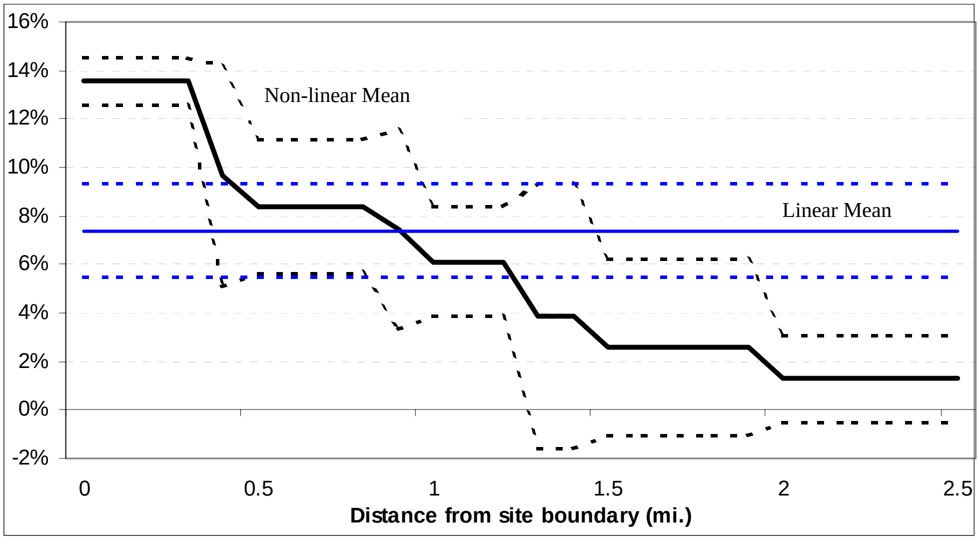


Figure 4.6. Mean Percentage Price Effect Estimates and 95% Confidence Intervals



Because changes in home prices are the basis for this analysis, it is important to determine how representative the home prices evaluated in the Table 4.2 studies are of the prices for all homes near NPL sites. Thus prices for homes in the HPM data set were compared with home prices in the rest of the United States. The U.S. Census reports that the median price for SOD homes in the U.S. in 2000 was $139,000 for existing units and $169,000 for new units (U.S. Bureau of the Census 2002, 592-3). Median SOD prices are also reported on the census block group level. The mean of these medians for census block groups within 2.5 miles of NPL sites, weighted by the number of homes in each block group, is $132,000. Seven of the studies in Table 4.2 reported the mean values of the SOD homes in their samples. The mean of these values is about $160,000. This is 22% higher than the national median value, but means tend to be higher than medians for data sets that have lower bounds (e.g., zero). Thus, it is reasonable that the home prices used in the studies in Table 4.2 are representative of home prices in the U.S. and homes near NPL sites. Table 4.2 summarizes the linear price effect estimates.

Having determined the magnitude of the decline in residential property values associated with proximity to NPL sites, the next issue is timing, for which the evidence is even more mixed. The general sequence of events that an NPL site will undergo includes: site discovery, proposal to the NPL (which most people take as being placed on the NPL), listing on the NPL, release of the Record of Decision (ROD) that documents the remedy selection, remedial action, construction completion (when the construction of the remedial action but not necessarily all treatment is essentially complete), and deletion from the NPL. (See chapter 3 for more information.) The dates for specific events in this sequence, along with the periods during which property data were collected for each study are shown in Table 4.3.

Meta-analysis: Decline

Sites that eventually end up on the NPL must be 'discovered' first. Discoveries of hazardous substance spills or hazardous waste are often made by concerned citizens, first responders (e.g., fire fighters or police), or local officials (Office of Technology Assessment 1989, 10-11; Hird 1994, 14-15, 19). Sometimes sites known to have hazardous substances may have no distinct discovery event and homes nearby may suffer a longstanding depression in home prices (Dale, Murdoch et al. 1999; McMillen 2003). In this section, we review the evidence on this point from each of the studies listed in Table 4.2 as well as comment on a small number of other relevant papers.

Kohlhase (1991) find no effects in 1976 and 1980, which is before discovery for all but one of the seven sites she examined (not in Table 4.2). She finds significant effects in 1985, which was after all seven had been discovered and proposed to the NPL, but after only three had been listed. Based on this evidence, Kohlhase suggests that the period 1980-81 is particularly important because this is the period during which CERCLA was passed and the NPL began. Before this period, she argues, housing markets may have not had site-specific information with which to assess hazardous waste sites.

McClelland et al. (1990) and Hurd et al. (2002), who examine the same site, find a negative price effect in 1983-85, several years after discovery but before the site is listed on the NPL (1986). The site was proposed for listing on the NPL in the middle of this period.

Michaels and Smith (1990) find a small effect using data from 1977-81, a period that covers both before and after discovery, but before any of these sites are proposed for the NPL (1982 or 1984). One reason for the very low values reported by Michaels and Smith (1990) is that most of their data comes from before discovery. Note that if Kohlhase's argument above is correct, it would suggest that the data collected by Michaels and Smith for 1977 and 1978 might not be appropriate for finding a price effect after 1980.

Mendelsohn et al. find evidence that a negative price effect began in 1981, after some state and federal activities related to the discovery of hazardous waste, but before the site was proposed for (1982) or listed on (1983) the NPL (Mendelsohn, Hellerstein et al. 1992). This suggests the decline in home prices did not accompany placement on the NPL.

Kiel and Zabel (2001) find that houses near what later became an NPL site near Woburn, Massachusetts suffered no negative price effect during the 1970s while the facilities were operating. After contamination was discovered and the sites were closed down in 1979, a negative price effect quickly developed. This occurred before the sites were proposed for the NPL in 1982. A lengthy, high profile lawsuit took place over the course of the next several years during which these sites became very widely know. They were later the subject of the popular book and movie, *A Civil Action*. The results from Kiel and Zabel (2001) suggest the price effect fluctuated after discovery, seeming to rise with major events that might draw attention to the site (e.g., release of the ROD and the start of remedial action).

Reichert (1997) examines 17 years of data individually, and finds little evidence of a price effect from discovery (1980) through proposal (1984) and listing (1986). The price effect in this study appears during and after 1987, when the ROD is released. These results contradict much of the rest of the literature, but it is not clear why, although some prior knowledge of the existence of the landfill may explain this result.

Dale, Murdoch et al. (1999) find that the site they evaluate (the RSR lead smelter) had a negative effect on the prices of nearby homes while the facility was operating in the late 1970s, before CERCLA and the NPL. This site has a complex history and the nearby housing market may have received confusing signals. (More details about this site can be found in the RSR Smelter case study on page 4-21.) Most of the study period for Dale, Murdoch et al. (1999), and much of the response action, occurred before the site was proposed for the NPL. The site was first the subject of municipal and state lawsuits and then response actions. A Texas judge declared the site was clean and the negative price effect began to reverse. However, EPA subsequently discovered new problems at the site and changed the applicable health standard. Thus, the proposal to list this site on the NPL (1993) comes after the site had previously been declared cleaned up, so listing led to a return of the negative price effect. McCluskey and Rausser (2003a) evaluate the same site, but use a somewhat different data set and technique (repeat sales data) and also find that proximity to the site reduces appreciation in home prices (not prices, per se) in 1979-80, and that the effect varies after that period. Moreover, McCluskey and Rausser interpret their results to show that housing markets can take a significant period to adjust to new equilibrium conditions following the addition of new information. Subsequent research by McCluskey and Rausser (2003b), using data similar to Dale (1999), suggests a similar conclusion.

Unique among the studies reviewed here, McMillen and Thorsnes (2000) use nonparametric methods to examine the price effect of proximity to an NPL site (not in Table 4.2). They find a significant negative price effect while the site (a smelter in Tacoma, WA) was operating, which was well before NPL proposal or listing.

Unique among the studies in Table 4.2, Gayer, Hamilton et al. (2002) use no data prior to discovery; for all but one of the seven sites they examined, the sites had been listed several years (mean 4.5) before their data begins. They hypothesize that potential home buyers learn by incorporating new site-specific information from the media in their decision-making, and test this hypothesis by evaluating changes in the price effect due to proximity to NPL sites in the city of Grand Rapids, Michigan. Previous research had shown that these sites have relatively less cancer risk than do more typical NPL sites (Hamilton and Viscusi 1999a). Gayer et al. find support for their hypothesis in a reversal of the negative price effect over the period they study. However, their maximum estimate is from 1988, well after almost all of the sites had been listed. Hence, by that time the media could have already broadcast considerable information about the sites, and the price decline could have already occurred. This has no bearing on Gayer et al.'s conclusions, but it makes their data problematic for use here because it may not capture the total price effect, which may explain why Gayer et al. report the second lowest values for the negative price effect.

This evidence strongly suggests that discovery is the CERCLIS event that best corresponds to the event that initiates a decline in home prices near NPL sites.

Case Study: RSR Smelter

The smelting facilities of the RSR Smelter NPL site, cover 6.7 acres in west Dallas County, Texas, and are set amid residential, industrial, and commercial properties.[1] The processing of lead slag and scrap from batteries began in the 1930's. In the subsequent decades, lead emissions into the air contaminated much of the surrounding area, along with arsenic and cadmium. In addition, battery casing chips and slag were dumped in landfills and used as fill in residential areas, furthering the lead contamination in the area. By 1983, blood lead analyses showed that 90% of resident children under the age of six had blood lead levels (BLLs) greater than 10 µg/dL (micrograms per deciliter), the current level of concern set by ATSDR. There is a public housing complex adjacent to the former smelter, with 1,600 units occupied primarily by Black, low-income families. The neighborhoods surrounding RSR Smelter are predominantly Black and Hispanic.

The City of Dallas initiated legal actions against RSR Corp. in 1968, but it was only in 1984 that the smelter was successfully shut down and operations ceased. In 1982, prior to the closure of the smelter and the initial cleanup conducted by RSR, ATSDR tested blood lead levels (BLLs) in 227 randomly selected children under the age of six. The average BLL at that time was 20.1 µg/dL, well above the current health benchmark of 10 µg/dL. RSR Corp. agreed to clean up the contamination near the site beginning in 1983. However, this initial cleanup addressed only soils with lead content greater than 1000 parts per million (ppm) within half a mile of the smelter. In 1986, EPA confirmed completion of these cleanup activities, and later a Texas state judge found that the site was clean.

However, in 1991, in response to complaints from residents about slag piles remaining onsite, a new investigation of the site area was undertaken. Lead was found to still pose a health risk to residents, partly due to increased knowledge about the effects of lead and changes in the levels of lead considered safe. In 1993, RSR Smelter site was placed on the National Priorities List (NPL) and divided by EPA into five operable units (OUs). They are, in order of health risk:

1. OU1—residential areas (private residences) and recreational areas (greatest risk)
2. OU2—public housing complex
3. OU3—landfills and disposal areas for smelter wastes
4. OU4—actual smelter facilities
5. OU5—industrial facilities and the groundwater underlying the area (least risk)

To illustrate some key points about the Superfund program, two OUs at the RSR Smelter site will be discussed in detail: the relatively simple (but high-risk) OU1 and the more complex, more conventional OU4 (which presented far less current risk). The response actions illustrate the flexibility that CERCLA provides to address differences in health risk: OU1 was addressed entirely with a removal action while OU4 received a remedial action.

Almost immediately after discovery of the contamination, but well before the site was placed on the NPL, EPA and the Texas Natural Resource Conservation Commission (TNRCC) began to conduct further cleanups as removal actions under CERCLA. Together the TNRCC and EPA surveyed 6,800 potentially contaminated properties in OU1 and undertook cleanup at 420 private residences and other high-risk areas where children could be expected to play, including playgrounds, schools, and parks. This removal action included areas further from the smelter than considered in the previous cleanup, and all soils contaminated with lead greater than 500 ppm, arsenic greater than 20 ppm, or cadmium above 30 ppm were removed.

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[1] Most of the information used to create this case study was obtained from various documents available on the Internet in July 2004, including: EPA's NPL Site Narrative for RSR Corp., May 1993, www.epa.gov/superfund/sites/npl/ nar1381.htm; ATSDR's Public Health Assessment of the RSR Smelter site, August 16, 1995, www.atsdr.cdc.gov/HAC/PHA/rsrcorp/rsr_toc.html; EPA's NPL Site Fact Sheet for RSR Corp., February 2004, www.epa.gov/earth1r6/6sf/pdffiles/rsr.pdf; EPA's ROD for the RSR Corporation site, February 1996, www.epa.gov/superfund/ sites/rods/fulltext/r0696099.pdf; as well as (Dale 1999) and (McCluskey and Rausser 2003a).

Case Study: RSR Smelter (continued)

The cleanups in the 1980s and early 1990s greatly reduced exposure. By 1993, blood lead analyses indicated that only 8% of children in the area exceeded 10 µg/dL, and blood lead level testing of 305 randomly-selected children showed an average BLL of 5.5 µg/dL. The population within 2.5 miles of this site was approximately 50,000, with over 7,000 children under the age of seven. Therefore, a considerable number of individuals vulnerable to lead-induced neuropsychological disorders were exposed.

After the removal action, OU1 no longer was contaminated above levels of concern, so no remedial action was necessary, so the ROD for OU1 declared the location to have “no further remedial action planned.” In August 1995, ATSDR determined that OU1 posed “no apparent public health hazard.” Importantly, because BLRAs were conducted only for the OUs that were listed (i.e. not OU1), they did not include residential portion of the site, which had been associated with the greatest health risk, because it had already been addressed by a removal action.

Operable unit 4 comprises the actual smelter facilities. Because there are no residents living in this area, cleanup of OU4 was less of a priority than cleanup of residential areas. To prevent human exposure to contaminants on the site prior to remedial action, OU4 was made inaccessible to the public using a barbed-wire topped fence and a 24-hour guard, relatively intrusive and expensive form of institutional control.

OU4 was addressed primarily through a conventional NPL remedial action. However, the investigation of the site revealed several actual or potential uncontrolled releases of hazardous substances, so in 1995 the sources of these releases were addressed with a removal action. This effort resulted in the removal of over 500 waste drums, 72 waste piles, and 50 laboratory containers and addressed immediate threats to human health and the environment, enabling the remedial process to continue. BLRAs for this site also not include the risk reduction accomplished by this removal, because they were not part of the residual risks that the BLRA was designed to address. Therefore, any assessments based on the ROD data for this site would not include these risks. The 1996 ROD for OU4 called for demolition of on-site structures and safe disposal of all building materials as well as all contaminated soil to a depth of 2 feet. This remedial action was completed in December 2001, paid for and conducted by seven of the parties potentially responsible for the site’s contamination, under a Consent Decree with EPA.

Dividing the site into multiple OUs and prioritizing threats posed by each allowed EPA to address risks at the RSR Smelter to protect human health in a timely manner in accordance with the relevant statutes. Using removal authorities to quickly reduce health risks to exposed populations, while restricting access to uninhabited areas until remedial actions could be devised and implemented, enabled EPA to protect human health without sacrificing the need for site study and careful remedial planning. It also illustrates that a benefits analysis based solely on information from BLRAs and RODs that includes only cancer risk reductions from remedial actions can overlook very substantial benefits from Superfund response actions.

Meta-analysis: Reversal

Compared to the studies that have looked for price declines experienced by homes near NPL sites, few studies have looked for possible reversals. In general, those that have seem to find mixed results, but at least some of the variation can be explained by examining the site history and data used in each study. Some studies, that show no reversal, simply do not have data for the periods during which a reversal might occur. Other studies, that show no reversal, report on sites with unusual and complex site histories. Those studies that examine sites with relatively typical site histories and have the data needed to observe a reversal tend to find one. The discussion below of the relevant studies is organized around these three groups.

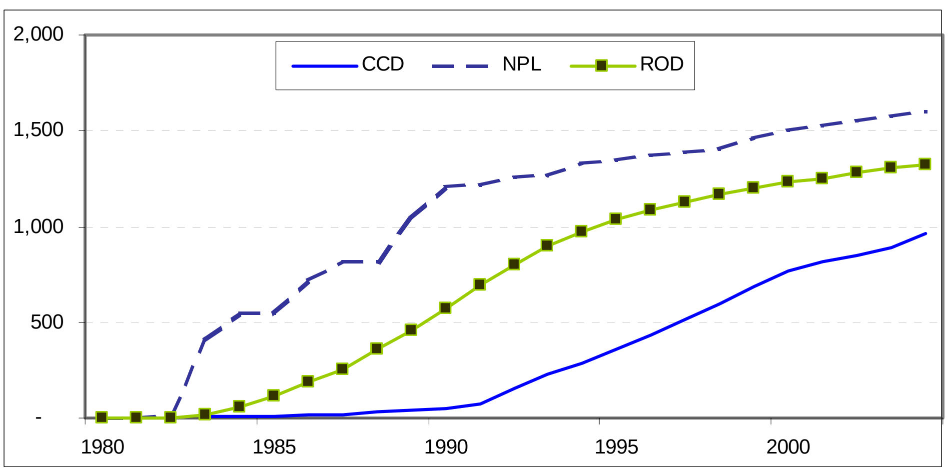
Several do not use data sets that cover events that might be expected to reverse the effect. McClelland (1990) finds no rebound, using data that was gathered before listing. Subsequently, Hurd (2002) compared McClelland's data from before listing to data after listing, ROD, and the start of the remedial action and finds a significant reversal of the negative price effect. Kohlhase (1991) does not find a rebound, using data that includes the listing of only three of seven sites and the ROD of only one.

Studies that have found no evidence of a reversal of the negative price effect, or a very delayed effect have evaluated somewhat unusual sites at which stigmatization has probably occurred, which would tend to make reversal of the price effect much slower (Gregory, Flynn et al. 1995; Kasperson, Jhaveri et al. 2001). Kiel and Zabel (2001) evaluate data that covers the period from before discovery through the beginning of remedial action, but shows no consistent reversal. However, this study evaluates the atypical Woburn, Massachusetts sites. The site evaluated by Dale et al. (1999) and McCluskey and Rausser (2003a, 2003b) had a very complex, atypical history. This site was declared clean by a Texas state court but EPA later found it to still be contaminated, leading to further response and listing on the NPL. This reversal in status appears to fit the critical requirement to create stigma; a violation or overturning of a standard of what is right and a discrediting (here of environmental regulators as well as the site). McCluskey and Rausser show theoretically that both stigmatized and non-stigmatized equilibrium outcomes are possible and find evidence of such an effect, but within a relatively limited distance (1.2 miles) of the site. Both groups of researchers conclude that information is more important to housing prices than response actions, but they differ as to whether or where a reversal occurred and whether stigma was involved. The same is true of a more recent study that also looked at Woburn, as well as three other sites with very long, contentious histories, and found little or only partial reversal of the negative price effect (Schulze, Messer et al. 2004).

Studies that examined more typical NPL sites and included data from appropriate time periods find clear evidence of reversal of the negative price effect between listing and the time the RODs are announced. McMillen and Thorsnes (2000) evaluate data that stretches from before discovery until well after remedial action had begun. They find that at about the time the site was listed, the negative price effect began to disappear. Further, they find this location subsequently gained an additional value over time after the smelter closed and the remedial action had proceeded. This seems to suggest there can be both an instantaneous and long-term reversals from the negative price effect that begin after listing. Gayer et al. (2003) find evidence of reversal occurring throughout the period they examined. Their study period began (with a small exception) after the seven sites had been listed and included the announcement of the ROD but (with one exception) did not include the start of remedial action. They find the release of the Remedial Investigation / Feasibility Study (RI/FS) (which occurs during the ROD process) is a key event in providing information to housing markets, initiating the reversal of the negative price effect of proximity to an NPL site.

Thus, there is evidence that some homes near NPL sites begin to experience a reversal of the decline in price associated with proximity to the NPL site after the site is listed and before the remedial action is complete, with the possible exception of sites with very complex histories. The release of information is very important to this process and the single most important informational event is the release of the ROD. Therefore, the release of RODs is used in the current study to count the number of sites to which benefits are transferred. For most NPL sites, this occurs about halfway between the Listing and the end of remedial action as shown in Chapter 3 of Probst and Konisky (2001) and in Figure 4.7. This Figure shows the cumulative numbers of sites: i) that were proposed, final, or deleted from the NPL (NPL); ii) for which RODs have been published (ROD); or, iii) for which remedial action is essentially complete (construction complete or deleted, CCD).[8] The year the ROD is published is a rough approximation of when most of the benefits of NPL remedial action occur (as measured by changes in home prices), and the value of the remedial action is capitalized immediately at that point. The benefits transfer analysis below assumes that this approach ignores the possibility of stigma and other issues associated with heterogeneity among NPL sites, which should be explored in further research. However, it appears that stigmatization occurs at a relatively small number of often highly visible NPL sites, so this simplification is not likely to introduce substantial error.

Figure 4.7. Sites in the NPL Pipeline



Note: NPL values are the number of sites that are Proposed, Final, or Deleted from the NPL; ROD values are the number of sites for which a Record Of Decision has been issued; CCD values are the number of sites that have reached Construction Complete or Deleted status.

[8] While no sites were proposed to the NPL before 1982, CERCLIS reports a small number of RODs in 1980-81, which were created for sites that EPA had begun working on under other authority before Superfund was created.

Benefits Transfer Analysis

Most of the values required have now been determined, including the measures of central tendency that will be transferred to homes near NPL, the number of NPL sites to which this applies, and the timing of these transfers. The last value that needs to be determined is the number of homes to which to transfer the benefit. Due to the limitations of the data and to avoid double-counting (see Chapter 3), the entire benefits transfer for all NPL sites that have had RODs issued are calculated, and then distributed over time in proportion to the number of sites, assuming all sites are similar to the average.

The U.S. Census data at the census block group level is used to estimate the number of number of residences near NPL sites, where "near" is defined as on the site or within 1, 2.5, or 4 miles of the site boundary. Because actual site boundary data are not available, sites are modeled as circles, using the site location data in EPA's CERCLIS database as the center of the circle and the area of the site to determine the radius of the circle. Following the convention in the literature, any effect of being near more than one site is ignored. Thus, for all calculations, residences are associated with the NPL site they are closest to, and counted only once. Residences are placed into one of 6 distance bins: <0.5 miles from the site boundary (including onsite), 0.5-1.0 miles from the site, 1.0-1.5 miles from the site, 1.5-2.0 miles from the site, 2.0-2.5 miles from the site, and 2.5-4.0 miles from the site. (See Chapter 3 for more information on how the data were treated.)

The four measures of central tendency presented above each require a slightly different method for transfer to the policy case, as shown in the four models in Equations 4.2, 4.3, 4.4, and 4.5.

$$B_r^{LA} = LE \times R_r$$ Linear Absolute (LA) model (Equation 4.2)

$$B_r^{LP} = LPE \times P_r \times R_r$$ Linear Percentage (LP) model (Equation 4.3)

$$B_r^{NLA} = \sum_i \left(NE_i \times R_{i,r} \right)$$ Non-Linear Absolute (NLA) model (Equation 4.4)

$$B_r^{NLP} = \sum_i \left(NPE_i \times P_r \times R_{i,r} \right)$$ Non-Linear Percentage (NLP) model (Equation 4.5)

where,

B_r^X = the benefit of the remedial actions at NPL sites that have had RODs issued from 1980-2004 using model *X* (i.e., LA, LP, NLA, or NLP) and assuming the negative price effect extends to *r* miles from the site and the reversal of the negative price effect is complete

R_r = the number of residences within distance *r* of any NPL site that has had a ROD issued

$R_{i,r}$ = the number of residences in bin *i* within distance *r* of any NPL site that has had a ROD issued

LE = the linear absolute price effect of proximity to an NPL site on home prices

NE_i = the non-linear absolute price effect of proximity to an NPL site on home prices

LPE = the linear percentage price effect of proximity to an NPL site on home prices

NPE_i = the non-linear percentage price effect of proximity to an NPL site on home prices

P_r = the mean of census block group median home prices for all census block groups within distance r of an NPL site, weighted by the number of homes per census block group

$P_{i,r}$ = the average of census block group median home prices for all census block groups in bin i, weighted by the number of homes per census block group

For r = 1, 2.5, or 4 and for bins i = <0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0, 2.0-2.5, 2.5-4.

In equations 4.2 and 4.3, the linear models, the per-home benefits are simply multiplied by the number of residences on or within distance r of all NPL sites. Similarly, in equations 4.4 and 4.5, the number of residences is disaggregated into a set of distance bins. Equations 4.2 and 4.4 use the absolute models, the estimate of the absolute effect in dollars. In Equations 4.3 and 4.5, the percentage models, the product of the percentage effect and median home prices (by census block group) is used. Note that these models are linear in all parameters except for maximum distance from the site boundary, r, simplifying sensitivity analysis.

The estimates for benefits found with these models are the undiscounted sums of the WTP for remedial actions at all NPL sites that have had RODs issued for them, for all residences using the mean benefits shown in Tables 4.4 and 4.5. An economic meaning cannot be inferred until this total benefit is distributed over time and discounted.

The determination of the annual (undiscounted) benefit ($AB_{r,t}^{X}$) is shown in Equation 4.6. Total benefit for distance r in year t is scaled by the ratio of NPL sites that have RODS issued that year to the total through 2004 (1,326) and a population growth factor (PGF_t). The population growth factor accounts for changes in population before and after 2000, which is the census year used to calculate the number of residences, R_r and $R_{i,r}$. In census block groups near NPL sites, population increased 7.7% from 1990 to 2000, which implies an average annual growth rate of 0.745%. The PGF_t simply accounts for this effect on an annual basis.

$$AB_{r,t}^{X} = B_r^{X} \times \frac{ROD_t}{1326} \times PGF_t \qquad \text{(Equation 4.6)}$$

These steps yield a stream of annual benefits for 1980-2004 in 2000$ for each of the four models given above, which is discounted at a 7% rate to yield present values in 1980.[9,10] Two sensitivity analyses were conducted. The first assumes that the price effects for non-SOD homes are only one half of those for SOD homes. This reduces the benefit by about one quarter. The second re-calculates the benefit assuming that the effect extends to 1 mile and to 4 miles.

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[9] The present value of a series of benefits (or costs) that occur in the future (in this case, annually) is equal to the sum of the individual benefits (or costs) discounted into present-day terms. The equation for discounting is $PV = B / (1+r)^t$ where B is the benefit, r is the discount rate, and t is the number of years in the future. The conceptual framework for discounting is based on the fact that present consumption is valued more than future consumption. Appropriate discount rates for analyses such as the one presented here include 3% and 7% (U.S. Environmental Protection Agency 2000 Chapter 6).

[10] For alternative base-year discounting see Appendix C of the current study.

Results and Discussion

The present values of this benefits transfer analysis are shown below in Tables 4.6 and 4.7 and Figure 4.8, along with 95% confidence intervals. Values for discount rates of 3% and 7% are given. For convenience, only the 3% values are discussed here. The mean values for the four models range from $63-$100 billion over the period 1980-2004. The 95% confidence intervals range from a low of $41 billion to a high of $130 billion. Each of the four models and the data used to estimate the parameters in each (specifically, the magnitude of the price effect) has different advantages and disadvantages. The Linear Absolute (LA) model has the largest amount of data associated with it, but it is the least theoretically appealing model. On the other hand, the most theoretically appealing model, the Non-Linear Percentage (NLP) model is supported by only a few studies. The issue thus becomes, partly, which provides a greater improvement over the LA model, using a percentage-based model or using a non-linear model? Given the close agreement of the absolute and percentage models, using a non-linear model probably provides more advantage. Considering both functional form and data quality, the results that are probably the most reliable come from the Non-Linear Absolute (NLA) model. Thus, the best point estimate of the present value (1980, r=3% in 2000$) of the benefits of NPL remedial actions for the first 25 years of the Superfund program appears to be about $63 billion.

These calculations are fairly sensitive to the maximum distance at which the price effect is assumed to operate. If this effect is only one mile, the benefit drops by 70%, if it extends all the way out to 4 miles, the benefit may be twice as large as the values shown in Figure 4.6. Note that only one of the studies in Table 4.2 found a non-linear effect extending past 3 miles, so non-linear results for 4 miles were not calculated. These calculations are less sensitive to assumptions about the price effect for non-single family, owner-occupied, detached (SOD) residences. If non-SOD homes experience only half the effect of SOD homes (for which there is no evidence), mean estimates of the benefits range from about $47-$77 billion.

Table 4.6 also presents annualized values of these benefits, which are another way (in addition to present values) of expressing the magnitude of benefits that vary across time. An annualized benefit is the size of a fixed annual benefit, which, if it occurred at the end of each year and was discounted back to the base year (1980, in this case) would result in the same present value as the actual series of benefits. Thus, calculating an annualized benefit converts a series of unequal benefits to a series of uniform benefits, both of which have the same present value. The annualized benefits of NPL remedial actions, using the assumptions and methods given above, range from $3.6-$5.9 billion per year over the period 1980-2004, depending on the model used and assuming a 3% discount rate. The 95% confidence interval is $2.4-$7.4 billion per year.

Table 4.6. Present Value of the Benefits of NPL Remedial Actions, 1980-2004
(Billion 2000$, Base year 1980)

Discount rate = 7%	Value	Model			
All residence types equivalent		LA	NLA	LP	NLP
Max distance 2.5 mi.	Mean	50	42	68	49
	95% CI	35-66	29-55	51-85	27-74
50% effect for Non SOD homes	Mean	38	31	51	36
Max distance 1 mi.	Mean	14	-	-	-
Max distance 4 mi.	Mean	94	-	-	-

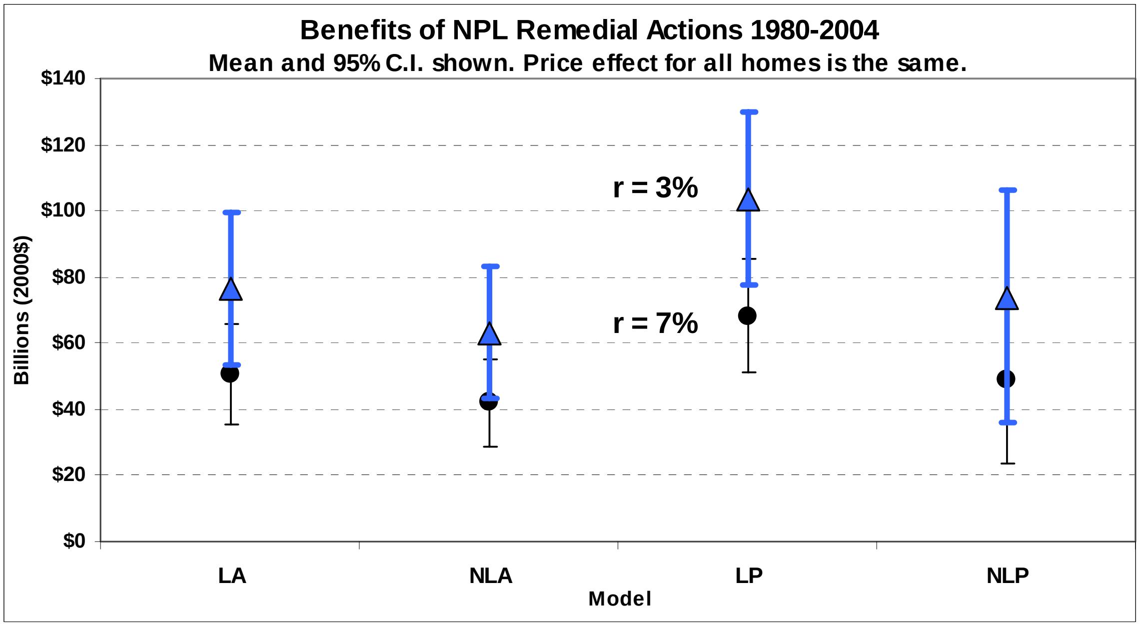
Discount rate = 3%	Value	Model			
All residence types equivalent		LA	NLA	LP	NLP
Max distance 2.5 mi.	Mean	77	63	100	74
	95% CI	53-100	43-83	77-130	41-110
50% effect for Non SOD homes	Mean	57	47	77	55
Max distance 1 mi.	Mean	22	-	-	-
Max distance 4 mi.	Mean	140	-	-	-

Table 4.7. Annualized Value of the Benefits of NPL Remedial Actions, 1980-2004
(Billion 2000$, Base year 1980)

r = 7%	Value	Model			
All residence types equivalent		LA	NLA	LP	NLP
Max distance 2.5 mi.	Mean	4.3	3.6	5.8	4.2
	95% CI	3.0-5.6	2.5-4.7	4.3-7.3	2.3-6.3

r = 3%	Value	Model			
All residence types equivalent		LA	NLA	LP	NLP
Max distance 2.5 mi.	Mean	4.4	3.6	5.9	4.2
	95% CI	3.1-5.7	2.5-4.8	4.4-7.4	2.4-6.4

Figure 4.8. Present Value of the Benefits of NPL Site Remedial Activities, 1980-2004
(Billion 2000$, Base year 1980, 2.5 miles)



However, there are four major limitations to these results.

