STIGMA: THE PSYCHOLOGY AND ECONOMICS OF SUPERFUND*

Prepared by:

William Schulze, Project Director

Kent Messer, Katherine Hackett
Department of Applied Economics and Management
Cornell University
Ithaca, New York 14853

Trudy Cameron, Graham Crawford
University of Oregon
Eugene, Oregon 97403

Gary McClelland
University of Colorado
Boulder, Colorado 80309

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Project Officer
Dr. Alan Carlin
National Center for Environmental Economics
Office of Policy, Economics and Innovation
U.S. Environmental Protection Agency
Washington, DC 20460

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Abstract

This study documents the long-term impacts of Superfund cleanup on property values in communities neighboring prominent Superfund sites. To understand the impacts, one must integrate the psychology of risk perceptions and stigma with the economics of property values that capture those perceptions. The research specifically examines the sale prices of nearly 35,000 homes for up to a thirty-year period near six very large Superfund sites. To our knowledge, no property value studies have examined sites in multiple areas with large property value losses over the length of time used here. The results we obtain for these very large sites are both surprising and inconsistent with most prior work. The principal result is it that, when cleanup is delayed for ten, fifteen, and even up to twenty years, the discounted present value of the cleanup is mostly lost, most likely because sites are stigmatized and the homes in the surrounding communities are shunned. The psychological model developed suggests that, for very large sites, expedited cleanup and simplifying the process to reduce the number of stigmatizing events that attract attention to sites would reduce property losses.

Chapter 1

Overview and Executive Summary

1.1 Introduction

This study attempts to evaluate the benefits (as captured in residential property values) of hazardous waste cleanup conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund. When this legislation was passed in 1983, following Love Canal, the public imagined that the Environmental Protection Agency (EPA) would begin immediate cleanup of sites deemed hazardous to human and environmental health, using tax money collected from the petroleum and chemical industries. However, CERCLA's provision of joint and several liability requires that all previous and current owners could be responsible for cleanup cost, regardless of the amount of hazardous waste deposited at the site. Thus the legal complexity of CERCLA in establishing fair and just responsibility substantially delayed cleanup at many listed Superfund sites (as described in detail in Chapter 2, which provides a brief history of Superfund).

This research documents the consequences of that delay on property values in communities neighboring prominent Superfund sites. To understand those consequences, one must integrate the psychology of risk perceptions and stigma with the economics of property values that capture those perceptions. To explore the possibility that stigma can help explain public reaction to potentially hazardous sites, six Superfund sites in four geographic areas are examined: the Operating Industries, Inc. landfill site near the communities of Monterey Park and Montebello, California; the radium pollution in Montclair, Glen Ridge, and East/West Orange Townships in northern New Jersey; the Industri-Plex and water Wells G & H in Woburn, Massachusetts, and the Eagle Mine outside Vail, Colorado. The research specifically examines the sale prices of nearly 35,000 homes for up to a thirty-year period, and describes the history of each site. It should be noted that many Superfund sites have shown no or small property value losses in surrounding communities. The sites selected for this study all have shown large losses at some point in time. Furthermore, to our knowledge, no prior property value study has examined sites in multiple areas with large property value losses over the length of time used here. The results we obtain are both surprising and inconsistent with most prior work that looks at shorter time periods (e.g., McClelland, Schulze and Hurd 1990; Gayer, Hamilton, and Viscusi, 2000; Gayer and Viscusi, 2002). For our prominent sites, one can draw a variety of conclusions depending on what part of the history of property values are examined. Our results are more consistent with studies that look beyond the complete cleanup which suggest property values may only recover after cleanup is complete (Kohlhase, 1991; Dale et al., 1999).

In summary, the principal result is it that over the long term, when cleanup is delayed for ten, fifteen, and even up to twenty years, the discounted present value of benefits of cleanup are mostly lost because sites are stigmatized and the homes in the surrounding communities are shunned. Additionally, the research documents how trends in the socio-demographic composition of the communities near the sites differed from the trends in communities farther from the site.

This chapter summarizes the key findings of the study and is organized as follows. The second section briefly describes the six Superfund sites in four geographic areas throughout the U.S. The third section discusses why residents of communities neighboring Superfund sites may not completely believe the opinion of scientific experts regarding the health risks associated with the sites. The fourth section outlines what is known about the psychology of risk perceptions and stigma. The fifth section integrates the psychology of stigma with economic hedonic property value approach which, as noted by Adams and Cantor (2001), is a nontrivial task. Finally, the sixth section presents our conclusions.