First, this analysis includes perceived risks and uncertainty, as measured by WTP in housing markets, as well as actual risks, so is not directly comparable to some previous analyses (Hamilton and Viscusi 1999b).

Second, this analysis also ignores many benefits (as do other studies). For instance, because removal actions at NPL sites may be largely ignored by the media and the public and appear to be ignored by housing markets, most of the real health risk reduction that occurs at NPL sites is probably not captured by home prices. In addition, benefits accruing to non-neighbors, including preserving ground water for safe human and non-human use in the future and restoring of land to productive use or ecological health, are not captured here.

Third, this analysis also ignores heterogeneity across NPL sites. Thus, while the approach suggests that, in aggregate, NPL remedial actions have significant benefits, this is almost certainly not true of each individual remedial action. Previous analysis shows that actual and perceived risks vary greatly across sites, and may be concentrated at a small number of sites (Hamilton and Viscusi 1999a). One of the most important aspects of site heterogeneity may be whether or not a site is stigmatized because property values at sites where stigmatization occurs may not recover quickly (Kunreuther and Slovic 2001; McCluskey and Rausser 2003b; Schulze, Messer et al. 2004).

Fourth, this data is retrospective only and may have limited applicability in thinking about the future of the Superfund program or of managing hazardous substances more generally. Most of the data used by the studies considered in the meta-analysis come largely from before 1990. Thus, it reflects site characteristics, EPA procedures, and remedial technologies that are somewhat different from those today and those expected in the future (Probst and Konisky 2001 Ch. 5).

References

Anonymous (2000). Raising the Roof- California Housing Development Projections and Constraints 1997-2020. Sacramento, CA, California Business, Transportation and Housing Agency.

Bartik, T. J. (1988). "Measuring the Benefits of Amenity Improvements in Hedonic Price Models." Land Economics **64**(2): 172-183.

Boyle, K. J. (2003). Introduction To Revealed Preference Methods. A Primer on Nonmarket Valuation. P. A. Champ, K. J. Boyle and T. C. Brown. Boston, Kluwer Academic Publishers**:** 259-267.

Boyle, M. A. and K. A. Kiel (2001). "A Survey of House Price Hedonic Studies of the Impact of Environmental Externalities." Journal of Real Estate Literature **9**(2): 117-144.

Cameron, T. and G. D. Crawford (2003). Superfund Taint and Neighborhood Change: Ethnicity, Age Distributions, and Household Structure. University of Oregon Economics Department Working Papers. Eugene**:** 28.

Dale, L., J. C. Murdoch, et al. (1999). "Do property values rebound from environmental stigmas? Evidence from Dallas." Land Economics **75**(2): 311-326.

EPA Science Advisory Board (2002). Underground Storage Tanks (UST) Cleanup & Resource Conservation & Recovery Act (RCRA) Subtitle C Program Benefits, Costs, & Impacts (BCI) Assessments: An SAB Advisory. Washington, DC, USEPA**:** 50.

Freeman, A. M. (1993). The Measurement of Environmental and Resource Values: Theory and Methods. Washington, DC, Resources For the Future.

Gayer, T., J. T. Hamilton, et al. (2000). "Private values of risk tradeoffs at superfund sites: Housing market evidence on learning about risk." Review of Economics and Statistics **82**(3): 439-451.

Gayer, T., J. T. Hamilton, et al. (2002). "The market value of reducing cancer risk: Hedonic housing prices with changing information." Southern Economic Journal **69**(2): 266-289.

Gayer, T. and W. K. Viscusi (2002). "Housing Price Responses to Newspaper Publicity of Hazardous Waste Sites." Resource & Energy Economics **24**(1): 33-51.

Gregory, R., J. Flynn, et al. (1995). "Technological Stigma." American Scientist **83**(3): 220-3.

Gregory, R. S. and T. A. Satterfield (2002). "Beyond perception: The experience of risk and stigma in community contexts." Risk Analysis **22**(2): 347-358.

Harrison, R. M. (2003). "Hazardous waste landfill sites and congenital anomalies: Where do we go from here?" Occupational and Environmental Medicine **60**(2): 79-80.

Hird, J. A. (1994). Superfund : the political economy of environmental risk. Baltimore, Johns Hopkins University Press.

Hite, D. (1998). "Information and bargaining in markets for environmental quality." Land Economics **74**(3): 303-316.

Hite, D., W. Chern, et al. (2001). "Property-value impacts of an environmental disamenity: The case of landfills." Journal of Real Estate Finance and Economics **22**(2-3): 185-202.

Hurd, B. H. (2002). "Valuing superfund site cleanup: Evidence of recovering stigmatized property values." The Appraisal Journal **70**(4): 426-437.

Ihlanfeldt, K. R. and L. O. Taylor (2004). "Externality effects of small-scale hazardous waste sites: evidence from urban commercial property markets." Journal of Environmental Economics and Management **47**: 117-139.

Johnson, B. L. (1999). Impact of hazardous waste on human health : hazard, health effects, equity, and communications issues. Boca Raton, Lewis Publishers.

Kasperson, R. E., N. Jhaveri, et al. (2001). Stigma and the Social Amplification of Risk. Risk, Media, and Stigma. J. Flynn, P. Slovic and H. Kunreuther. Sterling, VA, Earthscan**:** 9-27.

Kiel, K. and J. Zabel (2001). "Estimating the economic benefits of cleaning up Superfund sites: The case of Woburn, Massachusetts." Journal of Real Estate Finance and Economics **22**(2-3): 163-184.

Kiel, K. A. and K. T. McClain (1996). "House price recovery and stigma after a failed siting." Applied Economics **28**(11): 1351-1358.

Kohlhase, J. E. (1991). "The Impact of Toxic-Waste Sites on Housing Values." Journal of Urban Economics **30**(1): 1-26.

Kunreuther, H. and P. Slovic (2001). Coping with Stigma: Challenges and Opportunities. Risk, Media and Stigma. J. Flynn, P. Slovic and H. Kunreuther. Sterling, VA, Earthscan**:** 331-352.

Lipscomb, J. A., L. R. Goldman, et al. (1992). "A study of current residents' knowledge of a former environmental health survey of their community." Archives of Environmental Health **47**(4): 270-4.

McClelland, G. H., W. D. Schulze, et al. (1990). "The Effect of Risk Beliefs on Property Values: A Case Study of a Hazardous Waste Site." Risk Analysis **10**(4): 485-97.

McCluskey, J. J. and G. C. Rausser (2001). "Estimation of perceived risk and its effect on property values." Land Economics **77**(1): 42-55.

McCluskey, J. J. and G. C. Rausser (2003). "Hazardous waste sites and housing appreciation rates." Journal of Environmental Economics and Management **45**(2): 166-176.

McCluskey, J. J. and G. C. Rausser (2003). "Stigmatized Asset Value: Is It Temporary Or Long-Term?" Review of Economics and Statistics **85**(2): 276-285.

McConnell, K. E. (1993). Indirect Methods for Assessing Natural Resource Damages Under CERCLA. Valuing Natural Assets: The Economics of Natural Resource Damage Assessment. R. J. Kopp and V. K. Smith. Washington, DC, Resources For the Future**:** 153-203.

McMillen, D. P. (2003). "The aroma of Tacoma: Time varying average derivatives and the effect of a superfund site on house prices." Journal of Business & Economic Statistics **21**(2): 237-246.

McMillen, D. P. and P. Thorsnes (2000). The reaction of housing prices to information on superfund sites: A semiparametric analysis of the Tacoma, Washington market. Advances in Econometrics, Vol 14. **14:** 201-228.

Mendelsohn, R., D. Hellerstein, et al. (1992). "Measuring Hazardous-Waste Damages with Panel Models." Journal of Environmental Economics and Management **22**(3): 259-271.

Michaels, R. G. and V. K. Smith (1990). "Market-Segmentation And Valuing Amenities With Hedonic Models - The Case Of Hazardous-Waste Sites." Journal of Urban Economics **28**(2): 223-242.

Nelson, A. C., J. Genereux, et al. (1997). "Price effects of landfills on different house value strata." Journal of Urban Planning and Development-ASCE **123**(3): 59-67.

Office of Technology Assessment (1989). Coming Clean: Superfund Problems Can Be Solved. Washington, DC, U.S. Congress**:** 223.

Palmquist, R. B. (1991). Hedonic Methods. Measuring the Demand for Environmental Quality. J. Braden and C. Kolstad. Amsterdam, Elsevier Science**:** xxx-xxx.

Palmquist, R. B. (1992). "A Note on Transactions Costs, Moving Costs, and Benefit Measurement." Journal of Urban Economics **32**(1): 40-44.

Palmquist, R. B. (1992). "Valuing Localized Externalities." Journal of Urban Economics **31**(1): 59-68.

Probst, K. N. and D. M. Konisky (2001). Superfund's Future: What Will It Cost? Washington, DC, RFF Press.

Reichert, A. K. (1997). "Impact of a toxic waste Superfund site on property values." The Appraisal Journal **65**(4): 381-392.

Rosen, S. (1974). "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." Journal of Political Economics **82**(Jan/Feb): 34-55.

Rosenberger, R. S. and J. B. Loomis (2003). Benefit Transfer. A Primer on Non-Market Valuation. P. A. Champ, K. J. Boyle and T. C. Brown. Boston, Kluwer Academic Press**:** 445-482.

Schulze, W. D., K. Messer, et al. (2004). Stigma: The Psychology and Economics of Superfund. Washington, DC, U.S. Environmental Protection Agency**:** 228.

Slovic, P., B. Fischhoff, et al. (1979). "Rating the Risks." Environment **21**(3): 14-20, 36-39.

Smith, V. K. and W. H. Desvousges (1986). "The Value of Avoiding a LULU - Hazardous-Waste Disposal Sites." Review of Economics and Statistics **68**(2): 293-299.

Thayer, M., H. Albers, et al. (1991). "The Benefits of Reducing Exposure to Waste Disposal Sites: A Hedonic Housing Value Approach." The Journal of Real Estate Research **7**(3): 265-281.

U.S. Environmental Protection Agency (1987). Unfinished business : a comparative assessment of environmental problems (Volume 1 - Overview). Washington, DC**:** 120.

U.S. Environmental Protection Agency (2000). Guidelines For Preparing Economic Analyses. Washington, DC**:** 210.

Viscusi, W. K., J. T. Hamilton, et al. (1997). "Conservative versus mean risk assessments: Implications for superfund policies." Journal of Environmental Economics and Management **34**(3): 187-206.

Walker, K. D., M. Sadowitz, et al. (1995). Confronting Superfund Mythology: The Case of Risk Assessment and Management. Analyzing Superfund: Economics, Science and Law. R. L. Revesz and R. B. Stewart. Washington, DC, RFF Press**:** 25-53.

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Chapter 5: Effect-by-Effect Analysis

Overview

Like many environmental policies, Superfund produces a variety of benefits that do not have a natural, common metric for valuation.[1] To evaluate these benefits, an "effect by effect" analysis is useful (U.S. Environmental Protection Agency 2000, 59, 62-65). Effect-by-effect analysis usually involves classifying the physical effects of the pollutants (e.g., various types of damages to human health and ecological systems) and assessing each type of effect separately. Several effect-specific analyses are proposed in this chapter to estimate the benefits of some specific improvements in human health (i.e., lower health risk), ecological conditions, and ground water protection. Due to data limitations, only the benefits associated with NPL sites will be estimated, with one exception: the analysis of the benefits created by natural resource restorations. The estimates of benefits proposed in this chapter cannot be added to the estimate of benefits developed in Chapter 4 because there is the potential for double-counting of benefits by the two methods of estimation. This chapter has three major sections corresponding to the major classes of benefits: health effects, ecological effects, and ground water protection effects.

In several places in this chapter the text stops before the analysis being described is completed, by agreement with the EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed-upon process is for EPA to provide a description of the data and proposed methodology but not to go forward with an analysis until we receive input from the Advisory Panel on our intended approach.

Health

Overview

Like other environmental programs, a key motivation for the Superfund program is to reduce human health risks. The health risks presented by hazardous substances include acute effects (e.g., poisoning or injuries from fires or explosions) and a variety of long-termeffects (e.g., cancers or birth defects) (Johnson 1999; Bove, Shim, and Zeitz 2002; Dolk and Vrijheid 2003). Examples of the more than 250 hazardous substances that create these dangers and are addressed by the Superfund program include lead, arsenic, benzene, trichloroethylene, and mercury. Since 1990, completed exposure pathways for hazardous substances in the environment have been found at over 15,000 sites (NPL and non-NPL) in the United States (Agency for Toxic Substances and Disease Registry 2003a, 2003b). In addition, the Superfund program sometimes deals with substances that are explosive or radioactive (Probst and Konisky 2001, 20; Johnson 1999, 85).

This section contains a general review of the literature and data available on the epidemiology of hazardous substances in the environment. This is followed by five subsections on the valuation of health risks, birth defects, acute accidents and injuries, lead-induced health effects, and cancer and other health effects. In each of the subsections on specific health endpoints, a table that briefly summarizes the available data is presented.

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[1] Here, Superfund is defined as all the activities and programs created by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA).

Literature on Health Effects
Uncontrolled releases of hazardous substances to the environment can increase the risk of adverse health effects to exposed populations, especially to sensitive sub-populations, such as children (Schettler 2001). Superfund mitigates these risks by interrupting exposure pathways and reducing the amount, mobility, and toxicity of hazardous substances found in the environment. Measuring the size of these health risk reductions is extremely challenging. The most robust method is site-specific risk assessment (Paustenbach 2002); however, this method is not used in this study. The main reason is resources – the time and budget allocated to this project were not sufficient to conduct a formal risk assessment of a meaningful sample of Superfund sites.

EPA conducts risk assessments for all sites on the National Priorities List (NPL) as part of the NPL process (specifically in the baseline risk assessment, or BLRA, see Figure 3.1), but these data are both limited in availability and applicability. These data are limited in availability (or perhaps accessibility) because, like much of the data associated with Superfund, they are not collected in a single database or location. Summaries of these studies are available in the Records of Decision (ROD) for each NPL site, but the BLRAs are usually only available in hard copy at the appropriate Regional EPA office. More importantly, BLRAs are only conducted for NPL sites, which are a small fraction (less than 10%, see Chapter 3) of all responses. For removal actions and state responses, some documentation (e.g., an Action Memo for a removal) may be available, but even where documentation is available, it almost never includes a formal risk assessment. Indeed, one of the major distinctions between removal and remedial actions is that the removal process is designed to operate without formal risk assessments because they are not necessary for sound management decisions and because the delay they would cause would often have significant risk consequences of its own. However, the most important problem with the idea of using BLRAs or similar risk assessments in this analysis is that the conservative assumptions that are protective of human health on which they are based are appropriate for making decisions about remedies at NPL sites, but may not be appropriate for calculating benefits (Viscusi, et al. 1997; EPA Science Advisory Board 2002).

The level of effort required to conduct an effect-by-effect benefits analysis using EPA risk assessment data as a starting place is indicated by the size of the multi-year project that resulted in *Calculating Risks?*, which examined a single effect, adult cancer risk at NPL sites (Hamilton and Viscusi 1999). That study is particularly strong in terms of understanding those particular risks. Possible improvements, such as updating the choice of NPL sites and repeating the entire analysis or adding other health risks (e.g., birth defects or childhood cancer) and repeating that entire study, are beyond the scope of this study. Thus, the results from *Calculating Risks?* are used below in a benefit transfer analysis for reductions in cancer health risks.[2]

Other risks are even more difficult to analyze because of the lack of data. While EPA does quantitatively rate the non-cancer health risk with a "hazard quotient", this value does not identify the type of outcome, which can "range from drowsiness to death" and "does not translate exposure to varying levels of non-cancer risks into the probability of an actual adverse outcome"

[2] In this version of the Superfund Benefits Analysis, no effect-by-effect health analysis is actually conducted, even though the introductory material is written as if it is. Through agreement with the EPA Science Advisory Board, methodologies are only proposed.

(Hamilton and Viscusi 1999, 53, 107). Even the more extensive data collected by the Agency for Toxic Substances and Disease Registry (ATSDR) do not provide the information needed for a formal risk assessment of non-cancer risks (General Accounting Office 1999; Agency for Toxic Substances and Disease Registry 2003a, 2003b). Thus, a different approach is needed.

The other feasible approaches to estimating the risk reduction benefits for specific health outcomes due to the Superfund program are i) to use the results of risk exposure models, ii) epidemiological studies, or iii) benefits transfer methods. These approaches have their own limitations, but they at least can provide some insight into the magnitude of the adverse health outcomes associated with uncontrolled releases of hazardous substances. Model-based approaches allow an estimate of the benefits of Superfund by reducing exposures through response actions, but the available epidemiological data only allow an estimate of the potential magnitude of the negative health effects associated with releases.

This study examines five categories of health effects: acute accidents and injuries; adult cancer; birth defects (also known as congenital anomalies); lead-induced health effects (mostly reduction in cognitive abilities, usually measured by decreases in IQ scores); and other chronic non-carcinogenic effects (e.g., thyroid dysfunction, endometriosis, etc.). As mentioned above, cancer risk reductions are estimated using a simple benefit transfer of the results from Hamilton and Viscusi (1999). EPA's Integrated Exposure Uptake Biokinetic model (IEUBK) is used to estimate the benefits of reducing lead exposure. Epidemiological data is used to estimate the potential magnitude of the negative health effects from acute accidents, birth defects, and other negative health outcomes.

For acute injuries, birth defects, and other chronic non-carcinogenic effects, epidemiological data are used to estimate the number of additional cases, following the approach used in a peer-reviewed paper, "Medical costs and lost productivity from health conditions at volatile organic compound-contaminated Superfund sites"(Lybarger et al. 1998), but using more recent and more detailed population data.[3] This method has three basic steps. First, relationships between specific substances and specific health endpoints are established based on published epidemiological research. The rates of excess occurrence are also estimated. Second, sites are identified at which completed exposure pathways for the specific substance exist (or existed in the past, prior to a response). Then, an exposed population is estimated by determining the number of residents (using the 2000 Census) within ½ mile (a value derived from a review by Lybarger et al. of all the relevant site assessment data collected by ATSDR). This approach can be applied only to NPL sites, because location data is available only for these sites. This limitation means that removal actions must be ignored in this analysis.

The number of excess cases is then calculated by taking the product of the exposed population and the rate of excess cases. Finally, the economic value of these excess cases is estimated by calculating the product of the number of excess cases and the cost of illness (COI) for that specific health endpoint, using the data from EPA's *Cost of Illness Handbook*, which is described below. This provides a rough estimate of the magnitude of the health risks, which should be

[3] Discussions with several of the authors of this paper indicated that they felt further applications such as those discussed here were likely to yield reasonable estimates of the effect.

close to the benefit of the Superfund program, assuming that the relevant exposure pathways are interrupted and no new ones are created. This seems to be a reasonable assumption.

A recent book summarizes much of the literature on the health effects of hazardous waste (Johnson 1999). The most comprehensively researched health risk associated with NPL sites is adult cancer; the work by Hamilton and colleagues is probably the most relevant and useful but there is some more recent work in this area as well (Costas, Knorr, and Condon 2002; Hamilton and Viscusi 1999). Several recent summaries of the effects of acute injures (e.g., inhalation of chlorine gas, explosions, etc.) are available (Horton, Berkowitz, and Kaye 2004; Zeitz et al. 2000; Palmer, Rees, and Coleman 2000). There is a large body of literature on increased incidence of birth defects associated with hazardous waste sites (Vrijheid et al. 2002; Bove, Shim, and Zeitz 2002; Castilla et al. 2001; Orr et al. 2002; Costas, Knorr, and Condon 2002; White et al. 1997; Bove et al. 1995). The principal health problems identified in the literature appear to be cardiac malformations and various central nervous system defects. The health impacts of lead at a few Superfund sites are fairly well documented, and there is good evidence of a general relationship between soil lead and elevated blood lead levels (Johnson and Bretsch 2002; von Lindern, Spalinger, Bero et al. 2003; von Lindern, Spalinger, Petroysan et al. 2003). The health risks due to response actions have received some analysis, suggesting that the greatest risks are to unborn children of mothers working on responses, and nearby children (Mushak 2003). However, in one study of cleanup of a lead smelter, exposure to neighboring children (and other residents) due to the cleanup was shown to be trivial (Khoury and Diamond 2003).

This literature is plagued by a lack of exposure data, making it very difficult to sort out exposed from non-exposed populations (Harrison 2003). Exposure occurs when five elements are present: a source of contamination, an environmental medium and transport mechanism, a route of exposure, a point of exposure, and a receptor population. (For a general discussion of this issue, see Williams and Paustenbach 2002.) Exposure to hazardous substances varies significantly from site to site, and human exposure to hazardous substances may occur through multiple routes. Some data on human exposure due to uncontrolled releases of hazardous substances exist for some cases but no collection of exposure data useful for an overall analysis of expected risk is available.[4] However, research based on site-specific investigations at NPL sites suggests that the most important exposure medium is ground water, followed by soil, air, biota, and other media, and that ingestion is by far the most important exposure pathway, followed by dermal contact and inhalation (Hamilton and Viscusi 1999, 24-57). Nonetheless, the lack of definitive exposure data limits the analysis that is possible in this study (Harrison 2003).

The estimation of the benefits of reducing these health risks involves two essential steps: estimating the number of negative health outcomes (cases) avoided, and valuing the avoidance of each outcome (case). The first step will be accomplished differently, as mentioned above, for each effect, while the second step will be accomplished in the same way for all, through the use of a “cost of illness” approach. The details of the method used for quantifying the avoided

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[4] Specifically, exposure and risk information for the maximally exposed individual (MEI) exists for most sites on the National Priorities List (NPL), but neither data for typical individuals nor population exposure data exist for these sites. Even less information is available for other sites with uncontrolled releases of hazardous substances, which are far greater in number (see Chapter 2).

outcomes are discussed in each of the sections below on specific effects, while valuation is discussed in the section below.

Valuation of Health Effects

The value of health risk reductions can be estimated by calculating the costs of the negative health outcome and using that amount for the value of an avoided case. Ideally, valuation of these human health benefits would include all costs to society associated with the benefits, including medical costs, work-related costs, educational costs, the cost of support services required by medical conditions, and the willingness of individuals to pay to avoid the health risks. Taken together, these factors could be called society's total willingness to pay to avoid illness. Most of this information is difficult to obtain, so accurate estimates of society's total willingness-to-pay to avoid illness are not usually possible. Consequently, alternative measures of the costs saved when illnesses are avoided may be used instead. Direct medical costs, which measure non-subjective aspects of an illness — the expenditures on medical care — are often used as lower-bound estimates of the benefits of avoiding an illness.

EPA's *Cost of Illness Handbook* provides a relatively straight-forward approach to calculating the medical and related costs avoided (U.S. Environmental Protection Agency 2002; Waitzman, Romano, and Scheffler 1994). The medical costs in this handbook provide a relatively simple and efficient lower-bound estimate of the costs of illnesses. The goal of the handbook is to provide cost estimates that are generalizable to any area of the United States. To obtain cost data representative of the nation as a whole, standard disease treatment methods, using generally acceptable practices, and the average patient experience regarding prognosis and survival (e.g., life expectancy) were used in cost estimates.

Thus, the cost of illness (COI) data provided in the handbook include some, but not all, of the components of the total benefit of avoiding a disease. Those outside the scope of this analysis are direct non-medical costs, the opportunity costs of patients, family members, or other unpaid caregivers, and what the patient and others would be willing to pay to avoid the anxiety, pain, and suffering associated with the illness. Due to the seriousness of most illnesses in this handbook, these components may be substantial.

The direct medical costs incurred as the result of an illness were estimated for the duration of the illness, i.e., from diagnosis to cure or patient death. However, this approach does not estimate the willingness to pay to avoid a premature death. Expected costs are estimated for each year post-diagnosis until cure or death, incorporating information on the likelihood and timing of receiving specific treatments, as well as survival data, information on the age of onset of the disease, and life expectancy data. Medical cost estimates are subject to advances in medical practice and changes in the costs of both services and materials. Most cost estimates are based on recent evaluations of medical practice; the handbook provides dates when cost and treatment data were obtained and descriptive information regarding disease definition and treatment. The user should consider changes in practice over time, however, if recent advances or changes in treatment have been reported.

The main advantages of the COI approach are that it is straightforward to implement, easy to understand, and likely to be accurate for the parts of willingness to pay (WTP) that it actually attempts to measure, the medical cost component. The main disadvantage is that it leaves unmeasured some potentially significant costs.

Birth Defects

Over a dozen studies on the health effects associated with sites that have hazardous substances have been published in the peer-reviewed literature since 1990, as well as several review articles. Almost all of these studies have appeared in the public health and medical literature and none of them have been referenced in the economics or risk assessment literature. The authors of these health studies uniformly decry the lack of adequate data for the task, and in particular the almost complete absence of exposure data. As a result, they are often forced to rely on proximity as a proxy for exposure.

Table 5.1 summarizes studies of birth defects and hazardous substances, reporting the odds ratios (OR) and associated confidence intervals (CI), along with some summary notes about the studies and their results. The OR is calculated by dividing the odds in the exposed group by the odds in the control group, where the odds of an event is the number of events (live births with birth defects) divided by the number of non-events (live births without birth defects). If the odds ratio is less than one then the odds (and therefore the risk) have decreased, and if the odds ratio is greater than one then they have increased. In epidemiological studies such as those in Table 5.1, the purpose is typically to identify factors that cause harm - those with odds ratios greater than one. When the risks (or odds) in the two groups being compared are both small (say less than 20%) then the odds will approximate the risks and the odds ratio will approximate the relative risk. The odds of any congenital malformation is less than 2% in the United States, and the odds of specific conditions is lower than that (Anonymous 2003). Thus, ORs for birth defects closely approximate increased risks, so an entry in Table 5.1 of an OR of 1.12 implies approximately a 12% increased risk, while an OR of three implies three times as much risk.

There are significant limitations to this approach. Relying solely on epidemiological studies would introduce significant uncertainties about causation. The assumption that proximity is an adequate proxy for exposure means that (1) epidemiological studies may not take into account the technology of disposal (e.g., well-designed hazardous waste landfills may significantly limit the release of contaminants); (2) there is no significant evaluation of exposure pathways; and, (3) it is difficult to control for some confounding factors, such as other industrial facilities and background pollutant levels. However, epidemiological data rely on known effects to humans, avoiding the uncertainties associated with approaches that rely on toxicological or assumptions in exposure models.

This discussion stops here without completing the analysis by agreement with the EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed upon process is for EPA to provide a description of the data and proposed methodology now and submit a completed analysis based on input received from the Advisory Panel on the intended approach.

Table 5.1. Studies of Birth Defects and Hazardous Materials

Study	Health endpoints	Results (95% CI)	Notes
(Goldberg et al. 1990)*	Heart defects	OR for children of parents with VOC contaminated water: 3 ($p<0.005$) Returned to near unity after well closure	Cited by Lybarger. Area not given. Trichloroethylene exposure in drinking water in Tucson up to 239 ppb.
(Geschwind et al. 1992)*	Birth defects (all) CNS MUS Skin defects Oral clefts	OR 1.12 (1.06 - 1.18) OR 1.29 (1.05 - 1.59) OR 1.16 (1.06 - 1.26) OR 1.32 (1.18 - 1.48) OR 1.15 (0.87 - 1.51)	Case-control, 9,313 cases. New York exposure analysis. Area is within one mile of New York hazwaste sites. Confounders investigated: race, maternal age, maternal education, pregnancy complications, sex, and previous live births. Indications of dose-response relationship. See Marshall.
(Shaw et al. 1992)*	Heart/circulatory CNS, MUS, oral clefts, skin, genitourinary Low birthweight	OR 1.5 (1.1 - 2.0) Not significant Not significant	Case-control, 5,046 birth defects. Area is census tract. Crude assessment of exposure. Confounders investigated included: maternal age, race, sex, and birth order.
(Sosniak, Kaye, and Gomez 1994)	Low birthweight, infant and fetal death, congenital malformation	Not significant	Case-control with 1,281 cases. Confounders investigated: smoking, drug use, family income, maternal age and education, and previous live births. Definition of congenital defects unclear. Area is one mile site to ZIP code centroid.
(Bove et al. 1995)*	Dichloroethylenes/ CNS Carbon tetrachloride/CNS Carbon tetrachloride /NTD Carbon tetrachloride/ low birthweight Benzene/NTD Trichloroethylene/ various	OR 2.52 (90% CI 1.25 - 5.09) OR 3.80 (90% CI 1.14 - 10.63) OR 5.39 (90% CI 1.12 - 18.95) OR 2.26 (90% CI 1.52 - 3.36) Not significant Not significant	Cited by Lybarger. Cross-sectional study of 75 New Jersey towns with contaminated ground water. 80,938 live births and 594 fetal deaths during 1985-1988. Monthly tap water surveys used for exposure analysis. Confounders analyzed include maternal age/race/sex, birth order, previous pregnancy complication, sex, and adequacy of prenatal care. Area not given.
(Berry and Bove 1997)	Low birthweight Preterm birth	OR 5.12 (2.14 - 12.27) OR 2.10 (1.01- 4.36)	Peak exposure periods only. 25 years of data. Confounders investigated: sex, birth order, maternal age, race, and education, and previous fetal deaths. Area is 1 km “downwind”.

Table 5.1 (Continued)

Study	Health endpoints	Results (95% CI)	Notes
(Marshall et al. 1997)*	CNS/proximity solvents	OR 1.3 (1.0 - 1.7)	Follow-up to Geschwind et al. Similar results found for associations of CNS birth defects with proximity to hazwaste sites, but more detailed analyses of specific compound/effect combinations with greater exposure specificity found no associations. Less than one half the number of observations as Geschwind et al. Area is within one mile of New York hazwaste sites.
	CNS/proximity metals	OR 1.4 (1.0 - 1.81)	
	CNS/exposure solvents	OR 0.8 (0.4 – 0.6)	
	CNS/exposure metals	OR 1.0 (0.7 - 1.7)	
	MUS/exposure solvents	OR 0.9 (0.5 - 1.3)	
	MUS/exposure metals	OR 0.8 (0.5 - 1.3)	
(Croen et al. 1997)	NTD	<¼miOR 2.1 (0.6 - 7.6)	Case-control with 507 NTD cases and 1,095 cardiac and cleft malformation cases. Confounders investigated included: maternal age,race, and education, maternal alcohol and tobacco use, maternal employment, household income, and neighborhood educational achievement. Area is ¼ and one mile to Superfund or hazwaste site.
	NTD/pesticides	<1mi OR 2.2 (0.9 - 5.2)	
	NTD/VOCs	<1mi OR 1.8 (0.9 - 3.4)	
	NTD/barium	<1mi OR 3.7 (1.2 - 9.8)	
	NTD/copper	<1mi OR 1.8 (1.1 - 5.2)	
	NTD/lead	<1mi OR 2.0 (0.9 - 4.1)	
	NTD/fluoranthene	<1mi OR 4.2 (1.1-12.4)	
	Heart defects	<¼miOR 4.2 (0.7-26.5)	
	Heart defects/chromium	<1mi OR 2.6 (0.9 - 7.4) .	
	Heart defects/lead	<1mi OR 2.3 (0.8 - 6.4)	
	Oral clefts	<1mi OR 1.2 (0.2 - 8.5)	
(Dolk et al. 1998)	Various congenital anomalies	OR 1.33 (1.11 - 1.59)	Confounders investigated: maternal age and socio-economic factors. Little heterogeneity across study sites. Case-control study with 1,089 cases but no detailed analysis of exposure. Area is within three km of 21 sites in Europe.
	NTD	OR 1.86 (1.24 - 2.79)	
	Malformed cardiac septa	OR 1.49 (1.09 – 2.04)	
	Great artery/vein malformations	OR 1.81 (1.02 – 3.02) .	
	Gastroschisis	OR 3.19 (0.95 – 10.77)	
(Orr et al. 2002)	Birth defects	OR 1.12 (0.98 - 1.27)	Multi-site, case-control study. Area is census tract with Superfund site.
	NTD	OR 1.54 (0.93 - 2.55)	
(Vrijheid et al. 2002)	Chromosomal congenital anomalies	OR 1.41 (1.00 - 1.99)	Anomalies include Down's Syndrome. No dose-response noted. 17 study areas with 23 hazwaste sites. Confounders investigated: maternal age and socioeconomic status. Area is within three km of 21 sites in Europe.