1.2 Case Studies

Operating Industries, Inc. Landfill: The OII Landfill covers 190 acres and is located 10 miles (16 kilometers) east of Los Angeles between the communities of Monterey Park and Montebello, California. The Pomona Freeway (Route 60) divides the site into two parcels; one 45-acre area lies north of the freeway and the other 145-acre parcel lies south of the freeway. The landfill is in the city of Monterey and the city of Montebello borders the southern end and portions of the northern section of the landfill. Throughout its operating life, from 1948 to 1984, the landfill received 30 million cubic yards of residential and commercial refuse, industrial wastes, liquid wastes, and a variety of hazardous wastes. The EPA determined that approximately 4,000 different parties sent waste to the landfill at one point or another. In October 1984, the landfill was closed and proposed for listing on the National Priority List (NPL). In June 1986, the landfill was officially listed as a NPL Superfund site, and experts estimated that the cleanup could take as long as 45 years, and more than $600 million to complete. As of 2002, the EPA had reached settlements with almost 4,000 parties to pay for the cleanup work, with the total settlements reaching over $600 million (Table 1.1).

OII Landfill and Neighboring Community

In the early 1980’s, residents near the landfill formed Homeowners to Eliminate Landfill Problems (HELP) to address increasing odor and potential health problems at the site, as well as specific issues such as leachate seepage, methane gas buildup, declining property values, and land use after closure of the site. This organization, comprised of 460 dues-paying families, was an essential force in the eventual closing of the landfill. Community council meetings became volatile as residents protested the “assaulting stench” of the air. “We could never open the [house] windows,” said Montebello resident Phyllis Lee. As another resident stated, “Some nights I wake up coughing at two, three, four o’clock in the morning. The methane gas is so strong that I have a hard time breathing.”

Table 1.1 Key Dates and Statistics

Site Name	Discovery	NPL Listing	Dates & Descriptions of Major Clean-up Phases		Homes in Sample	Clean-up Cost	Total Property Value Loss
Operating Industries, Inc. Landfill Los Angeles, California	1978	1985	1988	Drilling of wells and groundwater treatment	9,200	$600m	39.5%
			1997	Construction of cap on landfill			
Montclair, West Orange, & Glen Ridge New Jersey	1983	1985	1991	Phase 1	12,444	$200m	8.9%
			1993-1995	Phase 2 & 3			
			1996	Phase 4 & 5			
Industriplex and Water Wells G & H Woburn, Massachusetts	1979	1983	1992-1993	Main cleanup on both sites	11,940	$80m	14%
Eagle Mine Colorado	1984	1986	1989-1991	Problematic State-led cleanup	1,087	$70m + $0.7m/yr	15.3%
			1996	Removal of contaminated soils			
			1997	Tailing piles capped			

According to Katherine Shrine, assistant regional counsel for the EPA Region 9, “This site is basically a 300-foot-tall, 190-acre mountain of every kind of disposable item in the world.” Residents say the landfill is so large that it interferes with television reception. Approximately 53,000 people live within three miles of the sites, 23,000 within one mile of the site, and 2,150 within 1000 feet of the landfill. Three schools are located within 1 mile of the landfill. The area consists of heavy residential development and mostly middle income and multi-racial neighborhoods.

For the Operating Industries, Inc. (OII) Landfill case study, we were able to obtain data on selling prices, housing characteristics, and Census information for nearly three decades (1970 to 1999). The length of this sample enables an examination of how proximity to the landfill affected housing prices well *before* the problems began to arise in the late 1970’s. A relatively large footprint was selected in this study. The broader neighborhood surrounding the OII Landfill site includes 9,279 dwellings between 60 meters and about 8.5 kilometers (5.3 miles) from the boundary of the site. Chapter 3 presents a more detailed history of the OII Landfill site.