NOTES: * = The study had some direct measure of exposure and did not rely on proximity alone; OR = odds ratio; CNS = central nervous system defects; MUS = musculoskeletal system defects; NTD = neural tube defect.

Acute Accidents and Injuries

A considerable amount of data have been collected on acute accidents and injuries associated with hazardous substances. Some of these occur at schools, some at workplaces, and some are associated with releases. In many cases the first responders (e.g., fire, police) suffer potential or actual exposures to these materials, and first providers (e.g., hospital emergency staff) have also been exposed due to hazardous substances on the clothing or bodies of incoming patients. The Superfund program creates benefits by reducing the number of these exposures and by improving the capacity of various organizations to respond to them.

A considerable literature has been published on this topic, generally in journals associated with environmental health and emergency medicine. Table 5.2 summarizes some of this literature. The existence of a great majority of this information is directly attributable to work by ATSDR, which was created by CERCLA.

Table 5.2. Studies of Acute Accidents Associated with Hazardous Substances

Study	Effect Studied	Outcomes	Notes
(Binder 1989)	hazardous substance releases, injuries, deaths, and evacuations	587 releases resulted in death, injury or other event. 58 events resulted in 115 deaths; 496 resulted in 2254 injuries	Combined results from three systems (National Response Center, Hazardous Materials Information System, Acute Hazardous Events Database) indicated an average of 1.6 haz mat incidents per day resulting in death, injury or other.
(Hall et al. 1994)	hazardous substance releases, injuries, and deaths	1249 events in 5 states, 2 years; 204 resulted in 846 injured persons (1484 injuries) and 7 deaths	1990-91 HSEES included 200 priority substances; 5 participating states not selected randomly
(Hall et al. 1995)	hazardous substance releases, injuries, and deaths	1876 events in 9 states, 1 year; 263 resulted in 600 injured persons (1017 injuries) and 4 deaths	1992 HSEES included 200 priority substances; 1993 to include all haz subs except petroleum products and to include more states
(Hall et al. 1996)	hazardous substance releases, injuries, deaths, and evacuations	3125 events reported; 467 events resulted in 1446 injured persons (2501 injuries), 11 deaths	1990 - 1991: CO, IA, MI, NH, WI; 1992: CO, IA, NH, NY, NC, OR, RI, WA, WI
(Kales et al. 1997)	hazardous substances released and injuries produced in emergency responders	162 incidents, 47 of which caused injuries	respiratory symptoms most common; pesticides most often associated with victims; page 602 discussion addresses importance of preparedness and education
(Burgess et al. 2001)	incidence of acute health effects and persistent effects	various acute symptoms reported (Fig 1); 25% of subjects had symptoms persisting at least 8 days	acute symptoms included headache (40%), cough (33%), eye irritation (32%), throat irritation (32%), chest / lung irritation (26%), dizziness (25%), and nausea (20%)
(Berkowitz et al. 2002)	incidence of events with victims or evacuations following releases at schools	relative risk for event with victims = 3.94; avg # victims = 9 (compared with 4.3 in other industries); 393 events with 1053 victims	includes two "case reports" of children taking mercury from classrooms (page 20)
(Berkowitz, Barnhart, and Kaye 2003)	factors associated with severe injuries	2826 victims from 659 events; severe injuries assoc with explosions (aOR = 6.45) and other factors	limited to actual releases, manufacturing industry, fixed-facility; injury severity assoc with explosion (aOR = 6.45), multiple chemicals (1.75), multiple chem categories (1.70), acids (1.6), multiple injuries to individual (1.38-1.56), confinement within a structure (1.76-1.90), midwest facility location (1.76-1.90)

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Lead-Induced Health Effects

Many NPL sites are contaminated with lead and there has been considerable research into the effects of lead contamination and results of lead cleanups, both remedial actions and others. The table below summarizes some of the key studies.

Table 5.3. Studies of Lead Contamination and Cleanup

Study	Results
(Boon and Soltanpour 1992)	Samples of old silver mine dump materials, garden soils contaminated with mine dump materials, noncontaminated garden soils, and vegetation grown in these contaminated and noncontaminated gardens were collected near an NPL site in Aspen, Colorado. Many of the mine dump materials and soils contained sufficient quantities of lead and cadmium to pose potential health risks if the contaminated materials were ingested, especially by children.
(Weitzman et al. 1993; Weitzman, Aschengrau, and Bellinger 1993)	A study group whose homes got soil and interior dust abatement and loose paint removal experienced statistically significant declines in blood lead levels more rapidly than groups that got less or no intervention. When adjusted for preabatement lead level, the 11-month mean blood lead level was 1.28 µg/dL lower in the study group as compared with group A (p=0.02), and 1.49 µg/dL lower than in group B (p=0.01). The magnitude of the decline independently associated with soil abatement ranged from 0.8 to 1.6 µg/dL when the impact of potential confounders, such as water, dust, and paint lead levels, children's mouthing behaviors, and other characteristics was controlled for.
(Aschengrau et al. 1994)	Study in Boston of children with mildly elevated (<25 µg/dL) blood lead levels. Soil abatement of 2060 ppm was associated with a 2.25 to 2.70 µg/dL decline in children's blood lead level, and the benefits of intervention were persistent (i.e., low levels of soil recontamination after one to two years). Remediation of lead-based-paint hazard was less effective.
(Kimbrough, Levois, and Webb 1995)	Soil lead and blood lead levels near a closed smelter in Granite City, Illinois were investigated, including an 827-person survey. Based on multiple regression modeling, lead in house dust accounted for 18% of the variance in blood lead levels. Lead in paint and condition of the house were the main contributors to the dust lead variance (26%), with soil lead accounting for an additional 6%. Factors such as education of parents, household income, and behavior were associated.
(Maisonet, Bove, and Kaye 1997)	Results suggest that removal of lead-contaminated soil from residential yards was effective in reducing blood lead levels in children. Of the variables examined, yard soil remedial action showed the strongest association with changes in blood lead levels. Yard soil remedial action was found to be a statistically significant protective factor for elevated blood lead levels in children.
(Farrell et al. 1998)	A study of abatement of moderate soil lead contamination (reductions of about 470 ppm) in Baltimore, Maryland showed little effect on blood lead levels. Soil abatement is clearly less important than addressing the problem of lead-based paint in this setting.
(Mielke et al. 1999)	Large-scale assessment in New Orleans, Louisiana showed a strong association between soil lead and blood lead concentrations. Higher soil lead concentrations appear to be primarily due to localized deposits from leaded gasoline combustion, and are associated with lower income, residence in rental housing, and minority populations.
(Lewin, Sarasua, and Jones 1999)	A multivariate linear regression model was used to find a slope factor relating soil lead levels to blood lead levels. Previously collected data were used from the Agency for Toxic Substances and Disease Registry's (ATSDR's) multisite lead and cadmium study, including the blood lead measurements of 1015 children aged 6-71 months, and corresponding household-specific environmental samples. The environmental samples included lead in soil (18.1-9980 mg/kg) and other media. After adjusting for income, education of the parents, presence of a smoker in the household, sex, and dust lead, the predicted blood lead level corresponding to a soil lead level of 500 mg/kg was 5.99 µg/kg with a 95% prediction interval of 2.08-17.29. Predicted values from this regression model are subject to high levels of uncertainty and variability.

Table 5.3 (Continued)

Study	Results
(Brown 2002)	A decision analysis using population-based data of childhood lead exposure showed that strict enforcement of housing policies to prevent childhood blood lead elevation results in decreased societal costs due to the avoidance of future medical problems and special education needs, as well as increased productivity of resident children.
(Johnson and Bretsch 2002)	A study combined over 12,000 blood lead level screenings in Syracuse, New York with spatially detailed soil lead monitoring, and showed that when soil lead data are aggregated across spatial units of sufficient scale, strong associations are observed between blood lead levels and soil lead values. R^2>0.65 for the regression of GM blood lead level on median soil lead. Large samples appear necessary to detect this effect.
(Khoury and Diamond 2003)	Two models (ICRP and IEUBK) were used to estimate blood lead levels in children near a closed lead smelter in Dallas, Texas. Remedial and removal activities were found not to cause significant long-term or acute risk, or significant recontamination of remediated residential yards.
(Lanphear et al. 2003)	Soil abatement was associated with a significant decline in children's blood lead level. Blood lead levels in children aged 6-72 months who lived in soil-abated housing declined 42.8% faster than children who lived in unabated housing (p=0.14). In children aged 6-36 months, the decline was 45.4% faster (p=0.03). The reduction in blood lead levels in children aged 6-36 months was 3.5 µg/dL for every 1000 ppm reduction in soil lead (95% CI: 2.4-4.6).
(Lorenzana et al. 2003)	This article presents the results of a survey of the publicly available literature on the effectiveness of lead intervention on pediatric blood lead levels at six hazardous waste sites located in Canada, Australia, and the United States. Evaluation is often complicated due to confounding variables and statistical limitations. Nevertheless, the intervention studies reviewed in this report suggest that various approaches to the intervention of the dust ingestion pathway, alone or in combination, contributed to declines in blood lead levels in children living in areas heavily contaminated with lead.
(Sheldrake and Stifelman 2003)	A review of cleanup effectiveness at the Bunker Hill NPL site has shown that yard soil cleanup is an effective tool for reducing house dust lead concentrations, and thereby reducing children's blood lead levels. This review has also shown that contiguous cleanup of residences has a three-fold greater reduction of children's blood lead levels compared with cleaning only those homes where children currently reside by reducing exposures attributable to neighboring properties.
(von Lindern, Spalinger, Petroysan et al. 2003)	A comprehensive survey of lead exposure and health effects at the Bunker Hill NPL site showed that soil remedial action without "intervention" (parental education) reduced blood lead levels in two-year-olds by 7.5 µg/dL over 10 years. Those receiving intervention had an additional 2-15 µg/dL decrease. Correlations between local contamination and blood lead levels were observed: they increased 0.9 µg/dL per 1000 mg/kg house dust lead and 4.0 µg/dL per 1000 mg/kg lead in soil.
(Lidsky and Schneider 2004)	A total of 48 papers are reviewed with respect to reconsidering the 1991 recommendations by the CDC that children's blood lead level be controlled down to 10 µg/dL. Experimental and clinical bodies of literature are covered. The experimental studies show that even at low blood lead levels, brain cells in children may be exposed to concentrations at which several fundamental cellular processes are negatively affected (e.g., activity of the protein synaptotagmin I, which is active in signaling between brain cells). The clinical studies are consistent in showing detrimental effects on IQ and other measures of neuropsychological functioning at levels below 10 µg/dL. This research indicates that similar exposures manifest themselves differently in individual children. Lead-based paint is the primary source of lead poisoning for children with mildly elevated (<25 µg/dL) blood lead levels.

The studies in Table 5.3 support several relevant observations. First, a variety of significant negative health outcomes can result from even relatively low levels of childhood lead exposure. Second, while most childhood lead exposures in the United States are due to lead-based paint and soil contamination from pre-1980 gasoline exhaust, wastes near some former mining and smelting operations that are now NPL sites can cause significant exposures. Third, responses at NPL sites have been shown to significantly reduce blood lead levels in children living nearby without causing additional exposures.

There is also some evidence that some disease conditions in adults are linked to lead exposure, including high blood pressure, stroke, coronary heart disease, renal disorders, anemia, and reproductive abnormalities including miscarriage and increased infant mortality due to maternal exposure (Preuss 1993). However, because it is difficult to attribute these health effects solely to lead exposure, this study only evaluates lead-based health effects caused by lead exposure to children less than five years old.

Data obtained from ATSDR show that at least 120 NPL sites had completed exposure pathways for lead, all of which have been designated either an "Urgent Health Hazard" or "Public Health Hazard." Thus, health benefits from Superfund response actions can be expected at these sites.

This study will quantify and monetize three benefits due to such interventions: elimination of the need for medical exams and testing for lead-exposed children, reduced excess costs associated with special education for students with learning disabilities related to lead exposure, and elimination of the wage gap due to lower intelligence caused by childhood lead exposure. The wage gap results from both lower education attainment and from lower labor force participation.

The EPA Integrated Exposure Uptake Biokinetic (IEUBK) model is proposed for this analysis, similar to applications found in the literature (Khoury and Diamond 2003; von Lindern, Spalinger, Petroysan et al. 2003). The IEUBK calculates the intake and absorption of lead by children of different ages.[5] The model is designed to provide an expected mean blood lead level in a population of similarly exposed children, not to predict the blood lead level of any individual child. Lead concentration data from CERCLIS and ATSDR HazDat databases, and population data from the U.S. Census will be used for sites at which CEPs for lead exist. The IEUBK model will be used to determine each site's population's geometric mean blood lead level (BLL) and the percent of children whose BLL exceeds 25 µg/dL. However, because the IEUBK model has not been validated for blood lead levels above 30 µg/dL, the study will use the blood lead level of 30 µg/dL as a conservative estimate for any BLL that exceeds the 30 µg/dL threshold.

To determine the health conditions expected at different blood lead levels, two previous EPA reports will be relied upon (U.S. Environmental Protection Agency 1999, 1996) These reports assume that any increase in blood lead level above 0 µg/dL causes a decrease in intelligence, as measured by IQ. The IQ decrement was assessed at 0.245 points per µg/dL of blood lead, with no lower threshold. However, IQ decrements and other health effects do not appear to be well quantified for very low BLLs. Thus, the proposed method would include an assumption that Superfund responses would reduce childhood BLLs from the levels predicted by the IEUBK model to the current CDC standard of 10 µg/dL and that there are no effects below this level.

In addition to the decreased intelligence experienced by all children exposed to lead, children with blood lead levels exceeding 25 µg/dL require additional services, including medical care and testing and special education assistance to compensate for learning disabilities or behavioral

[5] Intake and absorption measures include dust lead loading that occurs at each soil lead level, the amount of water that children are likely to drink, the respiration rate of children of different ages, and the relative absorption of lead from each media of exposure. The IEUBK model is available at: www.epa.gov/superfund/programs/lead/ieubk.htm.

problems. The number of such children will be calculated and estimates of the treatment and other costs will be taken from the EPA's *Cost of Illness Handbook* (U.S. Environmental Protection Agency 2002).

This study will not include some potential benefits of lead remediation because there is insufficiently strong evidence to quantitatively link lead response actions at NPL sites with possible beneficial outcomes. An example includes possible reductions in levels of violence. Children exposed to lead often demonstrate antisocial behavior, poor impulse controls, and aggressive tendencies. One study compared convicted juvenile offenders to non-delinquent controls in Alleghany County, Pennsylvania (Needleman et al. 1996). Bone lead levels in the tibia were measured in subjects between the ages of 7 and 11 years old. Juvenile offenders, regardless of race, had higher mean bone lead concentrations than the non-delinquent controls. Another study compared air lead concentrations and blood lead levels in all counties in the contiguous 48 states (Stretesky and Lynch 2001). The incidence of homicides was nearly four times higher in counties with the highest air lead levels compared to counties with no air lead contamination. After adjusting for other sociological and air pollution factors, air lead concentration was the only factor associated with homicide rates. The potential benefits realized from reducing lead exposures could be substantial, with a 1998 study estimated that helping one high-risk youth avoid a life of crime provides $1.5-2 million in societal benefits (Cohen 1988). However, for the reasons noted above, these effects will not be included here.

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Cancer and Other Risks

A small number of studies have evaluated cancer and other (non-birth defect) risks related to hazardous substances in the environment. These are summarized in Table 5.4.

Table 5.4. Studies of Cancer and Other Health Effects

Study	**Effect Studies**	**Outcomes**	**Notes**
(White et al. 1997)*	Neurological effects (facial numbness, sensory impairment, peripheral neuropathy, reflex abnormalities)	Diagnosis of mild to moderate encephalopathy in over 80%. 75% of children had major behavioral difficulties.	Clinical study of trichloroethylene (TCE) in drinking water (mostly wells). No area given.
(Hamilton and Viscusi 1999)*	Cancer	Seven cases/site (mean, scenario 2, 30 yrs) but most sites have <0.1	Data from detailed review and analysis of 99 sites, using mean concentration values. Authors note data for noncancer risk may be provided by then-ongoing ATSDR research. Area is four miles from NPL site.
(Costas, Knorr, and Condon 2002)*	Childhood leukemia - Not exposed in utero - Least exposed in utero - Most exposed in utero	Significant dose-response, 95% OR 1.00 OR 3.53 (0.22 - 58.1) OR 14.3 (0.92 – 224.5)	Case-control with 19 cases in Woburn, Massachusetts. Detailed water contamination modeling. Confounders investigated included maternal alcohol consumption. Significant association with breast feeding was found. No area given.
(Jarup et al. 2002)	Cancers: bladder, brain, hepatobiliary leukemia	No excess risk	80% of the population of Great Britain lives within two km of a landfill, so 80% of the population was considered 'exposed'. Same results even when they looked at hazwaste landfills. Area is within two km of 9,565 landfills in Great Britain
(Carpenter et al. 2001)	Thyroid dysfunction Ovarian dysfunction Testicular dysfunction Female genital tract	Significant in females No significant increase No significant increase Significant increase	Hospitalization records. Peak increases: female thyroid ~65% (age 35-44), female genital tract ~40% (age 35-44). Area is ZIP codes within 15 miles of three Areas of Concern in New York State.

NOTES: * = The study had some direct measure of exposure and did not rely on proximity alone; OR = odds ratio.

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Ecological

Overview

Like many environmental policies, Superfund seeks to protect and restore the environment as well as protect human health. Because uncontrolled releases of hazardous substances can significantly injure ecological systems, Superfund legislation contains several provisions that address ecological impacts. Although ecosystems have a profound impact upon human well-being, the quantitative assessment of ecological benefits presents a formidable challenge for several reasons.[6] First, natural systems are inherently complex. Knowledge about the many services they provide and how they provide them is sparse. Moreover, conclusions about site-specific impacts are subject to considerable uncertainty. Second, ecological risks vary widely in terms of persistence, geographic extent, and the degree to which the overall threat can be predicted. For instance, uncontrolled releases of hazardous substances include one-time spills of chemicals into rivers as well as long-term conditions like acid mine drainage, which can have very different ecological outcomes. Third, many of the less tangible benefits are not readily amenable to monetary valuation.

This section provides a general discussion on the literature of ecological effects, measuring ecological benefits, the NRDA process and literature, and estimating benefits for NRDAs.

Literature of Ecological Effects

EPA's guidelines for ecological risk assessment require that ecological risk assessments (ERAs) be conducted at every response according to a well-established, consistent process (Luftig 1999; U.S. Environmental Protection Agency 1998). However, natural resource damages play a relatively small role in Superfund responses compared to health risks (Walker, Sadowitz, and Graham 1995, 29; Suter et al. 2000, chapter 8). Further, the problems of lack of readily accessible information and inappropriate assumptions for a benefits estimation that plague health risk assessments of Superfund sites also apply to ERAs. Searches in the published and gray literature for quantitative estimates of the ecological risks addressed by Superfund responses yielded no results.[7] Thus, there is little data available about improvements in ecological conditions due to Superfund responses. Nonetheless, Superfund responses may create ecological benefits by reducing the amount and type of hazardous substances to which wildlife are exposed, as illustrated by the LCP Chemicals case study on page 3-10.

At LCP Chemicals, EPA's rapid response to Georgia's request for assistance greatly reduced the site's environmental risks. The removal action carried out at the site resulted in lowered levels of PCBs and mercury in the site's aquatic species. Before the removal action, the Georgia Department of Natural Resources advised against consuming a species of fish (red drum) from Purvis Creek, which is near the site. Data collected after the removal action show that it is now safe to eat red drum once a week. These ecological improvements created by removal actions may be similar to the changes caused by natural resource restorations in the Lower Fox River, even though at LCP Chemicals the improvements were caused by responses designed to achieve health risk reduction goals, not natural resource restoration goals.

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[6] Some of this text as well as the accompanying figure are adapted from (U.S. Environmental Protection Agency 2000, 69-71).

[7] This search included the use of multiple electronic tools including online search engines, EPA's websites, and various databases such as EconLit and Web of Knowledge.

Provisions of CERCLA (42 U.S.C. 9601(16)) authorize and require federal and state agencies to mitigate harmful effects of releases on ecological systems.[8] The general term for these injuries is natural resource damages (NRD).[9] The analysis of the size and scope of these injuries is called natural resource damage assessment (NRDA). Natural resources are defined by CERCLA to provide fairly broad coverage under sec. 9601 as land, ground water, habitat, fish and other wildlife, and other resources owned, managed, held in trust, or otherwise controlled by the United States, any state or Indian tribe, or any foreign government. Natural resources can also be viewed as assets that provide flows of services over time to other natural resources and to people. When natural resources are damaged, the flows of ecological and human services provided by those natural resources (and thus the values they provide) may be interrupted for some time. Thus, the public incurs interim losses from the damage.

EPA's chief role with respect to NRDs under the Superfund legislation, is one of notification and coordination. The law requires the President to designate federal officials who shall act on behalf of the public as trustees for natural resources; these trustees include the Secretaries of Agriculture, Commerce, Interior, and others. Under the provisions of CERCLA and SARA, EPA notifies trustees of potential injuries to natural resources at sites where releases or threats of releases are under investigation, notifies trustees of relevant negotiations with potentially responsible parties (PRPs), encourages the participation of trustees in these negotiations, and coordinates various assessment and planning activities with trustees. The major role of the trustees under CERCLA is to conduct NRDAs and recover costs beyond cleanup to restore or replace natural resources to the conditions that would have existed without the hazardous substance release. The value of the injured resources is often calculated in NRDAs in order to facilitate this effort.

Sites at which NRDs occur are not necessarily associated with the National Priorities List (NPL), although many are. EPA is required to, and does, coordinate with the natural resource trustees who implement the NRD provisions of Superfund (Office of Solid Waste and Emergency Response 1992). Some NRDs are extensive and result in lawsuits seeking very large (>$10 million) settlements from responsible parties. These large cases may be studied extensively, resulting in significant NRDA reports that present an opportunity to gain some insight into the ecological benefits of Superfund (e.g., Stratus Consulting 2000; Morey et al. 2002). There are two opportunities. First, any benefits that are created by natural resource restoration can be attributed to Superfund because it is provisions of CERLA and SARA that lead to the restoration. Second, because most sites that are the subject of NRDAs are also NPL sites, this provides some insight into the potential ecological benefits of Superfund response actions. Specifically, that is because some of these response actions may include activities similar to some of those undertaken in natural resource restorations, or at least have similar impacts on wildlife.

[8] Pursuant to Executive Order 12316 those authorities were delegated by the President to the various trustee agencies (e.g., the Departments of Agriculture, Commerce, and Interior) and not to EPA. In addition, ecological restoration is not permitted nor undertaken with Trust Fund monies. The Clean Water Act and Oil Pollution Act contain similar provisions, but these are ignored here.

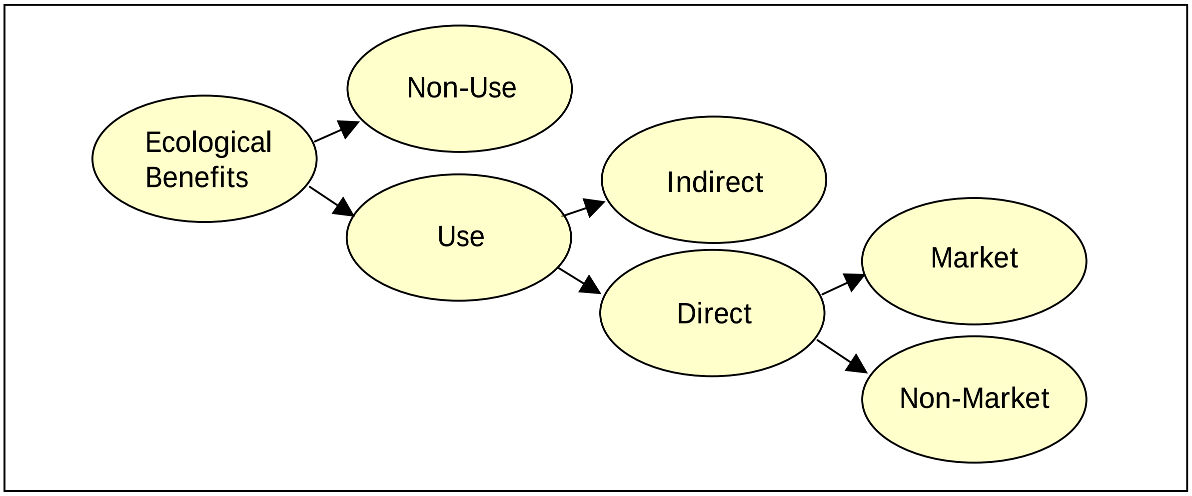
[9] In a legal sense, "damages" refers to monies that are recoverable in a lawsuit as compensation for interrupted flows of ecological services, not the physical harms, which are called injuries. As discussed in more detail below, the magnitude of damages calculated in NRDs are also not equal to the magnitude of the benefits of restoration.

Measuring Ecological Benefits
In general, ecological benefits may be thought of as flows of services from the natural asset in question. These can be categorized by how directly they are experienced. Figure 5.1 illustrates how the categories relate to one another, and how valuation techniques differ.

Direct market benefits are some of the most readily identified service flows provided by ecosystems. These typically relate to primary products that can be bought and sold competitively, either as factors of production or as final consumption products. Relevant examples include commercial fish species, which can be harmed by uncontrolled releases of hazardous substances into aquatic ecosystems. When access is controlled and appropriate user charges levied, recreational opportunities may also be considered direct market benefits, which may be reduced by degradation due to uncontrolled releases.

Non-market benefits include recreational opportunities and aesthetic qualities provided by ecosystems. These are also experienced directly by individuals, but typically do not have a market value associated with them directly. Non-market benefits can include both consumptive uses (e.g., recreational fishing and hunting) and non-consumptive uses (e.g., scenic vistas, wildlife viewing, hiking, and boating). These services are typically provided by natural assets held in common (e.g., public lands). They have public goods characteristics since access is not or cannot be controlled, and consumption is not exclusive.

Figure 5.1. Classification of Ecological Benefits



Source: U.S. Environmental Protection Agency 2000.

Indirect benefits are derived from ecosystem services that do not directly provide a good or opportunity to individuals, yet are valued because they support off-site ecological resources or maintain the biological and biochemical processes required for life support. These indirect benefits tend to be purely public in nature -- access to or use of the service is not exclusive and a virtually unlimited number of individuals can share in the benefits without reducing the average benefit accruing to each. Each type of ecosystem provides various indirect benefits. Wetlands recharge ground water, mitigate flooding, and trap sediments. Rivers provide spawning locations for anadramous fish. Terrestrial ecosystems provide habitat for natural pollinators. All of these systems support biodiversity.

Finally, non-use benefits are those that are not associated with any direct or indirect use by individuals or society. Rather, non-use benefits arise when people value an ecological resource without using it. Non-use values are often referred to as passive use values in the legal literature, and are those associated with, for example, knowledge that the resource could be used by the individual making the valuation (sometimes called *option value*), knowledge that the resource exists in an undisturbed state (sometimes called *existence value*), and knowledge that future generations will be able to use the resource (sometimes called *bequest value*).

Once the types of service flows associated with a natural resource have been identified, the next step in the analysis of ecological benefits is to estimate the physical effects of each policy option, comparing the flow of services with and without the policy. Ecologists and environmental toxicologists conduct ecological risk assessments to estimate expected adverse ecological effects. Environmental economists are typically then called upon to estimate the value of these effects.

Economists have developed a number of methodologies to measure the benefits of changes in the environment. Market methods can be used when direct markets for environmental goods and services exist. The benefits of a change in quantity of a good are estimated using data on these market transactions. Unfortunately, direct markets for environmental goods and services do not often exist. Revealed preference methods (or *indirect approaches*) allow economists to infer the value placed on environmental goods using data on actual choices made by individuals in related markets. Revealed preference methods include recreational demand models, hedonic wage and property models (the latter being approach used in Chapter 5), and averting behavior models. Stated preference methods (or *direct approaches*) allow economists to estimate the value placed on environmental goods using data on hypothetical choices made by individuals responding to a survey. Stated preference methods include contingent valuation methods (CVM), conjoint analysis, and contingent ranking.

For site-specific ecological benefits, the process of estimating the value of changes in the environment can take several years and cost several million dollars. Therefore, due to resource limitations, this study uses existing NRDAs and ground water studies to estimate the size of the ecological benefits of the Superfund program. This will yield only a rough underestimate

The NRDA Process and Literature

Over the last several decades, the number and quality of studies of natural resource damages has increased significantly. This includes both theoretical advances and practical applications. Some of this literature is summarized and theoretical issues are discussed in (Damage Assessment and Restoration Program (DARP) 2004; Reisch 2001; Barnthouse and Stahl 2002; Ofiara 2002; Deis and French 1998; Kopp and Smith 1989). Many of the methods and procedures for estimating the NRDs have been created through a combined legal-economic framework that has established the use of CVM methods in the context of specific cases and more generally (General Electric v. U.S. Department of Commerce (NOAA) 1997; National Association of Manufacturers v. U.S. Department of Interior 1998; Ohio v. Department of Interior 1989; Arrow et al. 1993).

Most NRDAs have been performed in conjunction with lawsuits and many of them appear to be unavailable publicly. However, data and results from some NRDAs have been published in one form or another.

The earliest NRDAs date from the late 1980s, such as a study of mining-damaged areas in Colorado (Kopp and Smith 1989a, 1989b). Other early NRDA studies included one that evaluated a large pesticide spill off the California coast (Carson et al. 1994). These NRDAs examined cases at or associated with NPL sites, but the damage estimates are not related to the response actions at those sites.

Some NRDAs are conducted for large spills of hazardous substances (Desvousges and Dunford 1992; Loomis and Anderson 1992; Stopher 2000; U.S. Fish and Wildlife Service Region 5 Virginia Field Office 2002). These sites are typically not NPL sites, and may not be eligible to become NPL sites, but they may be sites at which a removal action takes place. However, Section 9601 of CERCLA applies to these spills and trustees can recover damages in order to restore the environment. Some spills can result in sizeable damages. For instance, the Cantara Loop spill in California resulted in one of the largest NRDA settlements to date, $38 million, which is being used to support a number of restoration projects (Sheey et al. 2000).

NRDAs may or may not estimate the monetary value of ecological benefits. As mentioned above, no existing studies that attempt to value the ecological benefits of responses and/or restorations could be found in the peer-reviewed literature or in the gray literature. And while ecological risk assessment is becoming more widely practiced, it is not clear that the results of these assessments would be useful for the calculation of benefits (U.S. Environmental Protection Agency 1998; Pastorok, Shields, and Sexton 2002; Mathews, Gribben, and Desvousges 2002). However, remedial actions can have significant ecological benefits, as the case study of LCP Chemicals (p. 3-10) illustrates.

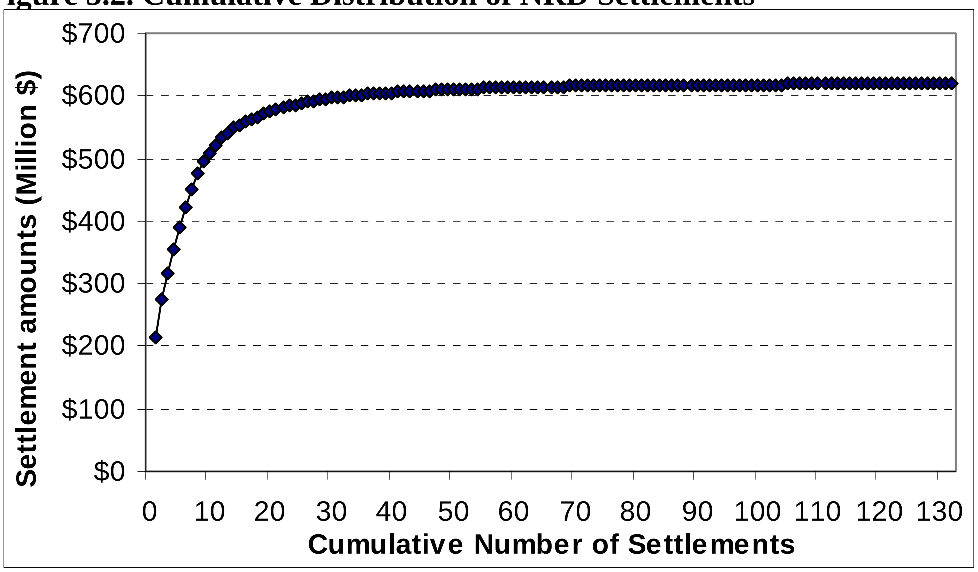
All NRDAs calculate damages, which in the context of NRDs are defined as injury to, destruction of, or loss of natural resources and are measured as the cost of restoring injured natural resources to their baseline condition, compensation for the interim loss of injured resources pending recovery, and the reasonable costs of a damage assessment. However, NRDAs are usually conducted as part of litigation, and some may never be available for public inspection. Others are accessible only by obtaining court documents, which have not been located for this study. A search was conducted to find information about NRDAs that is readily accessible. Over 130 NRDAs were found for which a settlement amount was identified. Table 5.5 contains part of this inventory and Figure 5.2 shows the cumulative distribution of these settlement amounts.

Settlements are arrived at through jury decisions or negotiated consent decrees, and may include many factors not included in economic analysis. Thus settlement amounts may not be very good indicators of benefits, but they are somewhat illustrative of the size of the NRD. The mean settlement amount in the inventory is $4.7 million, but the median value is only $0.18 million. Thus, a small number of NRD cases account for a large portion of the total value of settlements; the 12 settlements that are over $10 million represent about 10% of all cases but more than 85%

of the total settlement value. Of the 130 NRD settlements, 70 (or about half) are indicated as being associated with NPL sites, including almost all the larger settlements.

Table 5.5 contains information on several of the larger NRD settlements, and a small selection of the remainder. It illustrates the type of information that is readily available, from almost none (e.g., Kennecott) to very detailed (e.g., Lower Fox River). The table also shows there are some well-known NPL sites that also have NRD settlements associated with them (e.g., Times Beach). Table 5.5 also provides an indication of the very large range of settlement amounts (over four orders of magnitude). While it is not possible to make a quantitative comparison, this very large range suggests that the size of potential benefits created by natural resource restoration could also vary a great deal. Finally, this table shows that the actual natural resource damages are more than twice as large as the settlement amounts, however, the number of cases where this comparison can be made is very small.

Figure 5.2. Cumulative Distribution of NRD Settlements



Note: For illustrative purposes only. Settlement amounts do not correspond to benefits.

Table 5.5. Natural Resource Damage Cases

Site Name	State	NRDA Amount (Millions$)	Settlement Amount (Millions$)	Site Size	Site Type	Notes (Trustee Info, Contamination)
Clark Fork River	MT	764	215	26 riparian miles	NPL	Mining, smelting, industrial, & municipal wastes; vast mine tailings deposits along the creek; metals; waterfowl deaths; Trustees: State of Montana, Confederated Salish & Kootenai Tribes, DOI
Blackbird Mine	ID	-	60	830 acres	NPL	Acid mine drainage potentially affects two rare species of salmon; Trustees: NOAA, State of Idaho, US Forest Service
Lower Fox River	WI	86.8	41.5	-	NPL	PCBs; Trustee: FWS
Cantara Loop	CA	-	38	36 riparian miles	Non-NPL	Chemical spill (19,000 gallons of herbicide); Trustees: CA Dept. of Fish & Game; Central Valley Regional Water Quality Control Board; US FWS
Kennecott	UT	-	37	-	NPL	-
Montrose Settlements	CA	-	30	13 acres	NPL	DDT, PCB
New Bedford Harbor	MA	-	20.2	18,000 acres	NPL	PCBs; Trustees: NOAA, DOI, Commonwealth of Massachusetts
NYC Landfills	NY	-	8	-	-	-
Idarado	CO	-	5.35	-	Non-NPL	-
Tar Creek	OK	-	0.72	40 sq. mi.	NPL	Acid mine drainage with heavy metals; Trustees: FWS, State of Oklahoma
Times Beach	MO	-	0.37	8 sq. mi.	NPL	Dioxin
John Day River Acid Spill	OR	-	0.28	-	-	Trustees: FWS, State of Oregon, Confederated Tribes of the Umatilla Indian Reservation
Fort Wayne Reduction Dump	IN	-	.005	35 acres	NPL	VOCs, heavy metals, & PCBs in site soils
Volney Landfill	NY	-	.0065	85 acres	NPL	VOCs & heavy metals in ground water

Sources: See text

Although fairly little information is readily accessible about most NRDs, it may be possible to use those for which more information has been published to estimate the ecological benefits of the natural resource restoration. Probably the best-documented case is the Lower Fox River, which will be used in the following sections to illustrate how information from NRDAs can be used to estimate benefits (Lazo 2002; Stratus Consulting 2000). The Lower Fox River flows thorough parts of Wisconsin and empties into Green Bay on Lake Michigan. It has been contaminated with polychlorinated biphenyls (PCBs) that have harmed fish populations and other natural resources. This contamination has resulted in advisories against eating fish or fowl from these areas. In the environment, PCBs decompose over time, so eventually the Lower Fox River and Green Bay would be expected to return to a more natural condition. However, this process could take many decades.

The NRDA for the Lower Fox River extends over almost 700 pages and includes estimates of the nature and extent of harmful effect to the ecosystem as well as the value of the loss of various service flows through CVM techniques (Stratus Consulting 2000; Breffle et al. 2005). This study is the largest, most comprehensive, and one of the highest quality NRDAs available. It estimates a partial WTP for residents of ten Wisconsin counties (Michigan residents are ignored) for various restoration plans. For instance, the total WTP for restoration of the ecosystem in 20 years rather than waiting for natural processes to restore it over the course of a century is $356 million (Stratus Consulting 2000, 6-10). This is only one estimate of many and depends on assumptions about the rate of natural decomposition of PCBs, which is uncertain.

Case Study: Kennecott

Some of the largest and most complex NPL sites are former mines. For instance, metal ores, primarily copper, have been mined and smelted in the Oquirrh Mountains west of Salt Lake City for over one hundred years.[1] The Kennecott Utah Copper Corporation (Kennecott) conducts most of the mining in the Salt Lake City area, as close as 25 miles to the city. Mining activities at the South Zone began in the 1860s and continue to the present day at the Bingham Canyon open-pit mine. Historically, mining operations produced lead, zinc, silver, copper, molybdenum, and gold ores. For much of that time, environmental safeguards were unheard of, so early miners deposited mining wastes in creeks, floodplains, and valley slopes. These wastes have eroded and washed downstream. Therefore, it comes as no surprise that the streams, soils, and groundwater of the area became heavily contaminated.

Kennecott's contaminated property is a strong candidate for inclusion on the National Priorities List (NPL) and was proposed for the NPL in 1994, but EPA, working in cooperation with representatives of the state as well as Kennecott, chose to allow a private cleanup with joint federal and state oversight. This case study illustrates how EPA can creatively use its authority under Superfund to encourage voluntary cleanups without engaging in the NPL process. At sites such as Kennecott, this approach can result in a less expensive and contentious cleanup that meets stringent EPA environmental and health standards. A combination of factors is motivating Kennecott to work with EPA and state agencies to clean up its land. Because Kennecott felt certain that an NPL cleanup would be far more expensive, EPA was able to use the threat of NPL listing to motivate cooperation. Also, Kennecott's lands are on the fringe of the rapidly growing Salt Lake City metropolis. By cleaning up its property, Kennecott can parlay exhausted mine lands into valuable real estate developments. Lastly, by taking responsibility for its actions and voluntarily cleaning up its property, Kennecott is able to restore and preserve its good reputation with the people of the Salt Lake area.

The Kennecott site includes most of the mining area in the Oquirrh Mountains, the western boundary of the Salt Lake Valley. The huge site area – dozens of square miles – is divided into a South Zone, where ores are mined and concentrated, and a North Zone, where ores are processed and smelted. Ore and tailings mined in the South Zone are sent to the North Zone, 20 miles away, by slurry and rail. The site encompasses a number of communities, including Copperton, Herriman, South Jordan, Riverton, West Jordan, and Magna.

Contaminants found in the South Zone include arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. In the past, before the threat was recognized, homes were built on former flood plains contaminated with high levels of lead and arsenic. Drinking water wells contaminated with cadmium, chromium, and arsenic had to be shut down. Mining wastes have leached acid waters and created a 72-square-mile plume of sulfate-contaminated ground water, forcing a moratorium on well-drilling in the area. The ground water plume has precluded some communities from using the ground water as a municipal water supply, which would otherwise be their primary and least expensive source of drinking water.

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[1] Most of the information used to create this case study was obtained from various documents available on the Internet in February-August 2004. These sources include the following: ATSDR's Public Health Assessment for Kennecott (South Zone), undated, available online at http://www.atsdr.cdc.gov/HAC/PHA; EPA's NPL Site Narrative for Kennecott South Zone, 1994, www.epa.gov/superfund/sites/npl/nar1428.htm; EPA's Fact Sheet for Kennecott South Zone, 2003, www.epa.gov/region8/superfund/sites/ut/kennes.html; EPA's Fact Sheet for Kennecott North Zone, 2003, www.epa.gov/region8/superfund/sites/ut/kennn.html; ATSDR's Public Health Assessment for Kennecott (North Zone), undated, www.atsdr.cdc.gov/HAC/PHA/; http://www.daybreakutah.com/masterplan.shtml. Information was also obtained through a personal interview with Jon Callender of Kennecott Land on June 3, 2004.

Kennecott, and to a lesser extent, ARCO (the Atlantic Richfield Company) are conducting cleanup activities at the South Zone with oversight by state and federal agencies. Removal of the surface wastes was completed in 1999. More than 25 million tons of lead- and arsenic-contaminated mining wastes were removed. The University of Cincinnati conducted a study in 1993 of children under the age of six living in the Bingham Creek area of Kennecott's South Zone. Of the 1,706 eligible children, 971 participated in the investigation, which included an analysis of lead concentrations in the children's blood and arsenic levels in their urine. The study found that two of 284 children from contaminated areas had blood lead levels above 10 µg/L (the level the Centers for Disease Control and Prevention defines as elevated). One child had urine arsenic levels above 20 µg/L. The Agency for Toxic Substances and Disease (ATSDR) conducted a Public Health Assessment (PHA) for the South Zone and analyzed data from the University of Cincinnati study. The agency concluded that before removal of contaminated soil from residential property in the Bingham Creek flood plain, exposure to lead and arsenic may have resulted in a moderate increase in the lifetime risk of cancer. However, the PHA also determined that the subsequent removal of highly contaminated soil near Bingham Creek eliminated a public health hazard. The PHA also points out that children under six in another area of the South Zone, Butterfield Creek, could have adverse health effects from lead in soil if they were exposed to it on a regular basis. The Assessment found that soil lead levels of 1,000 mg/kg could increase lead levels in blood from 0.7 to 68 µg/dL with an average increase of 4 to 5 µg/dL. The health effects of such an increase would depend on the existing burden of lead in the body. The PHA concluded that residents on 30 properties at Butterfield Creek may have been exposed to high levels of lead and arsenic and that this health hazard will not be eliminated until the removal of contaminated soil there is complete.

The long-term remediation of contaminated ground water at the South Zone is underway. ATSDR's Public Health Assessment for the South Zone states that ground water monitoring and Kennecott's provision of alternate water supplies have greatly reduced the potential for exposure to sulfate-contaminated ground water.

Kennecott's North Zone is situated at the north end of the Oquirrh Mountains, on the south shore of the Great Salt Lake. Metal ores have been smelted and processed here for almost one hundred years, resulting in contaminated sludge, soil, surface water, and ground water. Lead, arsenic, and selenium are the main contaminants of concern. A plume of selenium-contaminated ground water is entering nearby wetlands through springs and seeps; this is a cause for concern because birds are particularly sensitive to selenium. Kennecott, as the primary landowner and only responsible party at the North Zone, is solely responsible for the area's cleanup.

Removal of the North Zone's surface wastes was completed in 2001. Sludges produced by the treatment of processing waters from the refinery and smelter were excavated and deposited in an on-site repository, along with contaminated soils found during the modernization of the smelter and refinery. The Kennecott site remediation provides another example of EPA's ability to address complex environmental problems with innovative approaches. To treat the groundwater plume, microbes that reduce selenium contamination will be injected into the aquifer.

In addition to the "stick" of potential NPL listing, there is also a "carrot" motivating Kennecott's cleanup activities. Salt Lake City's rapid growth has created lucrative development opportunities for Kennecott, which is a major landholder in the Salt Lake City suburbs. Kennecott's first major real estate development is Daybreak, a master-planned community in South Jordan slated to contain over 13,000 homes and millions of square feet of retail, office, and industrial space. Kennecott understands that cleaning up its property is an essential step in transforming depleted minelands into valuable real estate development opportunities.

Although the Kennecott site was never listed on the Superfund National Priorities List, its cleanup can be considered a major accomplishment of the Superfund program and law. The threat of NPL listing, with the additional expense and time it would entail, has served as a potent tool in motivating Kennecott to clean up the site voluntarily. CERCLA's enforcement and liability provisions, together with Kennecott's real estate opportunities, have resulted in the cleanup of extensive, serious contamination of roughly 93,000 acres.

Estimating benefits from NRDAs
This section contains a description of how the information contained in NRDAs can be used to estimate the benefits of natural resource restoration. It provides a theoretical discussion and a brief example.

The goal of Superfund responses is to remove hazardous substances from natural resources, to prevent them from entering the environment in the first place, or to isolate the substances and prevent further migration. The ecological benefit of the response and/or restoration is the resulting increase in the service flows derived from the improved natural resource. As defined in the courts and in practice, NRDAs cover damages prior to and during response actions, as well as residual damages, if any, following the response and/or removal. The increase in service flows following the removal and/or restoration is not included in this calculation. In effect, NRD claims compensate the public for damages not mitigated by response actions, and the NRD provisions in CERCLA are consistent with a substantial body of law and economics literature that argues that, in order to provide adequate incentives for firms to take precautions to prevent harm to the environment, the responsible parties should bear the full social cost of accidents. More importantly, NRDAs use accepted economic valuation approaches to estimate standard economic measures of WTP, so the information contained in NRDA reports may be useful.

Figure 5.3 illustrates these ideas and suggests several possible outcomes following releases.[10] The horizontal axis represents time, and the vertical axis represents the value of services provided by an ecosystem. Originally, a resource provides a service flow that is valued by various people. This value fluctuates somewhat based on both physical and social factors (e.g., rainfall, or the popularity of sport fishing). At some point hazardous substances are released to the environment, injuring the resource in some way. The figure shows this as a rapid event, but this need not be the case – the damage could occur over a long period of time, as suggested by the “chronic” designation by NOAA for some NRDs.

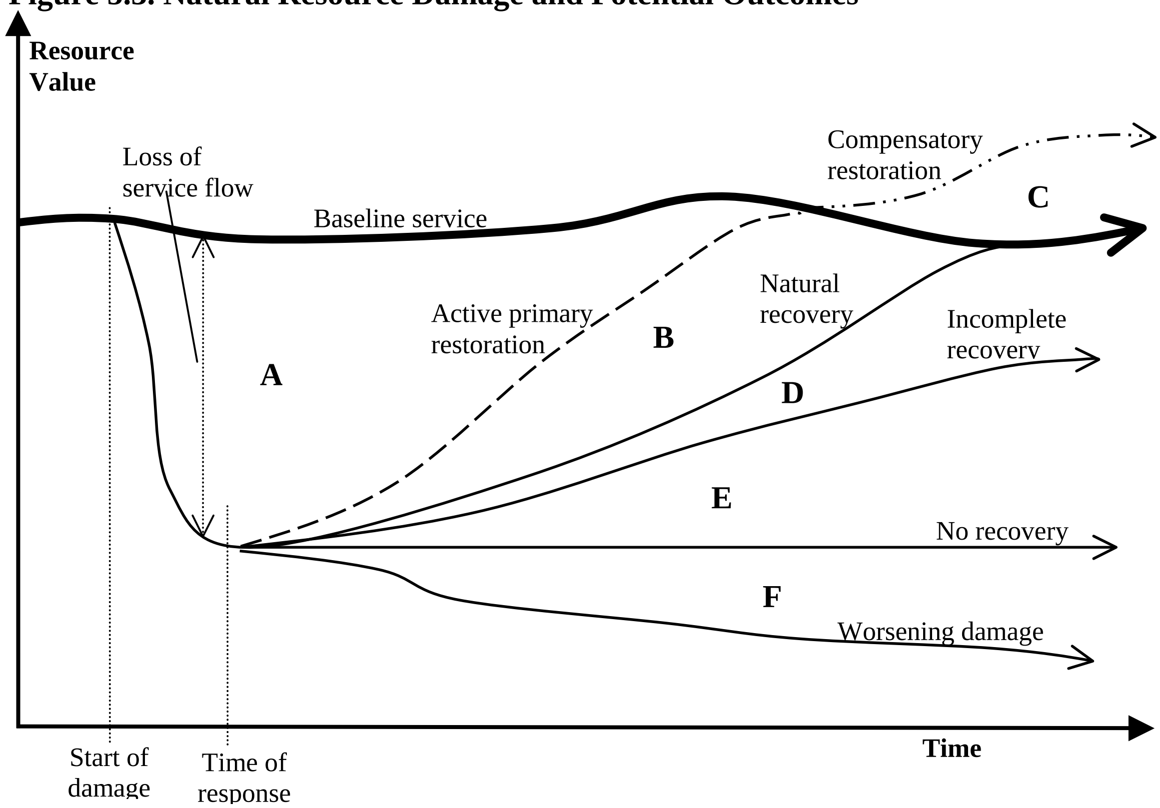
For instance, consider a spill of a hazardous chemical that flows into a tidal wetland area. The spill kills some of the wetland vegetation, and in addition birds, fish, and other animals are exposed to the hazardous substance. The loss of vegetation will reduce the amount of food and shelter (both ecological services) available and the exposure may impair the health or reproduction of wildlife. Other on-site ecological services provided by the wetland that may be impaired by the spill include sediment stabilization, nutrient cycling, and primary productivity. Potentially affected off-site human services, supported by the on-site ecological functions, may include water quality improvements, storm protection, and flood control for shoreline properties, as well as bird watching and commercial and recreational fishing.

If the release stops, for instance if manufacturing operations cease and discharges of pollutants to a water body end; the NRD might take one of several paths shown on Figure 5.3. Damages may remain the same or increase (i.e., the value of the service flow decreases further) until the response occurs. Consider the case of a mining operation that leaves a significant amount of acid-causing mine spoils. These wastes cause damage to the nearby streams and rivers, and

[10] Similar concepts and illustrations are presented in various places in the literature (Kopp and Smith 1989; Carson, Hanemann et al. 1994 p. 248; Jones 2000; Stratus Conusulting 2000, 692.)

continue to do so for year after year. While the mining operations continue, the amount of spoils grows, and the damage continues. At some point, mining stops and, typically, the spoils are left as the firm moves on or goes out of business. The future of the stream might take one of several different paths at this point. The resource might recover naturally. Alternatively, the resource might recover partially, following the "incomplete recovery" path. It might never recover (or not for several generations), so that the resource value would follow the horizontal "no recovery" path. Finally, the resource might continue to degrade, or an engineering solution (e.g., a dam to hold back mine tailings in a river) might fail, reducing ecological service flows further. Then the service flow would follow the "worsening damage" path into the future.

Figure 5.3. Natural Resource Damage and Potential Outcomes



Note: Adapted from (Jones 2000; Breffle et al. 2005).

If a response or a restoration occurs, then the future path changes. For instance, a response action might change the path away from worsening damage to a path that partially restores the service. An example might be a case where abandoned hazardous materials leaking into ground water are destroyed or isolated due to a removal or a remedial action. However, these effects might go largely unrecorded unless there is a programmatic reason to make note of this. In addition, ecological risk assessments are expensive and so such analyses are unlikely to be undertaken. Thus, the ecological benefits of most responses are likely to remain unknown.

The upward change in service flow back towards the baseline could be accelerated by active restoration if a trustee undertakes activities such as restocking a stream that was negatively affected by the contaminated ground water. This could move the future path from, for instance, incomplete recovery to a quicker return to ecosystem health along the "active restoration" pathway. Under some conditions, the ecological service might be enhanced, so the value rises above the historical baseline.

It is possible to define several areas in Figure 5.3 that relate to various losses in service flows. For instance, area *A* is the loss in service flow that occurs prior to any response, plus all subsequent losses, assuming the future of the site is described by the active primary restoration path. Consider the interim period from the time of response to the completion of recovery. The interim lost value associated with the natural recovery scenario (areas *A* + *B*) is higher than for the scenario with active primary restoration actions (area *A*). However, the lost value if no response action occurs, is even larger, either *A*+*B*+*D* if the recovery would be incomplete without response action, or *A*+*B*+*D*+*E* if the resource would not recover without the response action, or *A*+*B*+*D*+*E* +*F* if the response action stopped further damage from occurring. Note that the values for *D*, *E* and *F* as they are shown in Figure 5.3 are not discounted. While it is not difficult to understand how a change in service flows could persist for a very long time (decades to centuries), how to consider values in the distant future is quite complex, as discussed below.

Standard economic theory on benefits identifies the loss of service as a real loss to society, but the compensation paid to the trustee is simply a transfer payment, not a net gain in social welfare. Only the reversal of the physical injury creates a net benefit. The costs of response and restoration are still net costs, and should be minimized.

Estimates of damages and benefits differ in other ways as well. An important distinction is in discounting. The interim damages that NRDAs focus on may last a few years, or several decades, while the benefits created by natural resource restoration may last considerably longer, perhaps centuries. The treatment of benefits in the distant future is not settled in economic theory, and regulations and practice vary significantly on this topic. For instance, Howarth suggests very low (as low as zero) discount rates might be applied in some long-term situations, while Arrow and Manne suggests more standard discount rates of over 5% (Howarth 2003; Arrow 1999; Manne 1995). Some experts have suggested using time-varying discount rates, or choosing the discount rate based on various criteria of the problem at hand (Weitzman 1999; Moore et al. 2004). Practice in conducting NRDAs often leads to losses at a 3% rate, no matter how far into the future, while the EPA *Guidelines* recognize that discounting may sometimes be inappropriate for inter-generational environmental impacts. Thus, they indicate that a "no discounting" scenario should be considered for inter-generational effects (pp. 48-52) and that the way to do this is to display a stream of undiscounted costs and benefits. However, these streams should not be summed. It is not clear what "inter-generational" means in this context; however, the mean and median age of mothers in the United States is about 27 years, so an effect that occurs over more than 30 years could be considered inter-generational (Mathews and Hamilton 2002). Others suggest a 50-year definition (Moore et al. 2004).

Trustee claims about NRDs focus on losses in the past and during the interim before the resource is fully restored, which is area *A* in the figure. In addition, consent decrees include the costs of restoration and the costs of assessment activities. However, some ecological service increases represented by areas B, D, E, and F will also occur. These are the desired outcomes of the response and/or restoration, not the residual damage, and may constitute the majority of the ecological benefits of the Superfund program for that particular site. Although these benefits are not at issue in NRD lawsuits and are not always studied in NRDAs, it is possible to use the data in NRDAs to estimate benefits.

Figures 5.4 and 5.5 are stylized versions of the previous figure that show how ecological benefits will be estimated in this study for two types of sites. Figure 5.4 assumes that the resource recovers naturally over some time period, and that the response and restoration occur instantaneously. In this case, the area of triangle A' represents the past interim losses due to diminution of ecological service flows. The area of triangle A" represents the prospective interim losses imposed on the public while the restoration occurs. In some cases both areas represented by A' and A" are considered interim losses. In other cases, past losses are ignored Neither of these is a benefit. Rather, the area of triangle B represents the benefit of the combined response/restoration. NRDAs typically calculate past and prospective interim losses, represented by the magnitudes of triangles A' and A", although past losses are not always calculated (e.g., Carson et al. 1994; Stratus Consulting 2000). They also typically calculate the costs of the restoration itself, as well as the cost of the assessment.

To use a simple example, assume that it takes ten years from the time of response to the time to restoration, and that natural recovery takes 100 years from the time of response. It is not clear if this should be treated as an intergenerational effect or not. The effect is not permanent, but much of it occurs over a time period grater than thirty years. Thus, using NDRA-derived data about interim damages to understand benefits depends significantly upon assumptions about discount rates. Some parts of the benefits of natural recovery, in this case, would meet the definition of inter-generational given above, suggesting that conventional approaches to discounting might be inappropriate.

Figure 5.5 is a similar stylized representation of the case where there is no recovery without restoration. Some large NRD sites seem to be like this, including Eagle Mine, Idarado, Blackbird Mine, the Clark Fork River, and the Calumet River (Kopp and Smith 1989; State of Idaho vs. M. A. Hanna Company 1995; Stratus Consulting 2000; Industrial Economics Inc. 2004). As in the previous image, the benefit of the response/remedial action is much larger than the interim losses.

Figure 5.4. Natural Resource Benefits with Natural Recovery

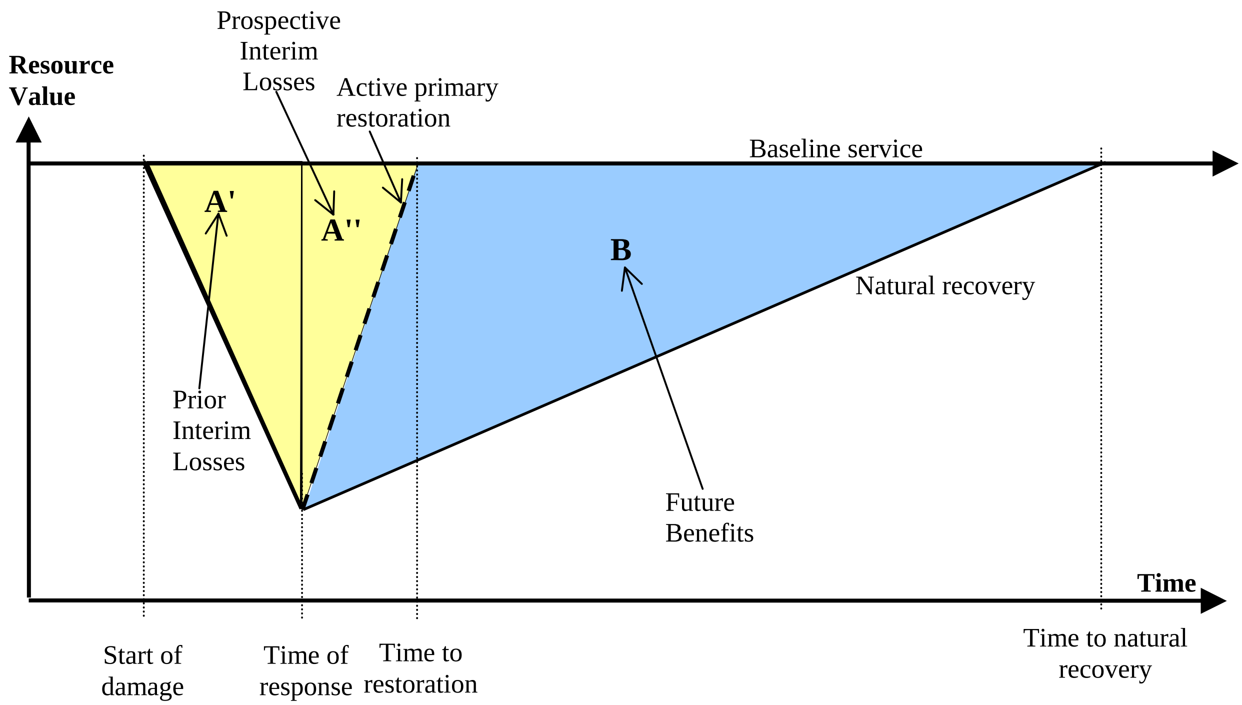
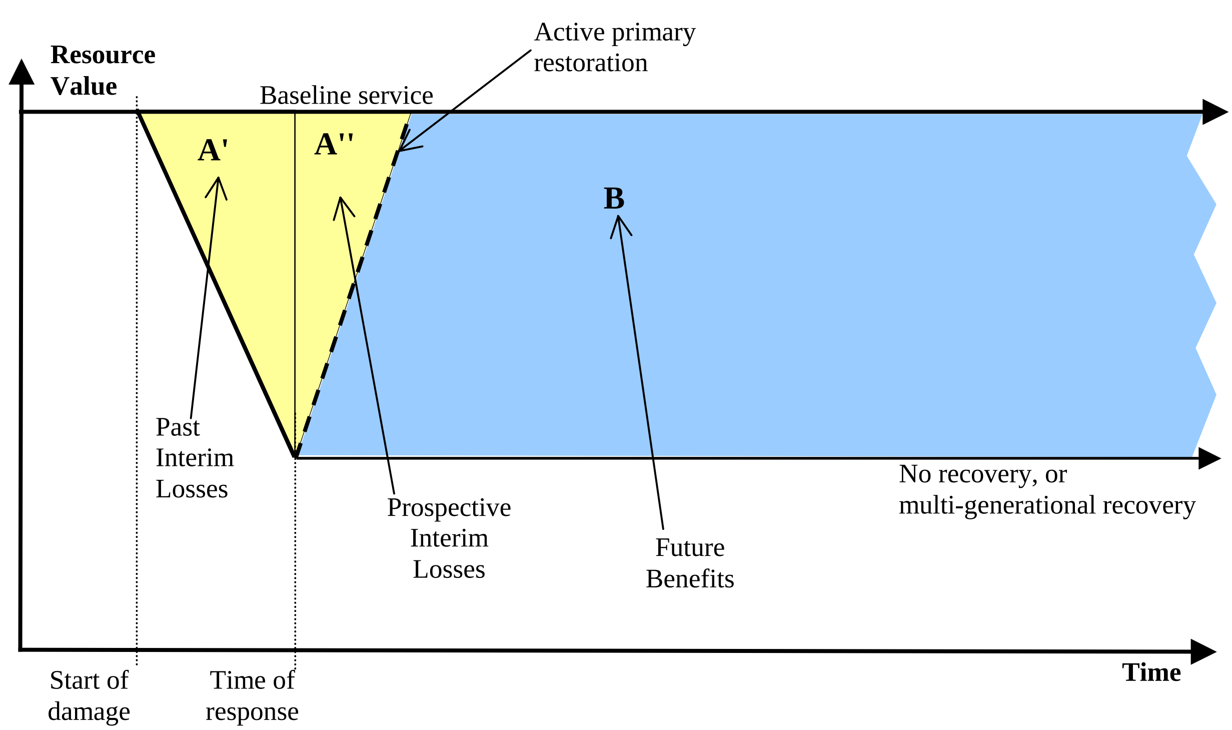
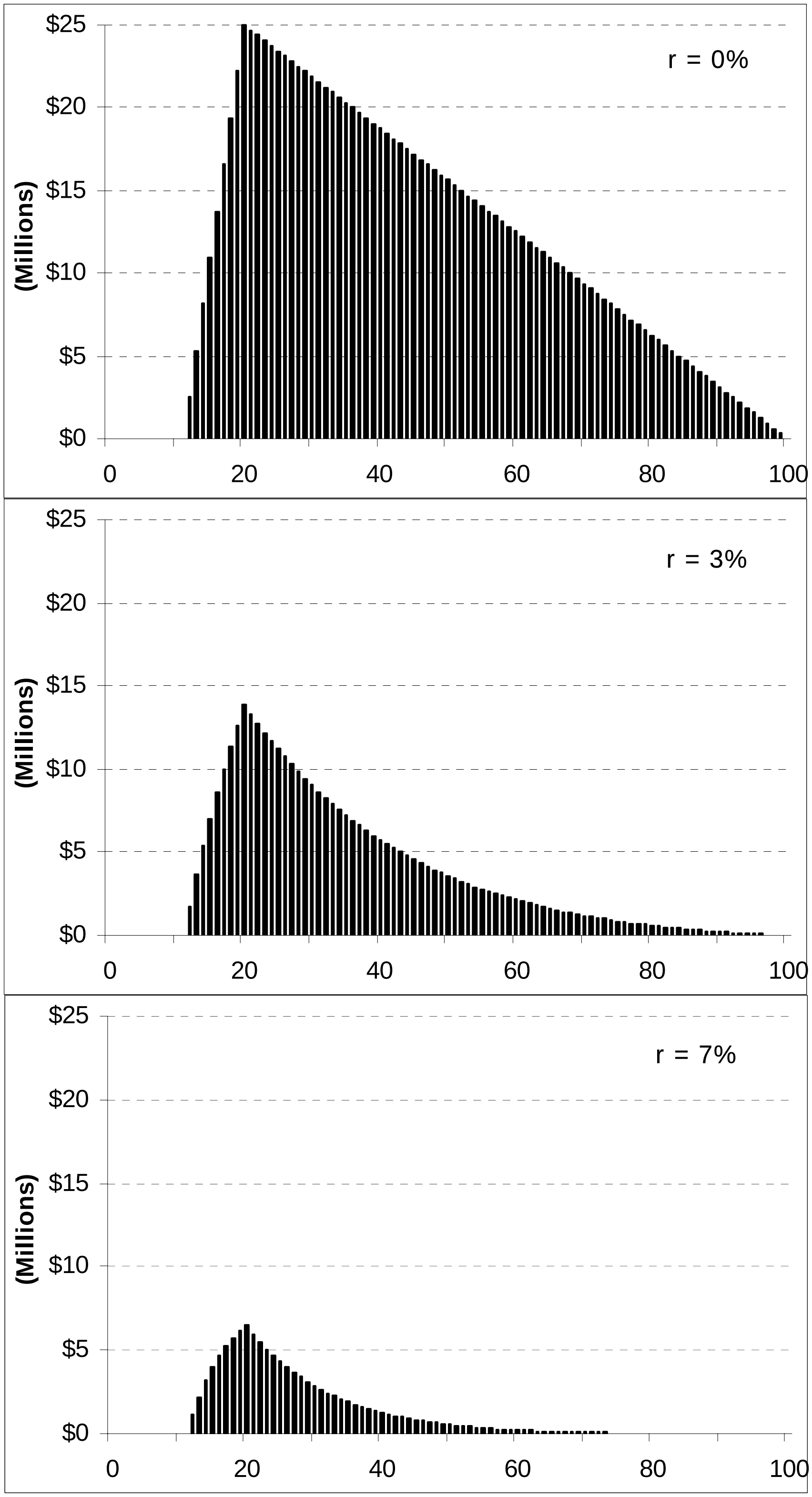


Figure 5.5. Natural Resource Benefits with No Recovery



Data from the Lower Fox River NRDA and settlement can be used to illustrate the approximate magnitude of benefits that the procedure described above produces, and the impact of different choices of discount rates. For the Lower Fox River, the settlement amount is estimated at $42 million, and the present value of the partial WTP for the resulting change is $356 million (The United States of America and The State of Wisconsin v. Fort James Operating Company Consent Decree 2002; Stratus Consulting 2000). The present value of the benefits was created using a 3% discount rate, which was removed to create real, undiscounted annual values for this analysis. This change accelerated the restoration of the ecosystem to twenty years, from a hundred. Figure 5.6 shows how these benefits compare with one another, assuming that benefits do not begin to occur until two years after the completion of a ten-year natural resource restoration, and that natural recovery would have occurred over the course of 100 years. Because benefits are being plotted, not reductions in service flows, the values are positive. The peak benefits occur in about year 20, but the actual value depends strongly on the discount rate that is applied. Annual benefits are shown for discount rates of 0%, 3%, and 7%.