Montclair, West Orange, and Glen Ridge, New Jersey: Montclair, Glen Ridge, and East and West Orange Townships are located about eight miles from Newark Airport in northern New Jersey. These towns are densely populated, and are located in one of the most densely populated regions of the United States. Approximately 50,000 people live within one mile of the Superfund sites. The Montclair/West Orange Radium Superfund site consists of 366 residential properties on 120 acres in Montclair and West Orange. The Glen Ridge Radium Superfund site is comprised of 306 properties on 90 acres of residential land in Glen Ridge and East Orange. The soil at both sites is contaminated with radium, a naturally occurring element that can result in high levels of radon gas and gamma radiation in nearby homes. Several plants occupied the area, the largest of which was the U.S. Radium Corporation (formerly the Radium Luminous Materials Corporation) which operated between 1915 and 1926. Because of its luminescent properties, radium was added to the paint that was used for numbers on watch dials and instruments, which became especially popular during World War I. The Center for Disease Control and the New Jersey Department of Health declared these sites to be a public health hazard due to concerns about lung cancer. Montclair/West Orange and Glen Ridge were listed on the NPL for Superfund sites in 1985 because of their proximity to radium waste generated by radium processing. These plants had operated in the area after the turn of the 20th century and an estimated 200,000 cubic yards of contaminated material were placed on private and public areas in the communities.

A USEPA contractor takes gamma radiation measurements in Montclair.

New Jersey Department of Environmental Protection officials were planning to notify local government officials and residents of their findings in early December 1983. However, despite a request by officials to hold the story until official notification had been made, a November 30th television news report broke the story early. According to the *New York Times* (October 16, 1984) article published one year later, "[Many] residents of the three communities – Montclair, West Orange and Glen Ridge – were not told about the problem until…technicians, wearing protective gear began taking soil and air samples in and around their homes." A couple of news reports, referred to the radium contamination in New Jersey as "another Love Canal," since both residential areas were built on contaminated soil.

Initial attempts to remove the contaminated soil were hampered by the lack of a suitable waste depository, resulting in 4,902 drums and 33 containers of soil being stored for nearly two years on the yards of partially excavated properties in Montclair. In 1999, nearly 20 years after the initial identification of the problem and 12 years after being put on the NPL, cleanup activities continued to occur as the streets were replaced and the EPA continued to investigate the possibility of additional groundwater contamination. By 1998, a total of $175 million had been spent to remediate over 300 houses and remove 80,000 cubic yards (or 5,000 large truck loads) of contaminated soil. In 2004, estimates of total cleanup exceeded $200 million (Table 1.1).

For this case study of the radium contamination in the communities of Montclair, Glen Ridge, and East and West Orange in northern New Jersey, we were able to obtain good data on selling prices, housing characteristics, and Census information for one decade (1987 to 1997), which started just two years after the sites were listed on the NPL. This data enabled us to examine the change over time of housing prices *during* the lengthy multi-phase cleanup process.

The data for this case study showed two different patterns of affects on housing prices. For homes that neighbored the affected communities, but did not experience the contamination themselves, there was a general decrease in property values as described below. For the homes that were within the affected communities, the swings in property value changes were greater, and the initial remediation efforts appear to have caused a temporary recovery in property value, however, this recovery does not appear permanent. One possible explanation for this recovery in property values is that the process of remediation often involved some remodeling of the homes directly, such as a new garage and/or landscape. Therefore, the cleanup not only removed potential hazards, but directly improved affected homes. Chapter 4 provides a more detailed description of these sites.

Industri-Plex and Water Wells G & H, Woburn, Massachusetts: Woburn is a historic city (founded in 1640) of about 35,000 people located 12 miles northwest of Boston. The community is predominantly blue-collar because of its industrial heritage. In the mid-1800s, Woburn became known for shoe manufacturing. Local manufacturing activity later shifted from shoes to leather production, and Woburn became a leader in the U.S. tanning industry by 1865. By 1884, Woburn was home to 26 large tanneries that employed approximately 1,500 employees and produced $4.5 million worth of leather. At the peak of Woburn's tanning industry, from 1900 to 1934, an estimated 2,000 to 4,000 tons of chromium was dumped directly into Woburn's water resources, as well as 65 to 140 tons of copper, 85 to 175 tons of lead, and 40 to 75 tons of zinc.

Abandoned 55-gallon Drum with the Entire Side Corroded; Found Near Wells G & H.

Woburn is also the location of two large Superfund sites: Wells G & H and Industri-Plex. Together the sites cover almost 600 acres of land in the 14 square mile community. Both sites are located in the section of Woburn east of Main Street, a low, swampy area that includes many streams and the Aberjona River. This section of Woburn, referred to as East Woburn, is a mix of industrial and residential areas. Roughly 13,000 households are located within two miles of the Industri-Plex site, and homes are located within 1,000 feet of the site. Approximately 34,000 people live within three miles of both sites. While the two sites are distinct from each other, the pollution problems at both sites were discovered within a few months of each other. Both sites were evaluated by the EPA and added to the NPL in the early 1980s (Table 1.1).

Throughout Woburn's history, more than 100 companies used the Aberjona River, which flows through the city, for industrial waste disposal. Companies dumped wastes on land, into lagoons and ponds adjacent to the river, as well as directly into the river itself. From 1853 to 1931, compounds and chemicals such as acetic acid, sulfuric acid, lead, arsenic, chromium, benzene and toluene were dumped behind buildings, used as fill for low spots, and included in construction material for dikes and levees. Woburn has a long history of public health problems, including elevated rates of kidney and liver cancer, colon-rectal cancer, child and adult leukemia, male breast cancer, melanoma, multiple myeloma, and brain and lung cancer.

The 330-acre Wells G & H site is located near the Aberjona River, about one and a quarter miles downstream (south) of the Industri-Plex site. It once ranked as the tenth worst site on the EPA's NPL list. The site is the location of two drinking water wells for the city of Woburn, which were built in 1964 (Well G) and 1967 (Well H). These wells were located near an automobile graveyard, an industrial barrel cleaning and reclamation company, a waste oil refinery, a tannery, a dry cleaner, and a machinery manufacturer. Despite public complaints about the water from these wells, Woburn continued to use the wells, especially during the summer. Both wells were finally closed in 1979 after testing showed that the water was contaminated. Soil and groundwater at the site are contaminated with volatile organic compounds (VOCs), such as trichlorethylene (TCE) and tetrachloroethylene (also called perchlorethylne, PCE, or 'perc'). Land in this area is zoned for industrial and commercial use, with some areas for residential and recreational use.

The Industri-Plex site, the location of Woburn's most intensive industrial activity since the 1850s, consists of 245 acres in an industrial park and once ranked as the fifth worst site on the NPL. This area is located one mile northwest of the intersection of Interstate 93 and Route 128 and is bordered by the communities of Wilmington and Reading. Two tributaries of the Aberjona River flow through the Industri-Plex site. Of the 245 acres at the site, one-third was contaminated and 60 acres were used for commercial purposes throughout the remediation of the site. Contamination at the Industri-Plex site includes heavy metals and hydrocarbons. In the soil, the contamination was primarily arsenic, lead, and chromium and in the water the contamination was primarily benzene, toluene, arsenic, and chromium. Additionally, hydrogen sulfide gas emanating from wastes and buried animal hides from the tanneries, once permeated the air.

The discovery of two major hazardous waste problems in one town prompted strong media interest as well as the active response and involvement of Woburn's residents. Area newspapers and TV stations ran multi-part stories about Woburn, alluding to it as a "toxic wasteland." Millions of dollars and several years were devoted to the Woburn court case which commanded front-page national media attention. The book describing the lawsuit, *A Civil Action*, was published in 1996 and became a bestseller. In 1999, the book was made into a movie starring John Travolta.

For Woburn, Massachusetts, we were able to obtain data on selling prices, housing characteristics, and Census information from 1978 to 1997 on 12,444 homes. Therefore, the sample begins one year before the discovery of contamination at Industri-Plex and Wells G & H and extends throughout the lengthy litigation and cleanup activities. The Woburn case most clearly demonstrates the importance of accounting for socio-demographic change when conducting economic studies on the value of neighboring homes. When these factors are included, it becomes evident that part of the decline in relative values for homes near the two sites is related to a general deterioration of the neighborhoods. If these factors are not controlled for in the analysis, the property affects of proximity to the sites may be overstated. However, the sites themselves are the likely cause of neighborhood deterioration. Chapter 5 provides a detailed history of these sites.

Eagle Mine, Colorado: Eagle Mine is centrally located between Vail and Beaver Creek ski areas, approximately 100 miles west of Denver, Colorado. Eagle Mine lies between the small towns of Minturn and Red Cliff, just off U.S. Highway 24 and was once one of the nation's top producers of zinc. The property consists of approximately 6,000 acres, 340 of which are contaminated with toxic waste. Most of the contamination originates from areas located along the Eagle River, and includes: the abandoned mining town of Gilman located on a cliff just above the mine, the old Eagle Mine processing plant in Belden, two ponds containing wastes from the smelting of ore, Maloit Park, Rex Flats, various waste rock and roaster piles, and an elevated pipeline. The Eagle River (a major tributary of the Colorado River), Cross Creek, and several other tributaries run through the site.