Figure 5.6: Benefits of Restoration of the Lower Fox River, Using Three Different Discount Rates. (2000 $).



Sources: see text.

Further examples of this sort of analysis would better illuminate the potential size of the ecological benefits of the Superfund program. Because a small number of NRD cases make up a large fraction of the settlement total, it may be the case that these natural resource restorations create a significant fraction of the total benefits as well. If the NRDAs for several of the larger cases are located, then a significant fraction of the ecological benefits of natural resource restorations under CERCLA might be estimated. However, smaller settlement amounts may be based on a variety of issues not related to the damages at the site or the potential benefits of restoring the natural resource. Investigation of some smaller NRD cases would be needed to understand this issue better.

If sufficient examples were gathered, it might be possible to extend this analysis and possibly apply the more-widely available data to obtain a more complete estimate of this benefit. One approach might be to take the following steps. First, the size of existing NRD settlements in dollars would be determined. Second, for cases where NRDA data are available, determine the relationship between NRDA estimate of the damages and the NRD settlement. Third, for these cases, use the method described above to estimate the relationship between NRD estimate of damages and the benefits of restoration. These values could be compared across different NRD cases to determine if an estimate for typical values for these ratios can be determined. These estimates might only apply to certain types of NRD cases, for instance river ecosystems. If typical values can be determined, they might be applied in a benefits transfer approach to other NRD cases. However, the number of cases in which NRDA data is available may be insufficient to allow this approach to yield useful results.

This discussion stops here without completing the analysis by agreement with the EPA's EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed upon process is for EPA to provide a description of the data and proposed methodology now and submit a completed analysis based on input received from the Advisory Panel on the intended approach..

Ground Water

Overview

A key goal of Superfund, and in particular of remedial actions at NPL sites, is the protection of ground water. Previous studies of Superfund stress the importance of "environmental and welfare risks that sites pose in addition to current and future health risks … [including] the nonuse value of ground water, which includes the psychological comfort of knowing that ground water is clean" (Walker, Sadowitz, and Graham 1995, 49-50). These authors conclude that, "one of the hidden yet worthy objectives of the program is to protect the quality of our nation's ground water for future yet unspecified uses by humans and nonhuman species". Therefore, the benefits of protecting (or restoring) ground water include not only the willingness to pay for current changes in quantity or quality, but also option, bequest, and existence values. In this study, the amount of ground water protected by Superfund is quantified and a benefits transfer approach is used to monetize the value of protecting ground water. Service flows associated with ground water include domestic uses (i.e., drinking water), water for livestock, commercial use, industrial use, and crop irrigation. Ground water provides these service flows not only to current generations, but to future generations as well.

The purpose of this section is to describe the literature and data associated with the benefits of mitigating ground water contamination and protecting ground water from further contamination. Several approaches that might be used to quantify, and possibly even monetize, the ground water-related benefits of Superfund are described.

Literature on ground water benefits

The existing literature contains many studies that discuss the theoretical aspects of estimating the option, existence, or bequest values of ground water. Most prevalent are CVM studies that examine option values. Table 5.6 summarizes some of the key results in the ground water literature, much of which appears in a recent volume. The two studies in that book that use benefits transfer mainly explore the problems associated with transferring benefits from one ground water study to another and present a fairly skeptical view (Delavan and Epp 2001; VandenBerg et al. 2001). However, the summary chapter is somewhat more positive, arguing that although both benefits transfer studies indicate that the approach does not work well when undertaken between states, “credible transfers could be conducted within each state” (Bergstrom et al. 2001). These authors also believe that there is hope for using benefits transfer techniques in the future but that more research is needed before widespread use is undertaken.

In order to determine the amount of benefits the Superfund program provides related to ground water, the amount of ground water that is contaminated and will ultimately will be remediated or restored through Superfund must be estimated. In addition, it would be useful to know the amount of ground water that will not be contaminated because of Superfund, but would have been contaminated had no Superfund program ever come into being. Quantifying the amount of ground water contaminated on NPL sites is difficult. An estimate of site size in terms of the number of acres can be made, and the sites with contaminated media of ground water can be extracted from CERCLIS. However, this does not provide data on the quantity of ground water that is contaminated, due to the three-dimensional variability of ground water contamination and due to variations in aquifer thickness, porosity, and flow rates.

Monetizing the option, bequest, or existence value of clean ground water is even more difficult. Although there is literature on bequest values, it often does not provide monetized values that would be available for use in a benefit transfer. When values are determined, they are very case-specific and heterogeneous.

Table 5.6. Studies of the Value of Ground Water

Study	Water type	Location	Notes
(Bergstrom, Boyle, and Yabe 2001)	Ground water - nitrate contamination	Georgia and Maine	Do not appear to come up with one range of WTP numbers, but instead estimate several different option price equations and come up with a variety of results for the option price for a ground water protection program in the study counties.
(Delavan and Epp 2001)	Ground water - nitrate contamination	Pennsylvania, Georgia, and Maine	In their benefits transfer study they find that the "difference in mean and median WTP was significant and highly variable with dichotomous choice models but closed rapidly with the addition of a follow-up open-ended question. In short, estimates are easily manipulated and sensitive to methodological changes. Similarly, using the benefits value at one site as the predicted benefits of another would give poor results for benefits transfer in most instances studied."
(Douglas and Taylor 1999)	River stream flows - quantity, not quality	Trinity River, north-central, California	Mean preservation benefits are $106 million for lowest flow and $803 million per year for returning maximum water to the river.
(Dunford 2000)	Ground water - household use only	N/A	"Any potential nonuse values for ground water should be very small from a conceptual perspective, because ground water is ubiquitous. Thus ground-water contamination should not produce significant nonuse damages…..it is very unlikely a reliable estimate of nonuse damages could be developed for ground-water contamination."
(Epp and Delavan 2001)	Ground water - nitrate contamination	Lebanon and Lancaster counties, Pennsylvania	"Estimates of mean and median WTP for the study region are between zero and $67 depending on how the question is asked and whether or not protest bids are included." "…the authors believe that …the mean WTP estimate of $51 should be used."
(Greenley, Walsh, and Young 1981)	River water quality - recreation	South Platte River Basin, Colorado	"WTP additional sales taxes for the option to choose to engage in water-based recreation activities in the future was estimated as $23 annually per household". "About 20 percent of the households interviewed who do not use the River Basin for recreation activities reported they were willing to pay an average of $25 annually for knowledge of the existence of the natural aquatic ecosystem and $17 annually to bequeath clean water to future generations, for a total non-user value of $42 annually". "Average existence value of recreation users was $34 and bequest value $33, for a total non-use value of $67 annually, or 60 percent more."

Table 5.6 (Continued)

Study	Water type	Location	Notes
(Poe 1998)	Ground water - drinking water – nitrate contamination	Portage County, Wisconsin	Their result suggests that estimation of a WTP function for ground water quality is dominated by income and the level of exposure. They say that if their results are supported by future research, transfers of these damage functions to other sites might be accomplished by relatively simple models of income and exposure. They find WTP from $0 for 0 probability of exceeding standards to $516 when probability is 1.
(Poe and Bishop 2001)	Ground water	Portage County, Wisconsin	They "…demonstrate that information effects do occur in risk and exposure perceptions and WTP, and provide the first CVM survey of ground water nitrate contamination to be based on actual exposure levels experienced by respondents." They conclude that "...damage functions based on objective data that is widely available may enhance the possibility of transferring these value to other sites." Their WTP estimates range from $151 for a 0 probability of exceeding standards in the subjective probability model to $569 in the nitrate exposure model when probability is one.
(Poe, Boyle, and Bergstrom 2001)	Ground water	Meta-analysis	They take meta analysis approach where each study is given equal weight. They report three equations, and determine that although there are wide variations in reported WTP values with divergent approaches, the meta analysis indicates that there is a strong systematic element of these studies. They determine that "...the emerging literature on ground water valuation appears to be demonstrating systematic variation."
(Randall, DeZoysa, and Yu 2001)	Enhancements to ground water, surface water, and wetland habitat	Maumee River Basin in northwestern Ohio	They report the estimated mean and lower bound mean WTP ($/household, one time pay) for each of the three programs they offered in their study. All program responses pooled had a median WTP of $32.96 to $52.45, depending on the sample group. Ground water program benefits were $17.55/acre of cropland, while surface water benefits were $26.06/acre cropland, and $21,566 per acre of wetland protected.
(Raucher 1986)	Ground water contamination from waste disposal facilities	Three case studies: 58th Street Landfill in Miami, Davie Landfill near Fort Lauderdale, and Gilson Road Landfill near Nashua, New Hampshire.	They present tables illustrating the benefits and costs for each of the sites with their main conclusions being: 1. potential contamination sites are unique even when similar types exist on the same aquifer 2. benefits do not exceed costs in all cases - responding to an incident may cost less than reducing the probability of contamination 3. corrective actions are not always supported even if drinking water supplies threatened. They use the most economical remedial response costs as an estimate of the benefits of prevention.

Table 5.6 (Continued)

Study	Water type	Location	Notes
(Sun, Bergstrom, and Dorfman 1992)	Ground water - agricultural chemical contamination	Southwestern Georgia	They calculate the mean option price of ground water pollution abatement as $641 annually per household.
(VandenBerg, Poe, and Powell 2001)	Ground water	Twelve towns in Massachusetts, Pennsylvania, and New York	They conduct a benefits transfer using a multi-site CVM study of ground water quality and find evidence to support conclusions that neither the direct nor benefits function transfer approaches are reliable for estimating values at a policy site. However, they think that reliability and accuracy can be improved by grouping sites in meaningful ways. In addition, they find that "...except for the case of the individual site to site transfers, benefit function transfers tend to dominate direct transfers in terms of accuracy."

Therefore, it is not clear if a benefits transfer analysis is appropriate for estimating the value of Superfund in protecting or restoring ground water. However, with ten states of significant diversity included in Table 5.6 (CA, CO, GA, MA, ME, NH, NY, OH, PA, WI), it might be possible to categorize the remaining states into ten relevant categories in order to conduct a benefits transfer analysis.[11] It should be possible to at least quantify the magnitude of the ground water resource that is protected or improved by the Superfund program. The next section addresses this problem.

Ground Water Data

The U.S. Geological Survey reports on water use in the United States (Hutson, Barber, and Kenny 2004). These data show that while the largest use of ground water withdrawals is for irrigation, 23% of ground water withdrawals are used for public and domestic supply. From the perspective of drinking water, 37% of public water supplies are from ground water, as are virtually all private supplies; almost half (46%) of all drinking water in the United States is ground water and thus a large portion of the U.S. population is potentially affected by ground water contamination and remedial action. See Table 5.7.

[11] The EPA Science Advisory Board's advice on this approach, or other, similar approaches, would be greatly appreciated.

Table 5.7. Water Withdrawals in 2000 (million gallons per day)

Water Use Category	Ground water withdrawals	Total water withdrawn from all sources	Ground water withdrawals as percentage of total
Public Supply[12]	16,000	43,300	37%
Domestic[13]	3,530	3,590	98%
Irrigation	56,900	137,000	42%
Livestock	1,010	1,760	57%
Aquaculture	1,060	3,700	29%
Industrial	3,577	19,780	18%
Mining	2,027	3,500	58%
Electric Power	409	195,500	0%
Total	**84,500**	**408,00**	**21%**

Source: (Hutson, Barber, and Kenny 2004)

In order to begin to quantify the amount of ground water potentially protected by Superfund, CERCLIS was queried for sites (NPL and non-NPL) that list one of the contaminated media as ground water. These data were then combined with information from a database that contained information on the size of sites that was created based on RODs, site fact sheets, site list narratives, and CERCLIS. The definition of "site" in CERCLA and the relevant regulations is the extent of contamination, so these site areas give a reasonable measure of the aerial extent of contaminated ground water. The result is list of 1,270 NPL sites with ground water contamination and another 887 non-NPL sites (e.g., sites where response actions have taken place) with ground water contamination. The area of the NPL sites total 4.6 million acres (area data for non-NPL sites are not available). At 162 of the NPL sites with ground water as a contaminated medium, alternative drinking water is one of the response technology types in the CERCLIS database. Many of these areas of contamination have been controlled or reversed through Superfund response actions, and there may be some sites where removal actions or state actions may have prevented potential ground water contamination. Thus, there appears to be a significant ground water resource protected by Superfund, although the actual extent is not clear.

Methodology

This study proposes further investigating these related data in order to better quantify the amount of ground water protected or restored by the Superfund program. It is clear that based on the previous literature, people care about ground water for both current and future generations. This study can probably answer the question, "What fraction of all aquifers in the nation does Superfund protect?" This question could be answered by using the U.S. Geological Survey's

[12] "Public supply refers to water withdrawn by public and private water suppliers that furnish water to at least 25 people or have a minimum of 15 connections. Public water may be delivered to users for domestic, commercial, industrial, or thermoelectric-power purposes." (Hutson, Barber, and Kenny 2004, 13)

[13] Here, "…domestic use refers to self-supplied withdrawals only. For self-supplied domestic water, the source usually is a well." (Hutson, Barber, and Kenny 2004, 16)

GIS map layer that gives the principal aquifers in the U.S. If these data are combined with the latitude and longitude and acreage data for the CERCLIS sites with ground water as a contaminated media, then an estimated fraction of the U.S. aquifers that are affected by Superfund could be obtained. It might be possible to go further and estimate the amount of ground water that will not be contaminated because of Superfund, but would have been in the baseline case where no Superfund program had ever come into being.

This study further proposes doing a meta-analysis of individual studies to get a range of willingness to pay for ground water quality, and possibly placing states into groups based on relevant metrics. This WTP range and category-based estimate could then be compared with some uniform metric such as household income. This may allow the development of a WTP for ground water as a percentage of income. The feasibility of this approach would depend on the ability for both the effect of Superfund on ground water quality and the WTP for ground water quality to be estimated in compatible units.

This discussion stops here without completing the analysis by agreement with the EPA's EPA Science Advisory Board's Environmental Economics Advisory Committee. The agreed upon process is for EPA to provide a description of the data and proposed methodology now and submit a completed analysis based on input received from the Advisory Panel on the intended approach.

References

Agency for Toxic Substances and Disease Registry. 2003a. ATSDR CEP Site Count Report.

———. 2003b. CERCLA Priority List of Hazardous Substances.

Anonymous. 2003. Birth defects surveillance data from selected states, 1996-2000. *Birth Defects Research Part a-Clinical and Molecular Teratology* 67 (9):729-818.

Arrow, K., R. Solow, P. R. Portney, E. E. Leamer, R. Radner, and H. Schuman. 1993. Report of the NOAA Panel on Contingent Valuation. 58 *FR*. 4601-4614.

Arrow, K. J. 1999. Discounting, Morality, and Gaming. In *Discounting and Intergenerational Equity*, edited by P. R. Portney and J. P. Weyant. Washington, DC: RFF Press.

Aschengrau, A., A. Beiser, D. Bellinger, D. Copenhafer, and M. Weitzman. 1994. The Impact of Soil Lead Abatement on Urban Childrens Blood Lead Levels - Phase-Ii Results from the Boston-Lead-in-Soil-Demonstration-Project. *Environmental Research* 67 (2):125-148.

Barnthouse, L. W., and R. G. Stahl. 2002. Quantifying natural resource injuries and ecological service reductions: Challenges and opportunities. *Environmental Management* 30 (1):1-12.

Bergstrom, J. C., K. J. Boyle, and M. Yabe. 2001. Determinants of Ground Water Quality Values: Georgia and Maine Case Studies. In *The Economic Value of Water Quality*, edited by J. C. Bergstrom, K. J. Boyle and G. L. Poe. Northhampton, MA: Edward Elgar.

Bergstrom, J. C., T. P. VandenBerg, and G. L. Poe. 2001. Summary and Conclusions. In *The Economic Value of Water Quality*, edited by J. C. Bergstrom, K. J. Boyle and G. L. Poe. Northhampton, MA: Edward Elgar.

Berkowitz, Z., H. X. Barnhart, and W. E. Kaye. 2003. Factors associated with severity of injury resulting from acute releases of hazardous substances in the manufacturing industry. *Journal of Occupational and Environmental Medicine* 45 (7):734-742.

Berkowitz, Z., G. S. Haugh, M. F. Orr, and W. E. Kaye. 2002. Releases of hazardous substances in schools: Data from the Hazardous Substances Emergency Events Surveillance system, 1993-1998. *Journal of Environmental Health* 65 (2):20-27.

Berry, M., and F. Bove. 1997. Birth weight reduction associated with residence near a hazardous waste landfill. *Environmental Health Perspectives* 105 (8):856-861.

Binder, S. 1989. Deaths, Injuries, and Evacuations from Acute Hazardous Materials Releases. *American Journal of Public Health* 79 (8):1042-1044.

Boon, D. Y., and P. N. Soltanpour. 1992. Lead, Cadmium, and Zinc Contamination of Aspen Garden Soils and Vegetation. *Journal of Environmental Quality* 21 (1):82-86.

Bove, F., Y. Shim, and P. Zeitz. 2002. Drinking water contaminants and adverse pregnancy outcomes: A review. *Environmental Health Perspectives* 110:61-74.

Bove, F. J., M. C. Fulcomer, J. B. Klotz, J. Esmart, E. M. Dufficy, and J. E. Savrin. 1995. Public Drinking-Water Contamination and Birth Outcomes. *American Journal of Epidemiology* 141 (9):850-862.

Breffle, W. S., E. R. Morey, R. D. Rowe, and D. M. Waldman. 2005. Combined Stated-Choice and Stated-Frequency Data with Observed Behavior to Value NRDA Compensable Damages: Green Bay, PCBs and Fish Consumption Advisories. In *The Handbook of Contingent Valuation*, edited by D. J. Bjornstad, J. Kahn and A. Alberini. Northhampton, MA: Edward Elgar.

Brown, M. J. 2002. Costs and benefits of enforcing housing policies to prevent childhood lead poisoning. *Medical Decision Making* 22 (6):482-492.

Burgess, J. L., D. F. Kovalchick, J. F. Lymp, K. B. Kyes, W. O. Robertson, and C. A. Brodkin. 2001. Risk factors for adverse health effects following hazardous materials incidents. *Journal of Occupational and Environmental Medicine* 43 (6):558-566.

Carpenter, D. O., Y. Shen, T. Nguyen, L. Le, and L. Lininger. 2001. Incidence of Endocrine Disease among Residents of New York Areas of Concern. *Environmental Health Perspectives* 109 (Supplement 6):845-851.

Carson, R. T., W. M. Hanemann, R. J. Kopp, J. A. Krosnick, R. C. Mitchell, S. Presser, P. A. Ruud, and V. K. Smith. 1994. Prospective Interim Lost Use Value Value Due To DDT and PCB Contamination in the Southern California Bight (Vol. 1). Washington, DC: National Oceanographic and Atmospheric Administration (NOAA).

Castilla, E. E., J. S. Lopez-Camelo, H. Carnpana, and M. Rittler. 2001. Epidemiological methods to assess the correlation between industrial contaminants and rates of congenital anomalies. *Mutation Research-Reviews in Mutation Research* 489 (2-3):123-145.

Costas, K., R. S. Knorr, and S. K. Condon. 2002. A case-control study of childhood leukemia in Woburn, Massachusetts: the relationship between leukemia incidence and exposure to public drinking water. *Science of the Total Environment* 300 (1-3):23-35.

Croen, L. A., G. M. Shaw, L. Sanbonmatsu, S. Selvin, and P. A. Buffler. 1997. Maternal residential proximity to hazardous waste sites and risk for selected congenital malformations. *Epidemiology* 8 (4):347-354.

Damage Assessment and Restoration Program (DARP). 2004. Natural Resource Damage Settlements and Judgments. Washington, DC: National Oceanic and Atmospheric Administration.

Deis, D. R., and D. P. French. 1998. The use of methods for injury determination and quantification from natural resource damage assessment in ecological risk assessment. *Human and Ecological Risk Assessment* 4 (4):887-903.

Delavan, W., and D. J. Epp. 2001. Benefits Transfer: The Case of Nitrate Contamination in Pennsylvania, Georgia and Maine. In *The Economic Value of Water Quality*, edited by J. C. Bergstrom, K. J. Boyle and G. L. Poe. Northhampton, MA: Edward Elgar.

Desvousges, W. H., and R. W. Dunford. 1992. Russian River Basin Formaldehyde Release. In *Natural Resource Damages: Law and Economics*, edited by K. M. Ward and J. W. Duffield. New York: John Wiley & Sons.

Dolk, H., and M. Vrijheid. 2003. The impact of environmental pollution on congenital anomalies. *British Medical Bulletin* 68:25-45.

Dolk, H., M. Vrijheid, B. Armstrong, L. Abramsky, F. Bianchi, E. Garne, V. Nelen, E. Robert, J. E. S. Scott, D. Stone, and R. Tenconi. 1998. Risk of congenital anomalies near hazardous-waste landfill sites in Europe: the EUROHAZCON study. *Lancet* 352 (9126):423-427.

Douglas, X., and X. Taylor. 1999. The Economic Value of Trinity River Water Resources Development. *Water Resources Development* 15 (3):309-322.

Dunford, R. W. 2000. Estimating ground-water damages from hazardous-substance releases. *Journal of Water Resources Planning and Management-Asce* 126 (6):366-373.

EPA Science Advisory Board. 2002. Underground Storage Tanks (UST) Cleanup & Resource Conservation & Recovery Act (RCRA) Subtitle C Program Benefits, Costs, & Impacts (BCI) Assessments: An SAB Advisory. Washington, DC: USEPA.

Epp, D. J., and W. Delavan. 2001. Measuring the Value of Protecting Ground Water Quality from Nitrate Contamination in Southeastern Pennsylvania. In *The Economic Value of Water Quality*, edited by J. C. Bergstrom, K. J. Boyle and G. L. Poe. Northhampton, MA: Edward Elgar.

Farrell, K. P., M. C. Brophy, J. J. Chisolm, C. A. Rohde, and W. J. Strauss. 1998. Soil lead abatement and children's blood lead levels in an urban setting. *American Journal of Public Health* 88 (12):1837-1839.

General Accounting Office. 1999. Superfund Program: Activities of the Agency for Toxic Substances and Disease Registry and Department of Justice. Washington, DC.

General Electric v. U.S. Department of Commerce (NOAA). 1997. District Court for the District of Columbia. 128 F.3d.

Geschwind, S. A., J. A. J. Stolwijk, M. Bracken, E. Fitzgerald, A. Stark, C. Olsen, and J. Melius. 1992. Risk of Congenital-Malformations Associated with Proximity to Hazardous-Waste Sites. *American Journal of Epidemiology* 135 (11):1197-1207.

Goldberg, S. J., M. D. Lebowitz, E. J. Graver, and S. Hicks. 1990. An Association of Human Congenital Cardiac-Malformations and Drinking-Water Contaminants. *Journal of the American College of Cardiology* 16 (1):155-164.

Greenley, D. A., R. G. Walsh, and R. A. Young. 1981. Option Value - Empirical-Evidence from a Case-Study of Recreation and Water-Quality. *Quarterly Journal of Economics* 96 (4):657-673.

Hall, H. I., V. R. Dhara, W. E. Kaye, and P. Pricegreen. 1994. Surveillance of Hazardous Substance Releases and Related Health-Effects. *Archives of Environmental Health* 49 (1):45-48.

Hall, H. I., G. S. Haugh, P. A. PriceGreen, V. R. Dhara, and W. E. Kaye. 1996. Risk factors for hazardous substance releases that result in injuries and evacuations: Data from 9 states. *American Journal of Public Health* 86 (6):855-857.

Hall, H. I., P. A. Pricegreen, V. R. Dhara, and W. E. Kaye. 1995. Health-Effects Related to Releases of Hazardous Substances on the Superfund Priority List. *Chemosphere* 31 (1):2455-2461.

Hamilton, J. T., and W. K. Viscusi. 1999. *Calculating Risks? The Spatial and Political Dimensions of Hazardous Waste Policy*. Edited by N. L. Rose and R. Schmalensee, *Regulation of Economic Activity*. Cambridge, MA: MIT Press.

———. 1999. How costly is "Clean"? An analysis of the benefits and costs of superfund site remediations. *Journal of Policy Analysis and Management* 18 (1):2-27.

Harrison, R. M. 2003. Hazardous waste landfill sites and congenital anomalies: Where do we go from here? *Occupational and Environmental Medicine* 60 (2):79-80.

Horton, D. K., Z. Berkowitz, and W. E. Kaye. 2004. Surveillance of hazardous materials events in 17 states, 1993-2001: A report from the hazardous substances emergency events surveillance (HSEES) system. *American Journal of Industrial Medicine* 45 (6):539-548.

Howarth, R. B. 2003. Discounting and uncertainty in climate change policy analysis. *Land Economics* 79 (3):369-381.

Hutson, S. S., N. L. Barber, and J. F. Kenny. 2004. Estimated use of water in the United States in 2000. Reston, VA: U.S. Geological Service.

Industrial Economics Inc. 2004. Restoration and Compensation Determination Plan: Grand Calumet River/Indiana Harbor Canal Natural Resource Damage Assessment. Washington, DC: U.S. Fish & Wildlife Service, Indiana Department of Environmental Management.

Jarup, L., D. Briggs, C. de Hoogh, S. Morris, C. Hurt, A. Lewin, I. Maitland, S. Richardson, J. Wakefield, and P. Elliott. 2002. Cancer risks in populations living near landfill sites in Great Britain. *British Journal of Cancer* 86 (11):1732-1736.

Johnson, B. L. 1999. *Impact of hazardous waste on human health : hazard, health effects, equity, and communications issues*. Boca Raton: Lewis Publishers.

Johnson, D. L., and J. K. Bretsch. 2002. Soil lead and children's blood lead levels in Syracuse, NY, USA. *Environmental Geochemistry and Health* 24 (4):375-385.

Jones, C. A. 2000. Economic valuation of resource injuries in natural resource liability suits. *Journal of Water Resources Planning and Management-Asce* 126 (6):358-365.

Kales, S. N., G. N. Polyhronopoulos, M. J. Castro, R. H. Goldman, and D. C. Christiani. 1997. Mechanisms of and facility types involved in hazardous materials incidents. *Environmental Health Perspectives* 105 (9):998-1000.

Khoury, G. A., and G. L. Diamond. 2003. Risks to children from exposure to lead in air during remedial or removal activities at Superfund sites: A case study of the RSR lead smelter Superfund site. *Journal of Exposure Analysis and Environmental Epidemiology* 13 (1):51-65.

Kimbrough, R., M. Levois, and D. Webb. 1995. Survey of Lead-Exposure around a Closed Lead Smelter. *Pediatrics* 95 (4):550-554.

Kopp, R. J., and V. K. Smith. 1989. Benefit Estimation Goes to Court: The Case of Natural Resource Damage Assessments. *Journal of Policy Analysis and Management* 8:593-612.

———. 1989. Eagle Mine and Idarado. In *Natural Resource Damages: Law and Economics*, edited by K. M. Ward and J. W. Duffield. New York: John Wiley & Sons, Inc.

Lanphear, B. P., P. Succop, S. Roda, and G. Henningsen. 2003. The effect of soil abatement on blood lead levels in children living near a former smelting and milling operation. *Public Health Reports* 118 (2):83-91.

Lazo, J. K. 2002. Economic valuation of ecosystem services: Discussion and application. *Drug and Chemical Toxicology* 25 (4):349-374.

Lewin, M. D., S. Sarasua, and P. A. Jones. 1999. A multivariate linear regression model for predicting children's blood lead levels based on soil lead levels: A study at four superfund sites. *Environmental Research* 81 (1):52-61.

Loomis, J. B., and P. Anderson. 1992. Idaho v. Southern Refrigerated. In *Natural Resource Damages: Law and Economics*, edited by K. M. Ward and J. W. Duffield. New York: John Wiley & Sons.

Lorenzana, R. M., R. Troast, M. Mastriano, M. H. Follansbee, and G. L. Diamond. 2003. Lead intervention and pediatric blood lead levels at hazardous waste sites. *Journal of Toxicology and Environmental Health-Part A* 66 (10):871-893.

Luftig, S. D. 1999. Issuance of Final Guidance: Ecological Risk Assessment and Risk Mangement Principles for Superfund Sites. Washington, DC: U.S. Environmental Protection Agency Office of Emergency and Remedial Response.