Warning sign at the entrance to Rex Flats & OTP.

The Eagle Mine site is contaminated with eight to ten million tons of hazardous substances including arsenic, nickel, chromium, zinc, manganese, cadmium, copper, and lead. The main cause of Eagle River contamination came from acid mine drainage, which occurs when sulfide minerals, such as pyrite, are exposed to oxygen and water and then oxidize. This process creates sulfuric acid, which contaminated soil, groundwater, and surface water surrounding Eagle Mine, producing water with low pH levels. Acid drainage at Eagle Mine resulted from precipitation flowing through the waste piles that accumulated from nearly 100 years of mining. As Eagle Mine acid drainage seeped into ground and surface water, it killed aquatic life and vegetation growing along the water's edge and contaminated the river with zinc, lead, manganese, and cadmium. Not only did this contamination threaten brown trout, the most populous fish in this segment of the river, but it also permanently stained the rocks in and along the river bright orange, providing Minturn and Red Cliff residents with a constant reminder of the contamination at Eagle River.

State studies conducted in 1984 revealed dangerously high levels of cadmium, copper, lead, and zinc in local water resources. Minturn, with a population of 1,500, is the closest town and draws drinking water from Cross Creek and two wells located within 2,000 feet of the mine tailings. While Eagle Mine had a history of environmental problems dating back to 1957, the majority of the problems arose after the mine closed in 1984. In March 1985, Ray Merry, the Eagle Mine Environmental Health Officer, ordered the 14 families remaining in Gilman to leave the site because of potential human health hazards. By July, all families had left the area and

Gilman became a ghost town. A gate prohibiting entrance to the town read "Town for Sale." Eagle Mine was placed on the NPL in June 1986.

As the cleanup began, public concern about the possibility of adverse human health effects intensified. Although the EPA chose not to endorse the State of Colorado's cleanup plan because it was skeptical of the plan's long-term effectiveness, the State forged ahead with the cleanup of the Eagle River site fearing the worsening of public health and environmental damages that might result from continued acid mine drainage. However, the State's decision to pump tailings pond water back into the mine, using the mine as a holding tank, proved to be disastrous and caused even more pollution to infiltrate the Eagle River. A dry winter caused mine seepage to make up most of river water, and the river turned orange. As a result, fish populations declined dramatically. Samples taken from the river that fall revealed zinc levels were 255 times higher than fish tolerance thresholds. No fish lived in the river, and contamination was turning the Eagle River various colors.

For the Eagle Mine, near Vail, Colorado, we were able to obtain data from 1,087 owner occupied properties downstream of the Eagle Mine over a 24-year period (1976 to 1999). Unfortunately, the data available from the Eagle County Assessor's office does not span enough distinct Census tracts for the differences in socio-demographic characteristics across these tracts to be useful in explaining the variation in housing prices. A challenge with this area is that, unlike the other three cases, a high percent of the homes are recreational and not owner occupied. There is substantial evidence that areas most effected by the pollution from Eagle Mine, such as Minturn, did not experience rapid development growth that occurred in other areas of the Vail area, even though they were in closer proximity to Vail resort. Due to the lack of socio-demographic data and the fact that Eagle Mine affected a mountain community where the main pollution was observed in a river, not just the original point source, the data from Eagle Mine was not included in the psychological model and analysis described below. Chapter 6 describes the Eagle mine site and history in more detail.

1.3 Expert Error

Gayer, Hamilton and Viscusi (2000) argue that residents living near Superfund sites judge risks to be of a magnitude consistent with EPA expert opinions and that these judgments are reflected in property values. The research presented here suggests quite the opposite. However, the sites studied here are much larger and likely to attract more attention. This section documents many cases of expert error to help explain why expert opinion plays a limited role in explaining residents' risk beliefs. Thus, the judgments of experts are only one component of the mix of news media stories and perceptual cues received by the typical citizen. Even if statements by scientific experts were accepted as credible, they would compete with a mix of the other signals and perceptual cues. As simply one component, such statements are unlikely to be the primary determinant of individual risk beliefs. Thus, risk beliefs determined largely by media stories and other perceptual cues are unlikely to be easily changed by the pronouncements of a few scientists (Fischhoff, 1989).