Lybarger, J. A., R. Lee, D. P. Vogt, R. M. Perhac, R. F. Spengler, and D. R. Brown. 1998. Medical costs and lost productivity from health conditions at volatile organic compound-contaminated superfund sites. *Environmental Research* 79 (1):9-19.

Maisonet, M., F. J. Bove, and W. E. Kaye. 1997. A case-control study to determine risk factors for elevated blood lead levels in children, Idaho. *Toxicology and Industrial Health* 13 (1):67-72.

Manne, A. S. 1995. The Rate of Time Preference: Implications for the Greenhouse Debate. *Energy Policy* 23:391-394.

Marshall, E. G., L. J. Gensburg, D. A. Deres, N. S. Geary, and M. R. Cayo. 1997. Maternal residential exposure to hazardous wastes and risk of central nervous system and musculoskeletal birth defects. *Archives of Environmental Health* 52 (6):416-425.

Mathews, K. E., K. J. Gribben, and W. H. Desvousges. 2002. Integration of Risk Assessment and Natural Resource Damange Assessment: Case Study of Lavaca Bay. In *Human and Ecological Risk Assessment: Theory and Practice*, edited by D. J. Paustenbach. New York: John Wiley and Sons.

Mathews, T. J., and B. E. Hamilton. 2002. Mean Age of Mother, 1970-2002. In *National Vital Statistics Report*. Atlanta, GA: Center for Disease Control.

Moore, M. A., A. E. Boardman, A. R. Vining, D. L. Weimer, and D. H. Greenberg. 2004. "Just give me a number!" - Practical values for the social discount rate. *Journal of Policy Analysis and Management* 23 (4):789-812.

Morey, E. R., W. S. Breffle, R. D. Rowe, and D. M. Waldman. 2002. Estimating recreational trout fishing damages in Montana's Clark Fork River basin: Summary of a natural resource damage assessment. *Journal of Environmental Management* 66 (2):159-170.

Mushak, P. 2003. Lead remediation and changes in human lead exposure: some physiological and biokinetic dimensions. *Science of the Total Environment* 303 (1-2):35-50.

National Association of Manufacturers v. U.S. Department of Interior. 1998. Court of Appeals for the District of Columbia. 134 F.3d.

Office of Solid Waste and Emergency Response. 1992. The Role of Natural Resource Trustees in the Superfund Process. In *ECO Update*. Washington, DC: U.S. Environmental Protection Aggency.

Ofiara, D. D. 2002. Natural resource damage assessments in the United States: rules and procedures for compensation from spills of hazardous substances and oil in waterways under US jurisdiction. *Marine Pollution Bulletin* 44 (2):96-110.

Ohio v. Department of Interior. 1989. D.C. Circuit. 880 F.2nd 432.

Orr, M., F. Bove, W. Kaye, and M. Stone. 2002. Elevated birth defects in racial or ethnic minority children of women living near hazardous waste sites. *International Journal of Hygiene and Environmental Health* 205 (1-2):19-27.

Palmer, S. R., H. Rees, and G. Coleman. 2000. Major chemical incidents: bridging the occupational-public health gap. *Occupational Medicine-Oxford* 50 (4):221-225.

Pastorok, R. A., W. J. Shields, and J. E. Sexton. 2002. Comparison of Aquatic Ecological Risk Assessments at a Former Zinc Smelter and a Former Wood Preservative Site. In *Human and Ecological Risk Assessment: Theory and Practice*, edited by D. J. Paustenbach. Washington, DC: Lewis Publishers.

Paustenbach, D. J. 2002. *Human and Ecological Risk Assessment: Theory and Practice*. New York: John Wiley and Sons.

Poe, G. L. 1998. Valuation of groundwater quality using a contingent valuation-damage function approach. *Water Resources Research* 34 (12):3627-3633.

Poe, G. L., and R. C. Bishop. 2001. Information and the Valuation of Nitrates in Ground Water, Portage County, Wisconsin. In *The Economic Value of Water Quality*, edited by J. C. Bergstrom, K. J. Boyle and G. L. Poe. Northhampton, MA: Edward Elgar.

Poe, G. L., K. J. Boyle, and J. C. Bergstrom. 2001. A Preliminary Meta Analysis of Contingent Values for Ground Water Quality Revisited. In *The Economic Value of Water Quality*, edited by J. C. Bergstrom, K. J. Boyle and G. L. Poe. Northhampton, MA: Edward Elgar.

Probst, K. N., and D. M. Konisky. 2001. *Superfund's Future: What Will It Cost?* Washington, DC: RFF Press.

Randall, A., D. DeZoysa, and S. Yu. 2001. Ground Water, Surface Water, and Wetlands Valuation in Ohio. In *The Economic Value of Water Quality*, edited by J. C. Bergstrom, K. J. Boyle and G. L. Poe. Northhampton, MA: Edward Elgar.

Raucher, R. L. 1986. The Benefits and Costs of Policies Related to Groundwater Contamination. *Land Economics* 62 (1):33-45.

Reisch, M. 2001. Superfund and Natural Resource Damages. In *CRS Report for Congress*, edited by Congressional Research Service. Washington: U.S. Congress.

Schettler, T. 2001. Toxic threats to neurologic development of children. *Environmental Health Perspectives* 109 (Supplement 6):813-816.

Shaw, G. M., J. Schulman, J. D. Frisch, S. K. Cummins, and J. A. Harris. 1992. Congenital-Malformations and Birth-Weight in Areas with Potential Environmental Contamination. *Archives of Environmental Health* 47 (2):147-154.

Sheey, D. J., C. P. Martz, M. C. Stopher, S. M. Turek, J. W. Miller, and J. P. Milton. 2000. Restoration Planning for the Canatara Metam Sodium Spill: A Group Multi-Attribute Decision Analysis Approach. *California Fish and Game* 86 (1):72-86.

Sheldrake, S., and M. Stifelman. 2003. A case study of lead contamination cleanup effectiveness at Bunker Hill. *Science of the Total Environment* 303 (1-2):105-123.

Sosniak, W. A., W. E. Kaye, and T. M. Gomez. 1994. Data Linkage to Explore the Risk of Low-Birth-Weight Associated with Maternal Proximity to Hazardous-Waste Sites from the National-Priorities List. *Archives of Environmental Health* 49 (4):251-255.

State of Idaho vs. M. A. Hanna Company. 1995. U.S. District Court of Idaho.

Stopher, M. C. 2000. Hindsight analysis for the Cantara spill natural resource damage assessment. *California Fish and Game* 86 (1):87-100.

Stratus Consulting. 2000. Restoration and Compensation Determination Plan: Lower Fox River/Green Bay Natural Resource Damage Assessment. Washington, DC: U.S. Department of the Interior, U.S. Department of Justice, Oneida Tribe of Indians of Wisconsin, Menominee Indian Tribe of Wisconsin, National Oceanographic and Atmospheric Administration, Little Traverse Bay Bands of Odawa Indians, Michigan Attorney General.

Sun, X., J. C. Bergstrom, and X. Dorfman. 1992. Estimating the benefits of groundwater contamination control. *Southern Journal of Agricultural Economics* 24 (1):63-71.

Suter, G. W., R. A. Efroymson, B. E. Sample, and D. S. Jones. 2000. *Ecological Risk Assessment for Contaminated Sites*. Washington, DC: Lewis Publishers.

U.S. Environmental Protection Agency. 1996. Regulatory Impact Analysis of Lead - Based Paint Hazard Disclosure Regulation for Residential Renovations. Washington, DC: Office of Pollution Prevention and Toxics.

———. 1998. Guidelines for Ecological Risk Assessment. 63 *FR* 93. May 14. 26846-26924.

———. 1999. Economic Analysis of the Proposed TSCA Section 402(a)(3) Lead-based Paint Accreditation and Certification Fee Rule. Washington, DC: Office of Pollution Prevention and Toxics.

———. 2000. Guidelines For Preparing Economic Analyses. Washington, DC.

———. 2002. Cost of Illness Handbook. Washington, DC.

U.S. Fish and Wildlife Service Region 5 Virginia Field Office. 2002. Certus Chemical Spill Natural Resource Damage Assessment. Gloucester, VA: U.S. Department of the Interior.

The United States of America and The State of Wisconsin v. Fort James Operating Company. Consent Decree. 2002. United States District Court for the Eastern District of Wisconsin.

VandenBerg, T. P., G. L. Poe, and J. R. Powell. 2001. Assessing the Accuracy of Benefits Transfers: Evidence From a Multi-Site Contingent Valuation Study of Ground Water Quality. In *The Economic Value of Water Quality*, edited by J. C. Bergstrom, K. J. Boyle and G. L. Poe. Northhampton, MA: Edward Elgar.

Viscusi, W. K., J. T. Hamilton, and P. C. Dockins. 1997. Conservative versus mean risk assessments: Implications for superfund policies. *Journal of Environmental Economics and Management* 34 (3):187-206.

von Lindern, I., S. Spalinger, V. Petroysan, and M. von Braun. 2003. Assessing remedial effectiveness through the blood lead : soil/dust lead relationship at the Bunker Hill Superfund Site in the Silver Valley of Idaho. *Science of the Total Environment* 303 (1-2):139-170.

von Lindern, I. H., S. M. Spalinger, B. N. Bero, V. Petrosyan, and M. C. von Braun. 2003. The influence of soil remediation on lead in house dust. *Science of the Total Environment* 303 (1-2):59-78.

Vrijheid, M., H. Dolk, B. Armstrong, L. Abramsky, F. Bianchi, I. Fazarinc, E. Garne, R. Ide, V. Nelen, E. Robert, J. E. S. Scott, D. Stone, and R. Tenconi. 2002. Chromosomal congenital anomalies and residence near hazardous waste landfill sites. *Lancet* 359 (9303):320-322.

Waitzman, N. J., P. S. Romano, and R. M. Scheffler. 1994. Estimates of the Economic Costs of Birth-Defects. *Inquiry-the Journal of Health Care Organization Provision and Financing* 31 (2):188-205.

Walker, K. D., M. Sadowitz, and J. D. Graham. 1995. Confronting Superfund Mythology: The Case of Risk Assessment and Management. In *Analyzing Superfund: Economics, Science and Law*, edited by R. L. Revesz and R. B. Stewart. Washington, DC: RFF Press.

Weitzman, M., A. Aschengrau, and D. Bellinger. 1993. Soil Abatement and Lead Levels in Children - Reply. *Jama-Journal of the American Medical Association* 270 (7):829-830.

Weitzman, M., A. Aschengrau, D. Bellinger, R. Jones, J. S. Hamlin, and A. Beiser. 1993. Lead-Contaminated Soil Abatement and Urban Childrens Blood Lead Levels. *Jama-Journal of the American Medical Association* 269 (13):1647-1654.

Weitzman, M. L. 1999. "Just Keep Discounting, But..." In *Discounting and Intergenerational Equity*, edited by P. R. Portney and J. P. Weyant. Washington, DC: RFF Press.

White, R. F., R. G. Feldman, Eviator, II, J. F. Jabre, and C. A. Niles. 1997. Hazardous waste and neurobehavioral effects: A developmental perspective. *Environmental Research* 73 (1-2):113-124.

Williams, P. R. D., and D. J. Paustenbach. 2002. Risk Characterization. In *Human and Ecological Risk Assessment: Theory and Practice*, edited by D. J. Paustenbach. New York: John Wiley & Sons.

Zeitz, P., Z. Berkowitz, M. F. Orr, G. S. Haugh, and W. E. Kaye. 2000. Frequency and type of injuries in responders of hazardous substances emergency events, 1996 to 1998. *Journal of Occupational and Environmental Medicine* 42 (11):1115-1120.

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CHAPTER 6: NON-QUANTIFIED BENEFITS

Introduction

This chapter describes analysis of Superfund program benefits that are not readily quantified due to gaps in data or a lack of suitable methods. The next section describes the relationship between property-based estimates and non-quantified benefits. Using the definitions from Chapter 1, the subsequent sections describe analyses of the benefits of Superfund that cannot be quantified, in turn: improved amenities, reduced material damage, additions to information and innovation, empowerment in solving problems of hazardous substance contamination, deterrence from further uncontrolled releases of hazardous substances, emergency preparedness, and benefits to the international community.

Relationship Between Property-Based Quantitative Benefits and Non-Quantified Benefits

Three benefit categories described here, *amenities*, *ecological*, and *deterrence*, may be partially accounted for by the property value-based benefit estimate presented in Chapter 4, and one category, *empowerment*, may be accounted for by the property value-based estimate almost entirely.[1] The amenities category is partly included in the property value-based benefit estimate because this benefit category includes the removal of unsightly facilities and perceived health risks. The latter may be particularly important to the pricing of homes near National Priorities List (NPL) sites, on which the property value-based benefit estimate relies (Gayer and Viscusi 2002). The deterrence category is partially included in the property value-based benefit estimate because people living near NPL sites may benefit more than the public at large from deterring further uncontrolled releases of hazardous substances.[2] Likewise, the ecological category may also be partially included in the property value-based benefits estimate because people living near NPL sites may benefit more than the public at large from the natural resource enhancements resulting from the Superfund program. The empowerment category is included in the property value-based benefit estimate in its entirety because people living near NPL sites make up the relevant communities and a major benefit of empowerment is the reduced uncertainty about health impacts from sites, likely leading to increased property values.

Although multiple benefit categories are included in the estimate of benefits calculated in Chapter 4, the property-based valuation methodology employed is unable to separate out the values for the different categories from one another. Thus, an individual estimate of any one benefit is not possible. In addition, health and ecological benefits are described in Chapter 5. Therefore, in order to better understand the benefits of the Superfund program, the seven benefits for which no estimate of the individual benefits is available are described in sections below. Brief definitions of these seven benefits are given in Table 6.1, which extracts the relevant categories from Table 1.2.

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[1] See Figure 1.2 and the associated discussion in Chapter 1.

[2] Any overlaps between the benefit estimate in Chapter 4 and categories that affect all Americans equally (e.g., Emergency Preparedness) are ignored.

Table 6.1. Brief Definitions of Non-Quantified Benefits

Benefit	**Definition**
Fundamental	
Amenities	Any feature of a place, object, or experience that enhances its attractiveness and increases the user's satisfaction, but is not essential to the place, object, or experience. In the context of Superfund, amenities include the removal of unsightly structures, the reuse of abandoned property, the avoidance of the stigma associated with contamination, and the reduction of perceived health risks from uncontrolled releases of hazardous substances.
Materials	The reduction of risk and perceived risk associated with non-residential (i.e., commercial and industrial) properties, and the ensuing ability and willingness of the business and financial community to use these properties.
Embedded	
Empowerment	The ability of people who live near Superfund sites (especially NPL sites) to learn about the site(s) of interest, have questions about the site(s) answered, participate in decision-making associated with the site(s), and hold the relevant organizations accountable.
Deterrence	Incentives for firms and individuals that may create or use hazardous substances to handle and dispose of them properly and to avoid uncontrolled releases to the environment.
Emergency Preparedness	The knowledge, skills, organization, and technologies necessary to limit harm to human health and the environment following disasters involving the release of hazardous substances. Includes preparation for natural disasters, homeland security measures, and similar activities.
Information and Innovation	Increases in knowledge and technical capabilities created as a result of research, development, and deployment supported by the Superfund program. This includes both basic scientific research as well as efforts to develop and build experience and confidence in new technologies.
International Benefits	Any benefits from any of the other benefit categories that accrue to people or organizations outside of the United States. These benefits are generally coordinated with the State Department and often involve overseas response actions or training.

Amenities

The *amenities* benefit of Superfund is associated with the removal of unsightly, often abandoned, facilities, as well as the psychological benefits associated with reducing the uncertainty and fear of unknown risks that might exist at nearby hazardous substance facilities. Even in cases where there may be little health risk, psychometric research has shown that individuals can experience genuine discomfort and anxiety if exposed to risks that are dreadful, imposed by others, out of their control, hard to understand, or have other features that hazardous substance sites are likely to have (Slovic et al. 1979; Slovic 1987). These effects can lead to larger, more permanent damages, sometimes called stigma (Gregory et al. 1995; Satterfield et al. 2001). Thus, reduction in perceived risks is likely an important part of the amenities benefit.

It is important to consider if and how the *amenities* benefit would appear in the policy case (i.e., no Superfund program). Without the Superfund program, far fewer responses to uncontrolled releases of hazardous substances would have occurred, and those that did would most likely have taken longer and been less stringent (because without Superfund neither the liability provisions that lead to private funds for response actions nor federal support for response actions would be available). In addition, without Superfund, uncertainties about the extent and impacts of hazardous substances would most likely be far larger and thus the perceived risks would be even larger. (This last effect blurs the distinction somewhat between the *amenities* benefit and the *information and innovation* benefit discussed later.)

Materials

Overview

In terms of avoiding or reversing material damages, the Superfund program often helps convert unusable commercial and industrial properties back into productive real estate. In many cases, the avoided damage is associated with removal of both uncertainty about the presence of hazardous substances and with uncertainty about the cost of restoring the site to a usable condition.

The analysis of residences near NPL sites discussed in detail in Chapter 3 showed that that single-family, owner-occupied, detached homes are the largest residence type, representing 47% of all residences, and that rental single-family detached homes accounted for another 8%. Other owner-occupied residences (duplexes, condominiums, etc.) account for 11%, and multi-family rental housing for 33%. Some studies include condominiums in their data, and the effect on prices for these properties are similar to those for other types (Hite et al. 2001; Ihlanfeldt and Taylor 2004).

Most of the literature on property values and hazardous waste sites, including both theoretical discussions and empirical studies, focuses on residential properties. At the same time, some literature by scholars and practitioners in the real estate field has addressed the impact of hazardous waste sites on commercial and industrial (C&I) properties. In addition, a few recent empirical studies using property-based[3] price theory to evaluate the impacts of C&I property have been published recently. This section reviews the existing literature and synthesizes it. In addition, it reflects the experience of the authors of the SBA in real estate and hazardous waste/brownfields cleanups.

Theory

The theory of hedonic valuation begins with the observation that some products (or commodities) can be differentiated by the amounts of various characteristics they embody (Rosen 1974; Freeman 1993). The consumers of different types of commodities derive utility from the characteristics of the commodities, while producers or sellers incur costs that are dependent on the types of commodities they provide. Hedonic price theory assumes a competitive market in equilibrium and assumes perfect information and zero transaction costs (Palmquist 1992; McConnell 1993). Most applications of property-based price theory to real estate have considered only residential properties (Boyle and Kiel 2001). Many of the most recent and most insightful property-based studies focus on the role of information in changing perceived risk near hazardous waste sites over time (Kiel 1995; McMillen and Thorsnes 2000; Gayer et al. 2002). There are a variety of factors that make it harder to determine condition-specific (proximity to hazardous waste) effects on commercial and industrial property values than it is to determine the effect that these conditions have on residential property values. There

[3] Throughout this study, property-based valuation refers to the economic concept of hedonic based valuation of housing markets as discussed in Chapter 10 of Champ et al. The term property-based valuation is used to facilitate common understanding by non-economists.

are significant differences between residential and C&I property markets, including market size, relevant amenities, structural economic changes, and differences in financing practices.

Market Size

There is a dramatically larger number of willing buyers, sellers, and transactions in the residential market than in either the commercial or industrial markets. (It is important to note that the difference between commercial and industrial is also significant – there are dramatically more commercial transactions than there are industrial). In addition to the much smaller number of properties, individual commercial and industrial properties tend to change hands with less frequency than the average residential property. Thus the quantity and quality of data that would be analyzed are not likely to be as good for C&I properties.

Relevant Amenities

There is a far greater range of amenities affecting price in the residential market compared to commercial properties, and more in commercial than industrial. Residential property owners may be affected by a wide array of factors when purchasing a property, such as school district, views, neighborhood, room sizes, lot size, charm, distance to work, house style, and so forth. While commercial property buyers may consider a number of factors, there are usually one or two factors that far outweigh the rest. The owners of a retail establishment, for instance, may not like the color of the awnings or the size of the bathroom, but they will locate where the most traffic appropriate for their business exists. With an industrial property, easy access to resources and markets will be the primary amenity sought. Quick access to airports is often a key amenity for business locations.

Structural Economic Changes

The resources important to industry, the location of markets, and the transportation networks that we rely on have all changed significantly over the past twenty years and extraordinarily over the past fifty years. Many Superfund sites are located in areas where resources important to yesterday's industries (e.g., mineral deposits and mining companies) and access to yesterday's transportation networks (e.g., river transportation for heavy iron ore, coke and steel) were advantageous. These locations are no longer valuable to today's products and markets. For instance, today's economy in Pittsburgh, Pennsylvania is dominated by education, government, health care, and high tech, none of which need the rivers for transportation. Thus it may be difficult to determine how much of an impact proximity to hazardous waste is having on property values as opposed to general economic decline of a particular industry. These sorts of structural changes need to be considered in the specification of any property-based model. They also need to be considered if the results from one area are to be generalized to another, where different patterns of change may dominate. For instance, estimates based on data from Atlanta may not be appropriate for Pittsburgh, due to vast differences in the patterns of economic growth in these two cities.

Sites on the NPL are often in areas of general economic decline that feature a number of bankruptcies that have nothing to do with the presence of hazardous waste sites. Indeed, bankruptcy may tend to be a cause of NPL status rather than a result. Solvent firms can take steps to avoid NPL listing, including site cleanups and negotiations to avoid listing. The numerous sites that are part of state voluntary programs for hazardous waste cleanup give some evidence of this.

Financing Practice

There are numerous differences between the practices for financing a residential property and a C&I property. One important factor is that due diligence (background investigation) requirements for C&I properties are much greater. Importantly, the concern is typically not the health or environmental risk associated with any contamination, but the cost of the associated liability, which may be far greater. Further, CERCLA's stringent liability provisions can amplify this risk tremendously, leading to concerns by lenders about the ability of borrowers to repay loans at all. This is a major difference between residential and C&I markets that would make the interpretation of property-based studies quite different for the two markets. The lack of financial institutions willing to finance industrial properties with potential contamination can have a dramatic effect on property values. Of course, firms may have recourses other than bank financing (e.g., debt or equity sales), but the amount any organization can afford to pay for a property diminishes dramatically if the purchase (investment) cannot be leveraged. Because the market for residential mortgages is so much larger than that for C&I real estate, and is collateralized by the Federal Home Loan Mortgage Corporation (Freddie Mac), among others, the risks associated with contaminated residences is much less on a proportional basis and much more easily managed.

Other Literature

Table 6.2 briefly describes some of the relevant studies. There are some inconsistencies among various authors. Some papers are anecdotal or theoretical, but five are empirical studies relevant to the cleanup of hazardous waste sites. These are discussed below, in chronological order.

Page and Rabinowitz compared six commercial real estate sites in Pittsburgh, Santa Fe, and Milwaukee with seven residential areas (818 homes), all in areas of ground water contamination (1993). They found significant property value effects in the commercial real estate market, with losses of 10%-50% and some projects simply being put on hold. They note an extreme example: In Wichita, Kansas, eight square miles of ground water contamination in the central business district reduced the assessed value of properties (which accounted for 7% of the city's tax base) by 40%, representing a loss of almost three percent of the city's property tax revenue.

Howland collected data on 480 industrial parcels (1,072 acres) in an area that included at least four closed hazardous waste sites (one of which was on the NPL) (2000). Howland is principally concerned with whether hazardous waste contamination accounts *entirely* for abandoned land use, as suggested by common perceptions and some earlier authors (Patchin 1988; Rinaldi 1991). Howland evaluates the impact of hazardous waste contamination on the supply and demand for industrial land, and finds that "in locations where there is an active market for industrial land, contamination – at least of the sort that exists in Southeast Baltimore – is not a [complete] deterrent to land purchase and reuse. The market operates just as economic theory would suggest: Land sellers can and do lower prices sufficiently to compensate for the costs of remediation and the perceived risks of future cleanup." In the cases she examines, Howland finds that a 55% discount on contaminated land relative to clean sites is sufficient, on average, to enable sales.

Schoenbaum conducted a similar study, also in Baltimore, in order to examine the validity of the assumption underlying brownfields legislation that real or potential environmental contamination systematically affects land use and economic value (2002). For various reasons, sale prices could not be used in this study, so assessed values were employed. Schoenbaum discusses the conceptual framework for urban land value and development and appears to take into consideration many of the theoretical issues discussed above. She states, "No systematic relationships were found between environmental contamination, on the one hand, and either land values (assessed), land vacancy, property turnover, or changes in economic development." However, Schoenbaum goes on to say that this "does not mean that environmental contamination is irrelevant. Indeed, numerous case studies have shown that it can be a substantial obstacle, and that removal of that obstacle by brownfields policies can lead to redevelopment of contaminated parcels. But if pollution alone does not cause vacancy and under use, as this study suggests, then brownfields legislation alone will presumably fail to solve the problem."

More recently, Howland examines three case studies in detail, all of which are in Baltimore to control for structural economic conditions and policies (2003). This study finds that somewhat different factors are important to redevelopment than did an earlier study that used survey and interview data (Meyer and Lyons 2000). Key factors include strong market demand for the project, retention of commercial or industrial use (instead of a switch to residential), higher levels of contamination, a novice developer (for this type of property), and bureaucratic delays.

A detailed property-based study of C&I properties in Fulton County, Georgia (which includes Atlanta) was recently completed by Ihlanfeldt and Taylor (2004). They focused on non-NPL sites and argued that these tended to have smaller effects on property than do NPL sites. They specify multiple property-based valuation models and look at various categories of C&I property. Overall, they find that for all C&I properties an approximately 10% decline in value is associated with proximity to (within 2 miles of) non-NPL hazardous waste sites, or as much as $1 billion in total impacts. This finding suggests that private cost sharing and tax-increment financing may be justified.

It is important to consider if and how the *materials* benefit would appear in the policy case (i.e., no Superfund program). Similar to other benefit categories, the fact that without Superfund fewer responses would occur and uncertainties associated with toxic contamination of real property would be greater suggests that a large fraction of the materials benefit should be assigned to Superfund.

Table 6.2. Literature Relevant to Commercial and Industrial (C&I) Properties

Paper	**Site**	**Property Data**	**Conclusions**
(Patchin 1988)	n/a	Anecdotal: no specific data reported	Seriously contaminated properties are unmarketable. Contaminated property still able to be utilized as originally intended may have moderate decline whereas one no longer possible for original use may see total loss. No chance of financing for a seriously contaminated property.
(Rinaldi 1991)	n/a	Anecdotal: no specific data reported	Views contamination as a loss in value (depreciation) from value as if uncontaminated. Believes properties generally cannot be sold, rented, or conveyed in contaminated condition.
(Page and Rabinowitz 1993)	Pittsburgh; Milwaukee; Commerce Center, CA	Case studies on effect of groundwater contamination on C&I and residential properties	range of 10-50% decrease in property value - found no effect on residential properties
(Roddewig 1996)	n/a	Ten critical inquiries that every real estate appraiser should bear in mind regarding contaminated properties	1. what type of risk is present, 2. how do five critical cycles affect perceptions of risk, 3. environmental site assessment, 4. designated federal or state SF site, 5. approved or completed remediation plans, 6. contamination's effect on current use, 7. contamination's effect on surrounding uses, 8. government programs to offset risk, 9. guarantee or insurance programs for buyers, 10. how are comparable sales
(Syms 1997)	n/a	n/a	Comparative psychometrics
(Roddewig 1999)	n/a	n/a	Sets up a scorecard system for classifying risk and stigma associated w/ contaminated sites. "Using sales of contaminated properties as direct evidence of the value of property after considering contamination is often difficult. This is because of the small number of such transactions and the problems involved in making proper adjustments to reflect distinguishing factors"
(Meyer and Lyons 2000)	n/a	None - survey and interview data from entrepreneurs who develop contaminated properties - called Environmental Merchant Bankers	Preferred characteristics: heavy contamination, high value location, private ownership, unusual pollution, large parcel size, high returns. Obstacles: competitive bidding, stigma, redevelopment restrictions
(Boyd et al. 1996)	n/a	Theoretical paper with no applied data.	Seeks to "develop a model to examine how CERCLA liability can modify the terms of trade and incentives for real estate redevelopment." Conclusion: "Land use inefficiency arises due to information asymmetries between buyers and sellers of potentially polluted property."

Table 6.2. (Continued)

Paper	Site	Property Data	Conclusions
(Howland 2000)	Canton/SE industrial area of Baltimore.	Property owner interviews and census bureau GIS info	The average price per acre of sites known to be contaminated was 55% of that for clean sites. Where there is an active market for industrial land, contamination is not a deterrent to land purchase and reuse. Sellers lower prices sufficiently to compensate for remediation & perceived risks of future cleanup costs. Little support for idea that owners hoard parcels to avoid cleanup costs.
(Schoenbaum 2002)	Two sq. mile area in industrially zoned Fairfield - southern edge of Baltimore	Deeds & tax assessment records at two-year intervals from 1963-1999, US Census data, field inspections, current and historical aerial photos, telephone directories, personal interviews, and secondary sources.	Suggest that contamination alone doesn't account for existence of vacant or underused industrial properties in central cities. Evidence suggests that the property market learned to cope with regulatory & liability problems posed by real or potential pollution.
(Howland 2003)	Baltimore - Three development projects:	Three case studies looking at environmental history and redevelopment history. Looks at success and failures in terms of cleanup and development	1. need a certain market for final product, 2. switch from industrial to residential increases project risks and costs, 3. character and level of contamination affects risk and probability of success
(Ihlanfeldt and Taylor 2004)	Fulton County, GA (31sites in GAEPD haz site inventory; 23 non-NPL sites in CERCLIS; 96 NFRAP sites)	Estimate property-based price models using property transactions data from Commercial Vendor and Census bureau. Used characteristics by tax roll, GIS location, and census location. Property types: apartment, office, retail, industrial, vacant	Found effect up to 1.5-2.0 miles. The total value loss per total assessed value is 10%; thought to be an upper bound since assessed values tend to underestimate market prices since assessor’s estimated lag behind changes in actual market prices: apartment 18%, office 13%, retail 7%, industrial 5%, vacant 19%

Empowerment

To ensure that local citizens are knowledgeable about and involved in Superfund-related decisions that affect their communities, EPA conducts formal and informal stakeholder involvement and public participation activities. Public participation activities and processes allow the public to participate in Agency actions and hold the Agency accountable for its decisions.

Among the clearest examples of how the Superfund program empowers communities is the Technical Assistance Grant (TAG) program. TAGs, which were authorized under the Superfund Amendments and Reauthorization Act (SARA), provide money to help local communities participate in decisions at eligible Superfund sites (NPL and proposed NPL sites). TAG funds, generally up to $50,000, can be used to pay a technical advisor to review site documents, interpret or explain technical information, and help a community communicate its concerns so that they and decision makers are better informed on site specific issues (U.S. Environmental Protection Agency 2000b).

In addition to TAGs, the Superfund program has other programs to empower communities in response actions. The Technical Outreach Services to Communities (TOSC) project provides services similar to those covered by TAGs and is available to communities that do not qualify for TAGs. It has provided independent university-based scientific and engineering expertise to 115 communities dealing with hazardous substance contamination questions. A community can also participate in response decisions through a Superfund Community Advisory Group (CAG). These are made up of community members and can serve as the focal point for the exchange of information among the local community, EPA, the state regulatory agency, and other pertinent federal agencies involved in cleanup of a Superfund site (Office of Solid Waste and Emergency Response 1998).[4]

EPA maintains a substantial outreach and information effort for sites under the Superfund program, which includes not only NPL sites but also every site assessed by the program. The Superfund web site allows access to some CERCLIS-based information on every site discovered. Preliminary assessment and site inspection reports, typically available at the regional offices, describe each site and provide information about the substances present, potential exposure pathways, and any known exposures. For NPL sites, there are dockets and local information repositories, and typically there are substantial outreach efforts. The program also provides information to the public on how to avoid exposures where sites have not yet been addressed. For example, the program might help disseminate fish consumption advisories.

The Superfund program also uses its community outreach mechanisms to create partnerships with local businesses, community organizations, and other federal agencies to develop and support job training. The Superfund Job Training Initiative (SuperJTI) supports job training programs in communities affected by nearby Superfund sites. Because EPA by law is unable to fund SuperJTI activities, its role is mainly advisory. EPA is responsible for deciding which sites are good candidates for SuperJTI, providing program guidance at the national level, and coordinating local SuperJTI participants. At its most basic level, the program provides outreach and organizational support to link a community with the National Institute of Environmental Health Sciences (NIEHS) Minority Worker Training Program, which may provide grant funding for life skills and hazardous waste training. SuperJTI benefits residents by increasing their understanding of the cleanup efforts in their communities and providing them with marketable skills, which will enhance their employment potential.[5]

Some benefits of the Superfund community empowerment activities are very likely indirectly captured by the property-based analysis of Chapter 4. By providing communities with the best scientific and technical information about nearby sites, the likelihood of stigma effects on property values is reduced. That information might include, for example, schedules for response

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[4] See www.epa.gov/superfund/tools/cag/index.htm and www.toscprogram.org/tosc-overview.html for more information.

[5] See www.epa.gov/superfund/tools/sfjti/index.htm and www.niehs.nih.gov/wetp/program/brownfields.htm for more information

actions, allowing the public to make informed decisions on how best to avoid disruption of their activities. It might include information about the likelihood of health impacts (or the likely absence of health impacts), thus allowing property purchasers and sellers to make better informed property transaction decisions. The availability of TAGs and the TOSC to communities enhances the effects of the information dissemination; through these, communities can access independent experts to evaluate EPA's statements, thereby leading to greater credibility for the Agency.

The site-specific information created by the Agency for Toxic Substances and Disease Registry (ATSDR) also contributes to the empowerment benefit. Due to the high level of concern about health impacts of uncontrolled hazardous substance releases, Congress created ATSDR as part of CERCLA in order to implement the statute's health-related provisions. ATSDR is an advisory agency that (among other tasks) makes recommendations for actions at specific sites or in response to specific issues, but cannot mandate actions (Agency for Toxic Substances and Disease Registry 2003c, 2004).[6] ATSDR's responsibilities include:

- Preventing or reducing exposure to hazardous substances and the illnesses that result from these exposures;
- Assessing the presence and nature of health hazards at NPL and other hazardous sites (Agency for Toxic Substances and Disease Registry 2003a);
- Expanding the available knowledge about health effects from exposure to hazardous substances;
- Assisting EPA in determining which substances should be regulated and the levels at which substances may pose a threat to human health;
- Establishing and maintaining toxicological databases (Agency for Toxic Substances and Disease Registry 2003b); and
- Educating physicians and other medical professionals about the signs and treatment of hazardous-substance-related illnesses.[7]

The role of ATSDR, therefore, is to study a site or scientific issue, develop and provide information, educate the community (both the physical community around a site and the larger scientific and medical community), and make recommendations. Each of these actions can have significant benefits for communities affected by hazardous substances and for the scientists and doctors who work with these affected communities. ATSDR is required to conduct a public health assessment (PHA) of any site on or proposed to the NPL. Additionally, ATSDR can assist at non-NPL sites, including performing a PHA, Public Health Advisory, health consultation, exposure investigation, and medical monitoring program (all discussed below), if requested by EPA, another federal agency, state or local governments, or citizens. On the basis of these

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[6] In this sentence, "community" can mean both the community proximate to specific sites, as well as the larger scientific and medical community, although only the former is associated with the empowerment benefit. Benefits resulting from information that flows to the larger scientific and medical community is different and is discussed as part of the information and innovation benefit category. ATSDR is discussed in more detail there as well.

[7] From the ATSDR's website, Background and Congressional Mandates: www.atsdr.cdc.gov/congress.html.

community health studies, ATSDR can identify risks to communities and the level of risk posed by a site, as well as actions recommended to interdict pathways of exposure.

ATSDR reports that "more than half" of the sites at which it works are not on the NPL.[8] Public Health Assessments can be requested by any individual citizen or group of citizens concerned about potential health effects of a contaminated site. When ATSDR is petitioned to investigate a site, a research team is formed to gather information, including visiting the site and talking with community members. This information is then presented to a committee, which determines what action, if any, ATSDR should take at the site. All of the decisions of ATSDR are documented and provided to the community.[9]

In addition to PHAs, ATSDR performs Health Consultations (HCs) to provide "advice on a specific public health issue related to real or possible human exposure to toxic material."[10] An HC is less in-depth than a Public Health Assessment and acts as a quick gauge of potential risk. HCs take into account concentrations of hazardous substances and their potential exposure routes to humans, as well as the potential health risks of these substances or other dangers posed by the site. An HC can lead to more intensive ATSDR involvement, such as a Public Health Assessment or a Public Health Advisory. ATSDR provides approximately 1,000 Health Consultations per year.

A Public Health Advisory allows ATSDR "to respond quickly when hazardous substances released into the environment pose an immediate and significant danger to people's health."[11] Based on ATSDR's study of a community potentially exposed to a hazardous site, through a Health Consultation or a Public Health Assessment, ATSDR can issue a Public Health Advisory notice directly to EPA's administrator, thereby alerting EPA and other government agencies that a public health threat exists. ATSDR can then work with involved agencies to determine protective actions and see that they are implemented.

In addition to PHAs and HCs, ATSDR can perform exposure investigations and medical monitoring. Exposure investigations are used to "develop better characterization of past, current, and possible future human exposures to hazardous substances in the environment and to evaluate existing and possible health effects related to those exposures."[12] Exposure investigations use bio-medical testing (such as blood or urine samples), environmental testing, and computer modeling to determine the potential health risks at a site. Medical monitoring includes conducting health surveillance for "populations at significant increased risk of adverse health effects as a result of exposure to hazardous substances." According to the recent Public Health Assessments and Advisories of ATSDR, "more than 3 million people were exposed or potentially exposed to contaminants at Superfund sites investigated; … about 4% of the sites

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[8] ATSDR Frequently Asked Questions webpage: www.atsdr.cdc.gov/faq/.

[9] ATSDR Petitioned Public Health Assessment webpage: http://www.atsdr.cdc.gov/COM/petition.html#3.

[10] ATSDR Health Consultation webpage: www.atsdr.cdc.gov/HAC/consult.html.

[11] ATSDR Public Health Advisory webpage: www.atsdr.cdc.gov/HAC/healthad.html.

[12] ATSDR Exposure Investigation webpage: www.atsdr.cdc.gov/HAC/expinfaq.html.

were categorized as urgent public (human) health hazards and 49% of the sites as public (human) health hazards."[13]

It is important to consider if and how the *empowerment* benefit would appear in the policy case (i.e., no Superfund program). Without the Superfund program, far fewer responses to uncontrolled releases of hazardous substances would have occurred; therefore, many communities would likely be dealing with a much worse problem: ongoing (and possibly worsening) contamination by hazardous substances without outside assistance. For this reason, and because essentially all activities designed to empower the community are attributable to the Superfund program, it seems realistic that all of the empowerment benefit can be attributed to the Superfund program.

Deterrence

Overview

The liability provisions of CERCLA, along with information provisions such as the Toxics Release Inventory (TRI) and Emergency Planning and Community Right-To-Know Act (EPCRA) provide opportunities for the Superfund program to act as a deterrent to possible hazardous releases.[14]

Many CERCLA responses involve the enforcement of CERCLA's liability provisions, in which EPA seeks to identify the potentially responsible parties (PRPs), those individuals or organizations responsible for creating or contributing to a hazardous waste site. CERCLA's two basic liability provisions permit EPA to either compel a PRP to abate an endangerment to public health, welfare, or the environment, or to recover the costs of EPA's response. This latter provision, plus the existence of the Trust Fund has allowed for timely response to minimize risks. The law also provides for citizen suits to enforce CERCLA's provisions (Section 310), and it provides authority for federal agencies, states, and tribes to bring actions for damages to natural resources (Section 107), as discussed in Chapter 5.

Liability can extend to site owners, facility operators, waste transporters, or anyone who generates hazardous substances that contaminate other sites. This liability is strict, joint, and several, with no requirement that a PRP's hazardous substance be the sole cause for the need for a response action. Legal proof of negligence is not required, and conducting activities consistent with standard industry practices is not considered an adequate defense. The original draft of CERCLA contained no statute of limitations. This was altered in 1986 with SARA's inclusion of limits on recovery actions, natural resource damages, and contribution actions.

Also known as Title III of SARA, the 1986 Emergency Planning and Community Right-to-Know Act (EPCRA) establishes requirements for federal, state, and local governments and industry regarding emergency planning and "Community Right-to-Know" reporting on hazardous and toxic chemicals. Section 313 of EPCRA requires EPA to establish an inventory of routine toxic chemical emissions from certain facilities subject to the Act's reporting requirements. These

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[13] ATSDR's Medical Monitoring webpage: www.atsdr.cdc.gov/COM/medmon.html.

[14] TRI and EPCRA have benefits that flow to both neighbors and non-neighbors of NPL sites; therefore, this benefit is included here rather than in Empowerment.

facilities are required to complete a Toxics Release Inventory (TRI) form for specified chemicals (Office of Information and Analysis 2004). The intent of these forms is to capture the extent and nature of chemical releases from the preceding calendar year. The TRI is a database and provides no direct requirements for companies to lower their emissions; they simply need to report their emission levels (although many TRI chemicals are also regulated under the Clean Air Act).

EPA compiles the TRI data each year and makes it available to the public through several data access tools, including the TRI Explorer and Envirofacts. There are other organizations which also make the data available to the public through their own data tools. For instance, OMB Watch operates a tool called "RTKNet,"[15] Environmental Defense has developed a database tool called "Scorecard," and the National Partnership for Environmental Priorities uses TRI data to identify facilities that may present pollution prevention opportunities.[16]

Reduced Emission Levels and Reduced Health Impacts

A quick glance at some TRI data indicates that releases to the environment of the TRI chemicals tracked since 1988 have decreased more than 50 percent while the economy has approximately doubled in size, an achievement due in part to the availability of information (Khanna et al. 1998). This translates to hundreds of billions of pounds of toxic chemicals no longer released to the environment and no longer serving as an exposure hazard to potentially receptive populations.

While the primary purpose of TRI is to inform about chemical hazards, release estimates alone are not sufficient to determine exposure or to calculate potential adverse risks to human health and the environment. Human health impacts are not directly related to emission releases, but rather to the exposures or inhaled doses. A chemical's release rate, toxicity, and environmental fate, as well as local meteorology and the proximity of nearby communities to the release must be considered when assessing exposure changes and their impact on human health (Office of Information and Analysis 2004). TRI contains no information or data about potential exposure to toxic chemicals or the potential for health or environmental effects if exposed. Therefore, there is limited ability to assess the extent of human health benefits that may have resulted from reductions in TRI-listed chemicals. In addition, only a small portion of industries releasing chemicals into the environment are required by EPA to submit the TRI report and the list of chemicals is not inclusive of all chemicals known to have significant public health or environmental impact (Harrison and Antweiler 2003).

Improved Corporate Environmental Management

The public availability of the TRI data has led many corporations to commit publicly to voluntary emissions reductions. One well-known pledge was Monsanto's 1989 commitment to reduce its worldwide air emissions of a subset of TRI chemicals by 90 percent by 1992 (Office of Information and Analysis 2002). Boeing has used TRI data to track the company's progress in managing its hazardous emissions. The company states that it uses TRI-based information as

[15] www.rtknet.org/. accessed July 1, 2004.

[16] See www.epa.gov/epaoswer/hazwaste/minimize/partnership.htm for more information. Accessed July 8, 2004.

a means for identifying and investing in pollution prevention programs that can supplement the company's current emission reduction programs.[17]

The TRI can help to develop environmental strategies and identify priorities by providing baseline information about the pollution burden and to identify priority areas for the introduction of technologies for cleaner production and provide indicators for monitoring the success of such approaches. A number of state and local voluntary emissions reduction programs have sprung up since the beginning of TRI reporting. Many of these programs use TRI data to set emission reduction goals and to track progress in meeting those goals (Office of Information and Analysis 2003).

For some industries, the creation of the TRI marked the first time that company managers and operators could look closely at the quantity of chemicals being released from their facilities. Initially, some companies expressed surprise at their own toxic chemical release amounts and set goals to improve their environmental performance. TRI data support voluntary pollution reduction efforts at facilities by revealing opportunities for operational changes that reduce releases of toxics. The TRI provides data that corporate managers previously did not have (or did not realize they had), which supports internal initiatives on pollution prevention. TRI data help managers identify and eliminate sources of waste, compare themselves to other similar facilities, and honestly confront the measured performance of their facility (Fung and O'Rourke 2000).

Facilitating Changes in Investor Decisions on Stock Valuation

There is evidence that investors use information created by the Superfund program to monitor environmental management and environmental compliance of companies. Environmental performance has become a common component of many corporate annual reports. In addition, public disclosure of TRI emissions has been increasingly accompanied by coverage in the media and in reports by environmental groups.

Research has established that bad media publicity from TRI-reported releases has a negative impact on stock prices of polluting firms and that those firms subsequently reduce toxic emissions. A study by James Hamilton found that firms releasing high levels of pollution were more likely to be reported in the news media and that publicly traded firms were likely to suffer a decline in stock price as a result of this negative publicity (1995). He reported that stockholders in firms reporting TRI pollution figures experienced negative, statistically significant abnormal returns upon the first release of the information. The lower returns resulted in an average loss of $4.1 million in stock value on the day the figures were released.

Research and analysis by Konar and Cohen similarly found that firms that received more negative media attention to their TRI reports than their peers responded by making greater emission reductions (Konar and Cohen 1997). In addition, research by Khanna et al. suggested that investors could be persistent in their valuation, penalizing firms whose TRI releases have increased over time and rewarding those firms that had made improvements over time (Khanna, Quimio et al. 1998).

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[17] Boeing annual EHS report. 2002.

Information Effect Benefits
EPCRA's primary purpose is to inform communities of chemical hazards in their areas. It appears that local and national environmental groups in the U.S. have embraced the TRI as a means to promote pollution reduction activities. EPA material on the TRI observes that "TRI provides citizens with information about potentially hazardous chemicals and their use so that communities have more power to hold companies accountable and make informed decisions about how toxic chemicals are to be managed."[18] While it has limitations, TRI data, when combined with hazard and exposure information, has been proven to be a valuable tool for risk identification in communities.

The public has used TRI data to identify facilities and chemical release patterns that warrant further study and analysis. Some community organizations have used TRI data to initiate discussions with local industries or to call on public interest organizations to lobby for their causes. For example, the Oneida Environmental Resources Board in Wisconsin used TRI data to convince leaders of the Oneida Tribe to organize a conference on cleaner ways to manufacture pulp and paper (Office of Information and Analysis 2003).

National organizations employ TRI data in many of the same ways as small community organizations, but on a larger scale. National organizations analyze TRI data, use it to conduct risk screening and risk assessment, and often help the public interpret the data. National organizations often work with local public interest and community organizations to initiate discussions between citizens and industry. Some national organizations also use TRI data to help them lobby for changes in national environmental policy (Office of Information and Analysis 2003).

It is important to consider if and how benefits in the *deterrence* category would appear in the policy case (i.e., no Superfund program). A significant amount of deterrence is likely due to related laws, especially RCRA, but there is considerable evidence that TRI and the liability provisions of Superfund create significant deterrents. Therefore, a considerable portion, perhaps most, of the *deterrence* benefits should be assigned to Superfund. Certainly all the benefits discussed above are clearly created by Superfund.

Emergency Preparedness
An important yet poorly-described benefit of Superfund stems from the large scale of its removal program; it allows for a critical mass of resources and expertise necessary to undertake responses at nationally significant hazardous substance problems (U.S. Environmental Protection Agency 1996).[19] In this way, the Superfund program has created a significant portion of the nation's capabilities to respond to certain types of homeland security threats.

The 250 On Scene Coordinators in the ten EPA regional offices, over 40 Environmental Response Team (ERT) staff at the national level, and their supporting consultants are a reserve

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[18] EPA 2004. Toxics Release Inventory (TRI) Program Fact Sheet. www.epa.gov/tri/tri_program_fact_sheet.htm. Accessed June 30, 2004.

[19] See www.ert.org/ for more information.

pool of highly trained response personnel available in the event of national emergencies. Also, CERCLA establishes the statutory and organizational framework for response to those emergencies across the federal government, states, and local governments. These structures have allowed Superfund personnel to respond effectively to a broad range of emergencies, from debris recovery after the Space Shuttle Columbia crash[20] to hazardous waste container recovery after hurricanes and other natural disasters.

The large scale of the program allows it to support the ERT at the national level. This is a group of experts who, in addition to supporting the EPA regions in routine removal and remedial actions, have developed expertise to address more unusual situations. For example, they maintain a dive team capable of performing underwater hazardous substance recovery operations. The ERT has been active in all 50 states, all U.S. territories and Commonwealths, and 28 foreign countries. The ERT has responded to more than 6,000 hazardous materials releases, oil spills, and terrorist incidents.

The significance of the benefits of preparedness and expertise, especially in the area of counter-terrorism, is illustrated by Superfund's response following the anthrax attacks on Congress in 2001. Shortly after the discovery of anthrax contamination in the Hart Senate Office Building, EPA was called upon to take whatever steps were necessary to determine the extent of the problems in all the Congressional office buildings and to decontaminate the Hart building. EPA led efforts to take samples and ship them to U.S. Army laboratory at Fort Dietrich for analysis. This type of monitoring and decontamination of anthrax in public buildings had never been attempted previously, and Congress' ability to be fully operational hinged on timely response. Within days EPA and the Army were able to confirm that only the Hart Building posed a threat, allowing the other offices to be reoccupied. Given the unprecedented nature of the decontamination problem, it took a total of three months to identify and test various fumigation options and put them in place. The response needed to be effective without damaging the building, personal property, and papers, and it needed to be safe for surrounding areas. In light of the associated considerations, the response represented a significant accomplishment. It is hard to speculate how long that response would have taken in the absence of the trained Superfund staff and a program designed to address such problems, but it is highly likely that the disruptions would have been much more costly and would have lasted much longer.

Similarly, Superfund had an important role in responding to terrorism at the World Trade Center on September 11, 2001. Within hours, the OSCs and ERT staff were monitoring air and water quality to determine whether they posed residual threats to human health and the environment. EPA staff provided worker health and safety support, making respirators available to all on-scene personnel in the days following the attacks. EPA also worked to remove residual hazardous substances (e.g., fuels) from tanks in the collapsed buildings.

Since 2001, Superfund has continued to expand its counter-terrorism response role by working with the Department of Homeland Security. Depending on the exact nature of a release, it is very likely that Superfund would take the lead in cleanup activities following a terrorist attack

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[20] Superfund was called upon due to the possibility that hazardous substances had been released during the breakup of the shuttle on re-entry; no significant releases were subsequently identified.

involving chemical, biological, or nuclear weapons. The removal program's staff is continually applying the type of expertise needed for environmental response to terrorist attacks; thus, a Superfund-led response is efficient. However, the increased training and coordination activities required by the counter-terrorism role are forced to compete for resources with the ongoing removal responsibilities.

It is important to consider if and how the *emergency preparedness* benefit would appear in the policy case (i.e., no Superfund program). Significant emergency preparedness has been gained through the activities of other parts of the federal government, but a large fraction should be assigned to Superfund. Without the Superfund program, the United States would likely have suffered more harm due to some recent terrorist attacks and taken longer to recover.

Information and Innovation

Overview

Superfund benefits in the areas of *information and innovation* stem from three basic efforts: basic research into the toxicology and environmental processes associated with hazardous substances in the environment; epidemiology and health impacts information associated with contaminated sites[21]; and technology innovation and transfer associated with various cleanup methods.

Research

Identifying the specific benefits of basic research poses major challenges for any benefits analysis. The SBA describes the research supported by Superfund, but does not quantify it.

The short-term research efforts most directly applicable to Superfund benefits are those of EPA's Office of Research and Development (ORD), which receives significant budgetary support from Superfund. The ORD's basic research supporting hazardous waste programs includes engineering studies for more efficient treatment systems, health effects studies, transport and fate studies, including those of the subsurface environment, research to improve risk assessments, and ecosystems research (Office of Research and Development 2004).

In the near term (5-10 years), the relevant goals of ORD Superfund research are to:

- Improve the scientific foundation for contaminated sediments remedy selection;
- Provide alternatives to ground water pump and treat remedies;
- Develop tools and methods for assessing and responding to contaminated soils with the goal of returning the land to productive uses; and
- Improve assessment and characterization tools, methods, and models related to multimedia site contamination, human health risk assessment, and innovative technologies.

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[21] This benefit is obviously related to ATSDR's site-specific benefits but is differentiated by having a broader set of beneficiaries and having a preventative role as well as a role in mitigation.

ORD plans its Superfund research in conjunction with EPA Superfund headquarters and regional staff so that it addresses the priority needs of the program (Office of Research and Development 2004).

While it is often very difficult to cite specific results of research and development, there are some qualitative benefits that EPA links to earlier research. For example, research and demonstration work on soil vapor extraction in the 1980s led to implementation of a highly cost-effective alternative to excavation and disposal of contaminated soils. Research on bioremediation in the 1980s and 1990s has led to increased applications of this technology for soil, both *in situ* and *ex situ*, and for ground water. Research on bioremediation also led to the development of monitored natural attenuation, which is now widely used for ground water remediation, either alone or in combination with source control, and is recommended as a component of remedies to be selected for contaminated sediment sites. More recent research on source control technologies for dense non-aqueous phase liquids (DNAPLs), such as thermal enhancement and dual phase extraction, is barely reflected yet in the ROD analysis. Similarly, phytoremediation and permeable reactive barriers are showing small increases in application that could accelerate as research and demonstration continue to document the performance and cost savings of these approaches.

In addition to EPA's internal research efforts, the National Institute of Environmental Health Sciences (NIEHS) sponsors the Superfund Basic Research Program (SBRP), which is a federally funded, university-based program, established under SARA. Research funded by SBRP includes developing:

- methods and technologies to detect hazardous substances in the environment;
- advanced techniques for the detection, assessment, and evaluation of the effects on human health of hazardous substances;
- methods to assess the risks to human health presented by hazardous substances; and
- basic biological, chemical, and physical methods to reduce the amount and toxicity of hazardous substances.[22]

These methods, techniques, and technologies can be used by other organizations and individuals (e.g., ATSDR, universities, state agencies, private firms) to advance Information and Innovation yet further, or to create benefits in other categories, such as better (e.g., more effective, or less expensive) response actions, or the sort of site-specific information associated with the community involvement benefit category.

The SBRP emphasizes understanding the factors that affect transport, fate, and transformation of hazardous substances. Research also emphasizes developing remedial action strategies that attenuate and mitigate exposure as necessary to protect human and ecological health. Table 6.3 lists the major areas of research covered under the SBRP.

[22] Superfund Basic Research Program website, http://www-apps.niehs.nih.gov/sbrp/Index.cfm. Accessed July 2, 2004.

Table 6.3. SBRP Major Research Areas[23]

Research Area	Research Focus
Ecology	Chemical contaminants at Superfund sites affect all living things. Some key areas of Ecology research include studies of how contaminants affect specific species, communities of organisms, and ecological processes (including how contaminants are transferred through food webs). In addition, research looks at how the physiological responses observed in organisms living in contaminated environments can serve as early warning systems for potential adverse human health effects.
Fate and Transport	Fate and transport research is focused on defining contaminant distribution, transport, and transformation on hazardous waste sites. It typically includes extensive field measurements that provide a picture of the extent of contamination at a site. This area of research also includes laboratory studies, which help identify the relevant physical, chemical, and biological processes governing contaminant fate and transport. Another part of this research is the development of advanced numerical, analytical, and statistical models of contaminant fate and transport.
Health Effects	Hazardous substances in the environment can affect human health in a number of ways, such as being suspected or known carcinogens, or being associated with vascular disease, reproductive toxicity, or endocrine disruption. Health effects research includes the following major areas of study: identification of causative agents, determination of the minimum dosages where adverse health effects occur, development of diagnostic tools for detecting chemical agents in biological systems, and discovery of mechanisms by which chemicals cause toxicity.
Risk/Exposure	Risk assessment evaluates the possible effects of Superfund sites on human health, ecosystem health, and the environment. EPA uses this process to view the extent of a problem at a Superfund site and to inform decision makers during various stages of site cleanup. Research includes: epidemiological studies that evaluate the relationship between exposure and disease; the development of new tools, models, and biomarkers to measure exposure and effect; and studies of the environmental pathways in which environmental contaminants are transported from a site to possible points of contact with humans.
Remediation	Remediation research covers the spectrum of technologies (except bioremediation) being developed for the cleanup of all contaminated media. A goal of this research is to develop innovative chemical and physical methods that effectively reduce the amount and toxicity of hazardous substances. Research also examines new and improved methods of hazardous waste containment, recovery, and separation. This area of research also includes laboratory and bench studies, and applied field research.

Knowledge of Health Impacts

In addition to this community-based work, discussed above in the section on Empowerment, ATSDR both performs and funds independent non-site-specific studies of contaminants and their health effects, including maintaining registries of people exposed to hazardous substances in order to study potential long-term health effects. ATSDR then uses the knowledge gained through their activities to educate physicians, scientists, others in the scientific and medical community, and concerned citizens about the risks posed by hazardous substances in general and at specific sites.

[23] Superfund Basic Research Program website, http://www-apps.niehs.nih.gov/sbrp/Index.cfm. Accessed July 2, 2004.

Health-related information is also disseminated through toxicological profiles and Tox FAQs. ATSDR is required under CERCLA to produce toxicological profiles for hazardous substances found at NPL, Department of Defense, and Department of Energy sites. As of 2004, ATSDR reports that 275 toxicological profiles have been published or are under development, covering more than 250 substances.[24] Toxicological profiles are peer-reviewed, and include reviews of current academic literature on toxicological properties of hazardous substances and general chemical information, as well as information about health effects, potential for exposure, and monitoring methods. Toxicological profiles are distributed to health professionals, academics working on issues relating to hazardous substances and human health, and members of the public, including special interest groups. In addition to the toxicological profiles written for chemical and medical professionals, ATSDR has drafted 185 "ToxFAQs," or answers to frequently asked questions about the human health effects of exposure to specific hazardous substances. These include basic information such as how exposure to a hazardous substance can occur, what the health effects of that exposure might be, how to reduce the risk of exposure, and what medical tests can be performed.[25]

ATSDR created and maintains a Hazardous Substance Release / Health Effects Database (HazDat) to provide information on the contaminants present at Superfund and other hazardous sites. HazDat includes information on "site characteristics, activities and site events, contaminants found, contaminant media and maximum concentration levels, impact on population, community health concerns, ATSDR public health threat categorization, ATSDR recommendations, environmental fate of hazardous substances, exposure routes, and physical hazards at the site/event," as well as substance-specific information about the contaminants present and their health effects and data from EPA's CERCLIS database.[26]

ATSDR also maintains a database known as HSEES, the Hazardous Substances Emergency Events Surveillance database, in order to make data publicly available and in order to analyze it and publish the results (Berkowitz et al. 2002; Horton et al. 2003, 2004a, 2004b). Currently fifteen states participate in this surveillance, reporting on the number and characteristics of hazardous substance releases or threatened releases. ATSDR reports that "the goal of HSEES is to reduce the morbidity (injury) and mortality (death) that result from hazardous substances events, which are experienced by first responders, employees, and the general public."[27]

Risk Assessment

As links between toxic chemicals and human health become better known, public health officials are looking for ways to assess the levels of risk in their communities. Toxics Release Inventory (TRI) data have been an important component in creating tools to address these assessments.[28]

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[24] ATSDR's Toxicological Profiles webpage: www.atsdr.cdc.gov/toxpro2.html.

[25] ATSDR's ToxFAQs webpage: www.atsdr.cdc.gov/toxfaq.html.

[26] ATSDR's HazDat webpage: www.atsdr.cdc.gov/hazdat.html.

[27] See www.atsdr.cdc.gov/HS/HSEES/ for more information.

[28] The TRI has also had important impacts in terms of Deterrence, as discussed above.

For example, the New York State Department of Health developed a risk screening protocol using TRI air release data and toxicity potency data to produce relative risk scores and rankings for facilities and chemicals within the state. Results suggested the need for a more careful evaluation of health effects resulting from large releases of non-carcinogenic compounds. In a study of the presence of endocrine disrupting chemicals in the Great Lakes region undertaken by the Environmental Information Center, scientists used TRI data to examine endocrine disrupters released in states bordering the Great Lakes. The study ranked the largest emitters of various classes of toxic chemicals by region.

In addition, the Risk-Screening Environmental Indicators Model, created by EPA's Office of Pollution Prevention and Toxics, provides year-to-year indicators of the potential impacts of TRI chemical releases on human health and the environment.[29] The RSEI tool uses reported quantities of TRI releases and transfers of chemicals to estimate the impacts associated with each type of air and water release by a facility. RSEI considers the amount of chemical released, the location of that release, the toxicity of the chemical, its fate and transport through the environment, the route of human exposure, and the size of receptor populations. It does not serve as a detailed or quantitative risk assessment, but can be used to identify situations where a more formal risk assessment is needed. In addition, both generic and site-specific exposure characteristics can be incorporated. The model allows the targeting and prioritization of chemicals, industries, and geographic areas. Facility scores can be tracked from year to year to analyze trends (Office of Information and Analysis 2003). The tool can also track risk-related results over time as a way to measure progress in environmental protection and pollution prevention programs. The values are for comparative purposes and are meaningful when compared to other values produced by RSEI.

EPA has also used TRI data in creating and implementing the Sector Facility Indexing Project (SFIP). SFIP has been designed to enable the public to access a wide range of environmental information about regulated facilities.[30] SFIP brings together environmental and other information from a number of data systems to generate facility-level profiles for five industry sectors (petroleum refining, iron and steel production, primary nonferrous metal refining and smelting, pulp manufacturing, and automobile assembly) and a subset of major federal facilities. SFIP includes compliance and enforcement information submitted to state and federal regulators, as well as chemical release information submitted under TRI. The SFIP couples emissions data from the TRI with toxicity weighting factors. The result is an index which accounts for both emissions volume and risk in assessing toxic pollution. This information helps to create a better multimedia profile of specific industry sectors and to provide public access to compliance and facility-level information.[31]

Technology Innovation and Transfer

The Superfund program supports a variety of activities to develop and promote innovative technological solutions for hazardous waste problems. Those activities range from establishing

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[29] See www.epa.gov/opptintr/rsei/ for more information.

[30] Note that SFIP benefits people who do not necessarily live near NPL sites, so this benefit is included here and not in the Empowerment category.

[31] EPA 1999. Sector Facility Indexing Project Evaluation. www.epa.gov/sfip/

cleanup technology databases to establishing public/private partnerships that apply new technologies to sponsoring forums for sharing information and results.