Furthermore, it is unlikely that statements by scientific experts will be accepted as completely credible. Even when different experts are in essential agreement, the news media often focuses on those aspects where experts disagree (Wilkins and Patterson, 1990), thus lowering the perceived credibility of experts. In a study examining news coverage of Three Mile Island and Chernobyl, Rubin (1987) found that news stories tended to dichotomize events rather than blend a continuum of information to recipients. The result is that the public discredits information it receives from experts because it appears that experts cannot agree among themselves and, therefore, do not really know the risk that a site presents.

Despite the ideal that science discovers absolute truths, for every health or environment related article there appears to be a corresponding article that rejects the tenets of the previously publicized claim. Numerous famous examples exist where experts from academia, government, and industry have made errors and misestimates:

- Soil contamination at Love Canal, Niagara, New York
- Dioxin contamination in Times Beach, Missouri
- The defective Dalkon Shield for birth control
- The false discovery of Cold Fusion
- The failures at Biosphere 2
- The near nuclear meltdown at Three Mile Island
- The Union Carbide Accident in Bhopal, India

These examples, which are described in detail in Chapter 7, are not just relegated to the past, as the costly search for weapons of mass destruction in Iraq, to date, has yet to support early claims by intelligence experts.

News about human and environmental health is omnipresent, yet much of this information is contradictory. Nearly every day newspapers, magazines, and television shows report new information that tends to further obscure issues rather than clarify them. A cursory survey of two major national newspapers conducted between September 1, 1999, and November 1, 1999, yielded several articles that contested previously reported claims or presented evidence of scientific or expert misjudgment and error. These articles reported the following:

- "Studies Bolster Link between Diet Drugs, Heart-Valve Leaks." Contrary to the previous claims of the manufacturer, the diet drugs Redux and fen-phen can cause permanent heart damage (*Wall Street Journal*, September 10, 1999).
- "Questions for Drug Maker on Honesty of Test Results: FBI Asks About Diet Product's Approval." A drug manufacturer did not report to the Federal Drug Administration all relevant test results prior to petitioning for approval of a drug (*New York Times*, September 10, 1999).
- "Tobacco Industry Accused of Fraud" For more than forty years, the tobacco industry suppressed evidence that tobacco use causes cancer (*New York Times*, September 23, 1999).
- "Japanese Fuel Plant Spews Radiation after Accident." Trained operators of a nuclear power plant in Japan poured more than six times the required amount of uranium into a tank, resulting in a nuclear chain reaction (*New York Times*, October 1, 1999).
- "Two Teams, Two Measures Equaled One Lost Spacecraft." The Mars Orbiter burned in space because the spacecraft's creator used imperial measurements when the spacecraft's navigational team used metric measurements (*New York Times*, October 1, 1999).
- "Drug May Be Cause of Veterans' Illness: Pentagon Survey Links Gulf War Syndrome to Nerve-Gas Antidote." Persian Gulf War soldiers who were given a drug to protect them from nerve gas attacks suffer from damage to areas of the brain that control reflexes, movement, memory, and emotion (*New York Times*, October 19, 1999).

- "Testing in Nevada Desert is Tied to Cancers." Soldiers who participated in nuclear tests for the military in the 1950s have higher than normal death rates and an increased likelihood of developing leukemia and prostrate and nasal cancer (*New York Times*, October 26, 1999).

Due to this steady flow of events and news stories that present contradictory, inaccurate, or incomplete expert evidence, the public is unlikely to accept expert evidence as absolutely accurate all the time. The frequency of events as well as the ambiguity and uncertainty of experts, government officials, and the media, as demonstrated by these examples, leads to doubt and skepticism on behalf of the public. The implication is that residents living near Superfund sites are forced to construct their own risk beliefs based on perceptual cues and media coverage. McClelland et al. (1990) surveyed residents near OII about their risk beliefs and found a bimodal response with more than half believing that living near the site was as dangerous as smoking more than one pack of cigarettes per day, with an incremental annual risk of death of approximately 1/100. Most of the remaining residents viewed the risk as trivial. Assuming typical values for statistical life and assuming three people per home, the discounted present value of the risk for the residents that assessed the risk as similar to smoking exceeds the price paid by these residents for their homes! Residents who responded this way did report that they were desperate to sell and sought immediate cleanup.