Among the databases supporting the technology transfer effort is the Hazardous Waste Clean-up Information (CLU-IN) website, which provides information about innovative treatment technologies to the hazardous substance remediation community. It describes programs, organizations, publications, and other tools for federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens. The site was developed by EPA but is intended as a forum for all waste remediation stakeholders. Another database is the Remediation and Characterization Technology Database (EPA ReachIt), sponsored by EPA, an online database with powerful search options for information on treatment and characterization technologies, plus updated information from remediation projects undertaken by EPA and other federal agencies.[32]

Among various technology demonstration programs is the Superfund Innovative Technology Evaluation (SITE) program established under SARA. The SITE program encourages use of innovative treatment technologies for hazardous substance site response and monitoring. In the SITE program, the technology is field-tested on hazardous substances. Engineering and cost data are gathered on the innovative technology so that potential users can assess the technology's applicability to a particular site. EPA uses the data to assess the performance of the technology, the potential need for pre- and post-processing of the wastes, applicable types of wastes and waste matrices, potential operating problems, and approximate capital and operating costs. The program prepares reports that evaluate all available information on the technology and analyze its overall applicability to other site characteristics, waste types, and waste matrices. Testing procedures, performance and cost data, and quality assurance and quality standards are also presented.[33]

The Environmental Technology Verification (ETV) Program of the EPA develops testing protocols and verifies the performance of innovative technologies that have the potential to improve protection of human health and the environment. ETV was created to accelerate the entrance of new environmental technologies into the domestic and international marketplace. ETV also verifies monitoring and treatment technologies relevant for homeland security. ETV operates through public/private testing partnerships to evaluate the performance of various types of environmental technology in all media: (air, water, soil, ecosystems, waste, pollution prevention, and monitoring). It seeks market input by actively involving technology buyers, sellers, permit writers, consultants, financiers, exporters, and others within each sector.[34]

The Remediation Technologies Development Forum (RTDF) was established after industry approached EPA to identify what they could do together to develop and improve the environmental technologies needed to address mutual cleanup problems in the safest, most cost-effective manner. The RTDF is a public-private partnership created to undertake research,

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[32] For more information, see www.epareachit.org/ , www.epa.gov/swerrims/cleanup/science.htm, and www.clu-in.org/techfocus/

[33] Superfund Innovative Technology Evaluation webpage www.epa.gov/ORD/SITE/

[34] EPA's Environmental Technology Verification (ETV) Program website www.epa.gov/etv/

development, demonstration, and evaluation efforts focused on finding innovative solutions to high priority problems. The RTDF includes partners from industry, several federal and state government agencies, and academia who voluntarily share knowledge, experience, equipment, facilities, and even proprietary technology to achieve common cleanup goals.[35]

The EPA Superfund Environmental Response Team (ERT), which has a key role in responding to national emergencies and in international response, also has a role in testing innovative monitoring and response technologies. The ERT is often called upon where unusual site circumstances present difficult technical or scientific problems. The ERT has been instrumental in promoting broader uses of phytoremediation and *in situ* bioremediation.[36]

This report has not attempted to identify all the benefits resulting from the technology transfer efforts, but some specific benefits are noted. According to EPA's Office of Research and Development, private sector environmental technologies have been verified in such areas as drinking water systems for small communities, air pollution control technologies that reduce smog-causing NO_x and lower greenhouse gases, new technologies that lower emissions and costs for metal finishing shops and industrial coatings operations, and innovative monitoring technologies of all types.[37]

It is important to consider if and how the *information and innovation* benefit would appear in the policy case (i.e., no Superfund program). Considerable evidence supports the claim that government action is necessary to encourage socially desirable levels of research and development for knowledge and technologies that are primarily associated with public goods, such as the environment (Skea 1996; Jaffe and Palmer 1997; Azar and Dowlatabadi 1999; Margolis and Kammen 1999; Norberg-Bohm 1999; Kerr and Newell 2001; Jaffe et al. 2002; Taylor et al. 2003). Thus, in the absence of the Superfund program, much or all of the activities discussed above would likely not have been undertaken. Therefore, much or all of the benefits associated with information and innovation should be assigned to the Superfund program.

International Benefits

The Superfund program staff support the U.S. diplomatic and humanitarian efforts internationally, especially by training and direct response actions.[38] For example, experts from the ERT provided air monitoring over the burning oil fields of Kuwait after the first Gulf War to support the firefighting teams who responded to those fires. The ERT in particular has provided direct response support in 28 countries, ranging from Cameroon to Vietnam. Through EPA's Office of International Activities, Superfund staff has provided training to a number of countries in such areas as preparedness, incident response, site assessment, and chemical safety audits. Superfund staff trained their counterparts in Eastern Europe to support them in establishing hazardous waste response programs after the dissolution of the Soviet Union.

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[35] Remediation Technologies Development Forum website www.rtdf.org

[36] From ERT's website, http://www.ertresponse.com.

[37] For more information see the EPA's ETV program website www.epa.gov/etv/

[38] CERCLA limits the use of the Trust Fund to domestic expenditures; significant expenditures to pay for Superfund staff working on international projects would be funded under other appropriations (e.g., under interagency agreements with the U.S. State Department).

It is important to consider if and how the *international* benefit would appear in the policy case (i.e., no Superfund program). The Superfund program provides only the technical capabilities, but not the statutory or budgetary support for International benefits. For the most part, these capabilities are already covered by other benefit categories, so the amount of the international benefit category that should be attributed to Superfund is slight.

References

Agency for Toxic Substances and Disease Registry. 2003a. *FR* 4, *ATSDR CEP site count report*, October.

Agency for Toxic Substances and Disease Registry. 2003b. *FR* 44, *CERCLA priority list of hazardous substances*, October.

Agency for Toxic Substances and Disease Registry. 2003c. *Fiscal year 2002 agency profile and annual report*. Atlanta, p. 80.

Agency for Toxic Substances and Disease Registry. 2004. *Final FY 2002 performance report, Final FY 2003 performance plan and draft FY 2004 performance plan*. Atlanta.

Azar, C. and H. Dowlatabadi. 1999. A review of technical change in assessment of climate policy. In *Annual review of energy and the environment*. R. Socolow, D. Anderson and J. Harte, eds. Palo Alto, California: Annual Reviews Inc. 24:513-544.

Berkowitz, Z., G. S. Haugh, et al. 2002. Releases of hazardous substances in schools: Data from the Hazardous Substances Emergency Events Surveillance system, 1993-1998. *Journal of Environmental Health* 65(2):20-27.

Boyd, J., W. Harrington, et al. 1996. The effects of environmental liability on industrial real estate development. *Journal of Real Estate Finance and Economics* 12(1):37-58.

Boyle, M. A. and K. A. Kiel. 2001. A survey of house price hedonic studies of the impact of environmental externalities. *Journal of Real Estate Literature* 9(2):117-144.

Champ, P. A., K. J. Boyle, and T. C. Brown (Eds.) 2003. *A Primer on Nonmarket Valuation.* Dordrecht, The Netherlands: Kluwar Academic Publishers.

Freeman, A. M. 1993. *The measurement of environmental and resource values: Theory and methods.* Washington, DC: Resources for the Future.

Fung, A. and D. O'Rourke. 2000. Reinventing environmental regulation from the grassroots up: Explaining and expanding the success of the Toxics Release Inventory. *Environmental Management* 25(2):115-127.

Gayer, T., J. T. Hamilton, et al. 2002. The market value of reducing cancer risk: Hedonic housing prices with changing information. *Southern Economic Journal* 69(2):266-289.

Gayer, T. and W. K. Viscusi. 2002. Housing price responses to newspaper publicity of hazardous waste sites. *Resource & Energy Economics* 24(1):33-51.

Gregory, R., J. Flynn, et al. 1995. Technological stigma. *American Scientist* 83(3):220-3.

Hamilton, J. T. 1995. Pollution as news: Media and stock market reactions to the Toxics Release Inventory data. *Journal of Environmental Economics and Management* 28(1):98-113.

Harrison, K. and W. Antweiler. 2003. Incentives for pollution abatement: Regulation, regulatory threats, and non-governmental pressures. *Journal of Policy Analysis and Management* 22(3):361-382.

Hite, D., W. Chern, et al. 2001. Property-value impacts of an environmental disamenity: The case of landfills. *Journal of Real Estate Finance and Economics* 22(2-3):185-202.

Horton, D. K., Z. Berkowitz, et al. 2003. Acute public health consequences associated with hazardous substances released during transit, 1993-2000. *Journal of Hazardous Materials* 98(1-3):161-175.

Horton, D. K., Z. Berkowitz, et al. 2004a. Hydrofluoric acid releases in 17 states and the acute health effects associated, 1993-2001. *Journal of Occupational and Environmental Medicine* 46(5):501-508.

Horton, D. K., Z. Berkowitz, et al. 2004b. Surveillance of hazardous materials events in 17 states, 1993-2001: A report from the Hazardous Substances Emergency Events Surveillance (HSEES) system. *American Journal of Industrial Medicine* 45(6):539-548.

Howland, M. 2000. The impact of contamination on the Canton/Southeast Baltimore land market. *Journal of the American Planning Association* 66(4):411-420.

Howland, M. 2003. Private initiative and public responsibility for the redevelopment of industrial brownfields: Three Baltimore case studies. *Economic Development Quarterly*: forthcoming.

Ihlanfeldt, K. R. and L. O. Taylor. 2004. Externality effects of small-scale hazardous waste sites: Evidence from urban commercial property markets. *Journal of Environmental Economics and Management* 47:117-139.

Jaffe, A. and K. Palmer. 1997. Environmental regulation and innovation: A panel data study. *Review of Economics and Statistics* 79(4):610-619.

Jaffe, A. B., R. G. Newell, et al. 2002. Environmental policy and technological change. *Environmental & Resource Economics* 22(1-2):41-69.

Kerr, S. and R. Newell. 2001. Policy-induced technology adoption: Evidence from the U.S. lead phasedown. *Journal of Industrial Ecology*: forthcoming.

Khanna, M., W. R. H. Quimio, et al. 1998. Toxics release information: A policy tool for environmental protection. *Journal of Environmental Economics and Managemen*t 36(3):243-266.

Kiel, K. A. 1995. Measuring the impact of the discovery and cleaning of identified hazardous-waste sites on house values. *Land Economics* 71(4):428-435.

Konar, S. and M. A. Cohen. 1997. Information as regulation: The effect of community right to know laws on toxic emissions. *Journal of Environmental Economics and Management* 32(1):109-124.

Margolis, R. M. and D. M. Kammen. 1999. Underinvestment: The energy technology and R&D policy challenge. *Science* 285:690-692.

McConnell, K. E. 1993. Indirect methods for assessing natural resource damages under CERCLA. In *Valuing natural assets: The economics of natural resource damage assessment.* R. J. Kopp and V. K. Smith, eds. Washington, DC: Resources for the Future: 153-203.

McMillen, D. P. and P. Thorsnes. 2000. The reaction of housing prices to information on Superfund sites: A semiparametric analysis of the Tacoma, Washington market. *Advances in Econometrics* 14:201-228.

Meyer, P. B. and T. S. Lyons. 2000. Lessons from private sector brownfield redevelopers: Planning public support for urban regeneration. *Journal of the American Planning Association* 66(1):46-57.

Norberg-Bohm, V. 1999. Stimulating 'green' technological innovation: An analysis of alternative policy mechanisms. *Policy Sciences* 32(1):13-38.

Office of Information and Analysis. 2002. *Toxic chemical release inventory information collection request supporting statement.* Washington, DC: U.S. Environmental Protection Agency, June 26, p. 87. http://www.epa.gov/triinter/lawsandregs/icr_1363.pdf.

Office of Information and Analysis. 2003. *How are the Toxics Release Inventory data used? Government, business, academic, and citizen uses.* Washington, DC: U.S. Environmental Protection Agency, May, EPA-260-R-002-004, p. 64. http://www.epa.gov/tri/guide_docs/2003_datausepaper.pdf.

Office of Information and Analysis. 2004. *Toxic Release Inventory public data release report*. Washington, DC: U.S. Environmental Protection Agency, June, 260-R-04-003, p. 8. http://www.epa.gov/tri/tridata/.

Office of Research and Development. 2004. Staff analysis. Beth Craig (Assistant Administrator for Air and Radiation). Washington, DC: U.S. Environmental Protection Agency

Office of Solid Waste and Emergency Response. 1998. The community advisory group toolkit for the community. Washington, DC: U.S. Environmental Protection Agency, September, p. 137. http://www.epa.gov/superfund/tools/cag/resource.htm.

Page, G. W. and H. Rabinowitz. 1993. Groundwater contamination: Its effects on property values and cities. *Journal of the American Planning Association* 59(4):473-481.

Palmquist, R. B. 1992. A note on transactions costs, moving costs, and benefit measurement. *Journal of Urban Economics* 32(1):40-44.

Patchin, P. J. 1988. Valuation of contaminated properties. *The Appraisal Journal* 56(1):7-16.

Rinaldi, A. J. 1991. Contaminated properties: Valuation solutions. *The Appraisal Journal* 59(3):377-381.

Roddewig, R. 1996. Stigma, environmental risk and property value: 10 critical inquiries. *The Appraisal Journal* 64(4):375-387.

Roddewig, R. 1999. Classifying the level of risk and stigma affecting contaminated property. *The Appraisal Journal* 67(1):98-102.

Rosen, S. 1974. Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economics* 82(Jan/Feb):34-55.

Satterfield, T. A., P. Slovic, et al. 2001. Risk lived, Stigma experienced. In *Risk, media and stigma*. J. Flynn, P. Slovic and H. Kunreuther, eds. Sterling, VA: Earthscan Publishers: 69-83.

Schoenbaum, M. 2002. Environmental contamination, brownfields policy, and economic redevelopment in an industrial area of Baltimore, Maryland. *Land Economics* 78(1):60-71.

Skea, J. 1996. Environmental regulation, investment and technical change. In *Energy and Environment regulation*. H. L. Smith and N. Woodward, eds. New York: St. Martin's Press: 171-192.

Slovic, P. 1987. Perception of risk. *Science* 236:280-5.

Slovic, P., B. Fischhoff, et al. 1979. Rating the risks. *Environment* 21(3):14-20, 36-39.

Syms, P. 1997. Perceptions of risk in the valuation of contaminated land. *Journal of Property Valuation and Investment* 15(1):27-39.

Taylor, M. R., E. S. Rubin, et al. 2003. Effect of government actions on technological innovation for SO_2 control." *Environmental Science & Technology*: forthcoming.

U.S. Environmental Protection Agency. 1996. 61, *FR* 31103-31104, *The national response team's integrated contingency plan guidance*, June 19.

U.S. Environmental Protection Agency. 2000b. 65, *FR* 58850-58868, *Technical assistance grant program: Final rule*, October 2. www.epa.gov/superfund/tools/tag/

CHAPTER 7: CONCLUSIONS AND FUTURE RESEARCH

In summary, this effort has presented the first comprehensive analysis and estimation of benefits of Superfund (CERCLA and SARA) for the period 1980-2004. The building blocks of the effort are as follows. Chapter 1 provides an analytical framework that defines the approaches taken by Superfund and the benefits that are created by this framework, and situates the current study within the broader setting of policy analysis. Chapter 2 provides an over-arching literature review for the study, including reviews of similar efforts in the past. Chapter 3 describes Superfund responses (both removal and remedial actions) in some detail, quantifies them, and characterizes sites on the National Priorities List (NPL). Chapter 4 presents a monetary estimate of the benefits of remedial actions at NPL sites, based on changes in the property values of nearby homes—an important but incomplete measure of the total benefits of Superfund. Chapter 5 contains proposals for several effect-by-effect analyses of various health, ecological, and groundwater cleanup and protection benefits. This chapter is incomplete in the current version pending comments from the Science Advisory Board. Chapter 6 contains detailed descriptions of the benefits that are not quantified. This chapter includes a few thoughts on possible future research directions.

While data and methodological limitations prevent a complete estimate of the benefits of the Superfund program at this time, this study sheds some light on their nature and magnitude. It is clear that the Superfund program creates a broad array of benefits associated with protection of human health, welfare, and the environment, only some of which can be quantified. For the first 25 years of the Superfund program (1980-2004), the methods used in Chapter 4 yield an estimate of the present value in 1980 of benefits of Superfund in the range of $63-$100 billion (in year 2000$, using a 3% discount rate). Converting these total present value estimates into annualized values yields $3.6-$5.9 billion per year, with a best point estimate of $3.6 billion per year.

Several important directions for future research emerge from this study.

First, in order to understand how best to regulate and manage hazardous substances in the future, we must understand better the benefits of various approaches used in the past. This research might improve environmental regulation and management quality broadly across the country, affecting numerous federal, state, local, and private policies and practices.

Second, if a better understanding of the total benefits of the management of hazardous substances is desired, a better understanding of non-NPL responses, especially their typical risk mitigation profile, is required.

Third, improved understanding of the exposures resulting from uncontrolled releases of hazardous substances into the environment would be extremely helpful in estimating both the risks of these events and the benefits of mitigating them.

Fourth, a great deal is left to learn about the ecological benefits of Superfund, especially in regard to response actions. Given the size, scope, and variety of challenges presented by many sites currently being evaluated for response actions, research in this area is likely to be necessary in order to gain a better understanding of the true impact of the Superfund program.

Fifth, it is likely that the analysis presented here could be expanded to further analyze and account for heterogeneity among NPL sites, possibly improving the estimates developed in this study.

Sixth, and lastly, an important but missing component of a comprehensive appreciation of Superfund is a quantitative characterization of the subtler benefits, such as deterrence, international, and emergency preparedness, which are embedded in larger processes in the U.S. economy.

Research into these areas would likely prove useful for managing multiple challenges related to the mandate of the Superfund program, and might well inform other decisions about environmental regulation and management.

APPENDIX A: DATA SOURCES

In addition to original research, this study relies on the authorizing statutes, relevant Executive Orders, the peer-reviewed literature, guidance such as EPA's *Guidelines for Preparing Economic Analyses* (U.S. Environmental Protection Agency 2000), and prior external analyses of the program (e.g., Office of Technology Assessment 1989; Hird 1994; Probst and Konisky 2001; Hamilton and Viscusi 1999) for concepts, methods, and data.

Because much of this study consists of benefits transfer analysis of one sort or another, previous research provides much of the "data." An exhaustive review is unnecessary here—see the appropriate chapters—but a representative list might be: EPA cost of illness handbook (U.S. Environmental Protection Agency 2002); a variety of epidemiological studies (Lidsky and Schneider 2004; Yoshida, Yamauchi, and Sun 2004; Vrijheid 2000; Horton, Berkowitz, and Kaye 2004); reviews of risk assessments at NPL sites (Walker, Sadowitz, and Graham 1995; Hamilton and Viscusi 1995); and hedonic data (Boyle and Kiel 2001); NRDAs (Damage Assessment and Restoration Program (DARP) 2004; Office of Environmental Management 1997).

Below are descriptions and information regarding the location of additional data sources used in the current study.

Table A.1. Data Source Descriptions

Data Source	Description
Archived Sites	The EPA maintains a database of archived sites. "Archive designation means that assessment at a site has been completed and EPA has determined no steps will be taken to designate the site as a priority by listing it on the National Priorities List (NPL). No further remedial action is planned for these sites under the Superfund Program." This database can be accessed online at http://cfpub.epa.gov/supercpad/arcsites/srchsites.cfm.
ATSDR PHA database	Agency for Toxic Substances and Disease Registry's (ATSDR's) public health assessments from October 1994 to the present are available online. This database can be accessed online at http://www.atsdr.cdc.gov/cgi-bin/search-pha.
ATSDR CEP database	ATSDR maintains a database which lists the hazardous substances found in completed exposure pathways (CEPs) at every site. This database is not available online.
ATSDR 2003	This Web Site lists the number of sites at which completed exposure pathways (CEPs) exist for the hazardous substances most often found in CEPs. This source can be found online at http://www.atsdr.cdc.gov/cep.html.

Table A.1. (Continued)

Data source	Description
CERCLIS	"CERCLIS is the Comprehensive Environmental Response, Compensation, and Liability Information System. CERCLIS contains information on hazardous waste sites, potential hazardous waste sites, and remedial activities across the nation, including sites that are on the National Priorities List (NPL) or being considered for the NPL." "CERCLIS offers a variety of search criteria, such as site name, state, ZIP code, contaminants, HRS score and remedial activities. You can also retrieve additional site-specific documents and records such as Records of Decision, Five-Year Reviews and fact sheets for many sites." This is a database maintained by EPA. Portions of it are available through a public on-line search at http://www.epa.gov/superfund/sites/cursites/. More in-depth searches are available by contacting EPA directly.
CLU-IN Web Site	"The Hazardous Waste Clean-Up Information (CLU-IN) Web Site provides information about innovative treatment and site characterization technologies to the hazardous waste remediation community. It describes programs, organizations, publications, and other tools for federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens. The site was developed by the U.S. Environmental Protection Agency (EPA) but is intended as a forum for all waste remediation stakeholders." The Web Site can be accessed at http://www.clu-in.org/.
Envirofacts Data Warehouse	The Envirofacts Data Warehouse is a "one stop source for environmental information" maintained by EPA. It offers information by topic, as well as advanced information in the form of queries, maps, and reports. This source can be accessed at http://www.epa.gov/enviro/index.html.
EPA REACH IT	The Remediation and Characterization Technology Database, "EPA REACH IT, is a system that lets environmental professionals use the power of the Internet to search, view, download and print information about innovative remediation and characterization technologies… It gives users access to comprehensive information about treatment and characterization technologies and their applications. It combines information submitted by technology service providers about remediation and characterization technologies with information from EPA, the U.S. Department of Defense (DoD), the U.S. Department of Energy (DOE), and state project mangers about sites at which innovative technologies are being deployed. Those sources together provide you with up-to-date information, not only about technologies you can use to characterize or remediate a site, but also about sites at which those technologies are being used and the service providers that offer them." EPA REACH IT is sponsored by EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) and can be accessed at http://www.epareachit.org/.

Table A.1. (Continued)

Data source	Description
Five-Year Reviews OnLine	"Five-Year Reviews Online is the source for obtaining Five-Year Reviews, documents prepared by EPA to evaluate the implementation and performance of site remedies to determine if they remain protective of human health and the environment. Using Five-Year Reviews Online, you can search by state, site name or EPA ID, region, keyword, or fiscal year across all available Five-Year Reviews." This source can be accessed at http://www.epa.gov/superfund/sites/fiveyear/index.htm.
HazDat	"HazDat, the Agency for Toxic Substances and Disease Registry's Hazardous Substance Release/Health Effects Database, is the scientific and administrative database developed to provide access to information on the release of hazardous substances from Superfund sites or from emergency events and on the effects of hazardous substances on the health of human populations. The following information is included in HazDat: site characteristics, activities and site events, contaminants found, contaminant media and maximum concentration levels, impact on population, community health concerns, ATSDR public health threat categorization, ATSDR recommendations, environmental fate of hazardous substances, exposure routes, and physical hazards at the site/event. In addition, HazDat contains substance-specific information such as the ATSDR Priority List of Hazardous Substances, health effects by route and duration of exposure, metabolites, interactions of substances, susceptible populations, and biomarkers of exposure and effects. HazDat also contains data from the U.S. Environmental Protection Agency (EPA) Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database, including site CERCLIS number, site description, latitude/longitude, operable units, and additional site information." HazDat can be accessed at http://www.atsdr.cdc.gov/hazdat.html.
HSEES	"The Hazardous Substances Emergency Events Surveillance (HSEES) system was established by ATSDR to collect and analyze information about releases of hazardous substances that need to be cleaned up or neutralized according to federal, state, or local law, as well as threatened releases that result in a public health action such as an evacuation. The goal of HSEES is to reduce the morbidity (injury) and mortality (death) that result from hazardous substances events, which are experienced by first responders, employees, and the general public." HSEES can be accessed at http://www.atsdr.cdc.gov/HS/HSEES/.

Table A.1. (Continued)

Data source	Description
IEUBK Model	"The Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) attempts to predict blood-lead concentrations (PbBs) for children exposed to lead in their environment. The IEUBK model allows the user to input relevant absorption parameters (e.g., the fraction of lead absorbed from water) as well as intake and exposure rates. Using these inputs, the model rapidly calculates and recalculates a complex set of equations to estimate the potential concentration of lead in the blood for a hypothetical child or population of children (6 months to 7 years of age)." This model is made available online by the EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) at http://www.epa.gov/superfund/programs/lead/ieubk.htm.
Record of Decision System	The Record of Decision System (RODS database) is maintained by EPA. "These decision documents describe the chosen remedy for site remediation. They also include detailed site description, history, and contaminants. The RODS database includes Amendments and Explanations of Significant Differences which describe both minor and significant changes from the original remedy stated in the ROD, such as a contingent remedy or new technology. RODS can be searched for a specific document or across the entire database by keyword." This database may be accessed at http://cfpub.epa.gov/superrods/srchrods.cfm.
U.S. Census Bureau (data from 1980, 1990, 2000)	Selected historical and decennial census population and housing counts are available from the Census Bureau. The Census Bureau also has released detailed reports from past censuses (1790 on) and past Statistical Abstracts online. In addition, a research and photocopy request can be submitted for historical census population data not available online. The Census Bureau's internet site can be accessed at http://www.census.gov/.
U.S. Geological Survey Ground-Water Data for the Nation	"The Ground-Water database contains ground-water site inventory, ground-water level data, and water-quality data." This database along with GIS map layers is available at http://waterdata.usgs.gov/nwis/gw.

References

Agency for Toxic Substances and Disease Registry. 2003. ATSDR CEP site count report.

Boyle, M.A., and K.A. Kiel. 2001. A survey of house price hedonic studies of the impact of environmental externalities. *Journal of Real Estate Literature* 9 (2):117-144.

Damage Assessment and Restoration Program (DARP). 2004. *Natural Resource Damage Settlements and Judgments.* Washington, DC: National Oceanic and Atmospheric Administration.

Hamilton, J.T., and W. K. Viscusi. 1995. The magnitude and policy implications of health risks from hazardous waste sites. In *Analyzing Superfund: Economics, science, and law,* edited by R. L. Revesz and R. B. Stewart. Washington, DC: RFF Press.

———. 1999. *Calculating risks? The spatial and political dimensions of hazardous waste policy*. Cambridge, MA: MIT Press.

Hird, J. A. 1994. *Superfund: the political economy of environmental risk*. Baltimore: Johns Hopkins University Press.

Horton, D. K., Z. Berkowitz, and W.E. Kaye. 2004. Surveillance of hazardous materials events in 17 states, 1993-2001: A report from the hazardous substances emergency events surveillance (HSEES) system. *American Journal of Industrial Medicine* 45 (6):539-548.

Lidsky, T.I., and J.S. Schneider. 2004. Lead and public health: Review of recent findings, re-evaluation of clinical risks. *Journal of Environmental Monitoring* 6:36-42.

Office of Environmental Management. 1997. Estimate of potential natural resource damage liabilities at U.S. Department of Energy sites. In *Report to the Congress of the United States*. Washington, DC: U.S. Department of Energy.

Office of Technology Assessment. 1989. *Coming clean: Superfund problems can be solved*. Washington, DC: U.S. Congress.

Probst, K. N., and D. M. Konisky. 2001. *Superfund's future: What will it cost?* Washington, DC: RFF Press.

U.S. Environmental Protection Agency. 2000. *Guidelines for preparing economic analyses*. Washington, DC.

U.S. Environmental Protection Agency. 2002. *Cost of illness handbook*. Washington, DC.

Vrijheid, M. 2000. Health effects of residence near hazardous waste landfill sites: A review of epidemiologic literature. *Environmental Health Perspectives* 108:101-112.

Walker, K.D., M. Sadowitz, and J.D. Graham. 1995. Confronting Superfund mythology: The case of risk assessment and management. In *Analyzing Superfund: Economics, science, and law*, edited by R. L. Revesz and R. B. Stewart. Washington, DC: RFF Press.

Yoshida, T., H. Yamauchi, and G. F. Sun. 2004. Chronic health effects in people exposed to arsenic via the drinking water: Dose-response relationships in review. *Toxicology and Applied Pharmacology* 198 (3):243-252.

APPENDIX B: CASE STUDIES

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APPENDIX C: ALTERNATIVE BASE-YEAR FOR DISCOUNTING (2004)

The tables and figures presented in the results and discussion in Chapter 4 of the current study are presented with a base-year for discounting of 1980. The figures and tables presented in this appendix represent the alternative base-year of 2004 for discounting. Table C.1 is a replication of Table 4.6, while Table C.2 contains the alternative calculations for Table 4.7.

The present values (PVs) of the benefits transfer analysis presented in Chapter 4 of the current study are shown in Tables C.1 and C.2 and Figure C.1, along with the 95% confidence intervals.[1] Values for discount rates of 3% and 7% are given. For convenience, only the 3% values are discussed here. The mean values for the four models range from $130-$210 billion over the period 1980-2004. The 95% confidence intervals range from a low of $84 billion to a high of $260 billion.

Each of the four models and the data used to estimate the parameters in each (specifically, the magnitude of the price effect, see Chapter 4) has different advantages and disadvantages. The Linear Absolute (LA) model has the largest amount of data associated with it, but it is the least theoretically appealing model. On the other hand, the most theoretically appealing model, the Non-Linear Percentage (NLP) model is supported by only a few studies. The issue thus becomes, partly, which provides a greater improvement over the LA model--using a percentage-based model or using a non-linear model? Given the close agreement of the absolute and percentage models, using a non-linear model probably provides more advantage. Considering both functional form and data quality, the results that are probably the most reliable come from the Non-Linear Absolute (NLA) model. Thus, the best point estimate of the present value (r=3% in 2000$) of the benefits of NPL remedial actions for the first 25 years of the Superfund program, using a base-year of 2004, appears to be about $130 billion.

These calculations are fairly sensitive to the maximum distance at which the price effect is assumed to operate. If this effect is only one mile, the benefit drops by about 70%; if it extends all the way out to four miles, the benefit may be twice as large as the values shown in Figure C.1. Note that only one of the studies in Table 4.2 found a non-linear effect extending past three miles, so non-linear results for four miles were not calculated. These calculations are less sensitive to assumptions about the price effect for non-single occupancy, detached (non-SOD) residences. If non-SOD homes experience only half the effect of SOD homes (for which there is no evidence), mean estimates of the benefits range from about $97-$160 billion.

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[1] The present value of a series of benefits (or costs) that occur in the future (in this case, annually) is equal to the sum of the individual benefits (or costs) discounted into present-day terms. The equation for discounting is $PV = B/(1+r)^t$ where *B* is the benefit, *r* is the discount rate, and *t* is the number of years in the future. The conceptual framework for discounting is based on the fact that present consumption is valued more than future consumption.

Table C.2 presents annualized values of these benefits, which is another way (in addition to present values) of expressing the magnitude of benefits that vary across time.[2] The annualized benefits of NPL remedial actions, using the assumptions and methods given above, range from $3.4-$5.5 billion per year over the period 1980-2004, depending on the model used and assuming a 3% discount rate. The 95% confidence interval is $2.2-$6.9 billion per year.

In comparing the values in Appendix C (base-year 2004) with those in Chapter 4 (base-year 1980), the present value of benefits are higher in 2004 while the annualized values are higher for 1980. The reason for this has to do with the details of discounting calculations, which reflect the preference for consumption sooner rather than later. Discounting back to the past (as in Chapter 4) tends to reduce the value of benefits that occur late in the period, while discounting forward in time (as in this appendix) tends to increase the value of the earlier benefits. Thus discounting forward yields a larger present value.

The reason that the 1980 annualized value is higher is that the pattern of actual benefits is skewed towards the beginning of the period. Discounting back to the past (as in Chapter 4) subjects the values at the end of the period to more compounding than those at the beginning, and the reverse occurs when discounting forward. If more benefits occur in the early part of the period, as is the case for the benefits calculated in Chapter 4, this effect makes the annualized value for a base-year at the beginning of the period somewhat larger than for a base-year at the end of the period.

[2] An annualized benefit is the size of a fixed annual benefit, which, if it occurred at the end of each year and was discounted forward to the base year (2004, in this case) would result in the same present value as the actual series of benefits. Thus, calculating an annualized benefit converts a series of unequal benefits to a series of uniform benefits, both of which have the same present value.

Table C.1. Present Value of the Benefits of NPL Remedial Actions, 1980-2004
(Billion 2000$, Base-year 2004)

r = 7%	Value	Model			
All residence types equivalent		LA	NLA	LP	NLP
Max distance 2.5 mi.	Mean	260	210	350	250
	95% CI	180-330	150-280	260-430	140-370
50% effect for non-SOD homes	Mean	190	160	260	180
Max distance 1 mi.	Mean	73	-	-	-
Max distance 4 mi.	Mean	480	-	-	-
r = 3%	**Value**	**Model**			
All residence types equivalent		LA	NLA	LP	NLP
Max distance 2.5 mi.	Mean	160	130	210	150
	95% CI	110-200	89-170	160-260	84-230
50% effect for non-SOD homes	Mean	120	97	160	110
Max distance 1 mi.	Mean	44	-	-	-
Max distance 4 mi.	Mean	290	-	-	-

Table C.2. Annualized Value of the Benefits of NPL Remedial Actions, 1980-2004
(Billion 2000$, Base-year 2004)

r = 7%	Value	Model			
All residence types equivalent		LA	NLA	LP	NLP
Max distance 2.5 mi.	Mean	3.5	2.9	4.7	3.4
	95% CI	2.4-4.6	2.0-3.8	3.5-5.9	1.9-5.1
r = 3%	**Value**	**Model**			
All residence types equivalent		LA	NLA	LP	NLP
Max distance 2.5 mi.	Mean	4.1	3.4	5.5	3.9
	95% CI	2.8-5.3	2.3-4.5	4.1-6.9	2.2-6.0

Figure C.1. Present Value of the Benefits of the NPL Site Remedial Activities, 1980-2004 (Billion 2000$, Base-year 2004)
Mean and 95% C.I. shown. Price effect for all homes is the same.