1.4 Events, Perceptual Cues, Risk Perception, and Stigma

Given the doubts that people will inevitably have with respect to the credibility of expert risk assessment, perceived risks will be based on personal and community judgments derived from other sources of information. Events that are associated with a Superfund site will lead to perceptual cues and media attention that will most likely elevate perceived risk and stigmatize the site for reasons documented below. Some of the most important determinants of risk beliefs are perceptual cues. Perceptual cues are physical aspects of a site that are perceived by local residents, and are suggestive of risk. Examples of perceptual cues include odors emanating from landfills, unusual odors or flavors in well water, unusual soil or water coloration at the site, and a heavy volume of truck traffic going in and out of the site. Ironically, some actions taken by authorities to minimize public health and safety risks tend to exacerbate risk beliefs by providing clear cues that some risk is present. Erecting chain link fences, posting 24-hour guards, placing warning signs, conducting on-site tests (especially by workers wearing protective clothing) are all cues to residents that risk levels may be higher than they thought. Such actions, which may be necessary, almost never lower risk beliefs. Proximity to a site increases the frequency and duration of contact with, or observation of, perceptual cues, which contributes directly to the intensity of risk beliefs.

The effects of strong perceptual cues are well illustrated by the OII Landfill. Initially, concern about high volumes of truck traffic and odors (produced by decomposition in the landfill) prompted local residents to organize and confront problems associated with the site. McClelland et al. (1990) found a significant correlation between recognition of these perceptual cues and the high risk beliefs of many residents living near the site. Several of the perceptual cues were removed or reduced by (a) installing wells to extract the methane gas for commercial use and (b) closing the site, which eliminated most of the truck traffic. Even though these actions did not address risks that hazardous substances would migrate into local neighborhoods, the risk estimates of many residents dropped dramatically after the principal perceptual cues were removed. McClelland et al. also demonstrated that there were significant property value losses associated with these risk beliefs.

Attention given to a site in the media, apart from the actual content of news stories, is itself a perceptual cue that risks may be high. Many studies have shown that frequent exposure to media reports about a site increases the likelihood that residents will believe the site is very risky. The specific risk at a site and perhaps the site itself will usually be unfamiliar to residents. That in itself increases risk beliefs (Wilkins and Patterson, 1987). But more importantly, it means that residents are almost totally dependent on the news media for information about the risk. Reflecting the concerns of their consumers, the news media often focus on aspects that accentuate dread, such as the uncontrollability of the risk and the frightful worst outcome (e.g., dying of cancer), rather than on information about the low probabilities of the risk and how those probabilities compare to other risks that residents accept.

The signals that the media sends to the public regarding risks from hazardous waste sites are important, but the way in which the public interprets this information is equally important. A key feature of how news coverage is interpreted by residents is whether there is an easily identifiable "villain" responsible for the hazardous waste problems at the site. For example, if the responsible party is a corporation whose primary business activity is outside the community, then it is more easily portrayed as a villain than a local business which has strong affiliations to the community. Russell et al. (1991) found that the more important a site's potentially responsible parties (PRPs) were to the local economy, the more skeptical residents living near the site were that it needed to be cleaned up. Personal familiarity with a site also influences how news reports are interpreted. The greater the prior familiarity, the less risk beliefs are likely to be elevated by news stories.

The largest PRP for the OII Landfill was an outside corporation that had not provided significant employment or other economic benefits for the residents who lived nearby. Most of the waste, especially hazardous waste, was generated and brought to OII from outside the community. OII was primarily a commercial landfill serving many interests outside of the community. In short, conditions were ripe for news stories to elevate risk concerns significantly.

How a risk affects the community, society, and the economy will depend on individual and group perceptions of the risk (Slovic et al., 1991; Kunreuther and Slovic, 2001). There can be a compounding or "rippling" effect as more and more individuals respond to the risk (Kasperson et al., 1988). Or, as Dr. Paul Slovic describes it, interactions among individuals can produce a "social amplification of the original risk concern." The greater the population living near a site, the greater the potential for compounding or social amplification.

When residents or potential buyers are extraordinarily fearful of a site, they may respond by shunning the site. This behavioral response has been labeled stigmatization and has been explored in a number of experiments that suggest that if risks are perceived as being excessive, people replace calculations of risk versus benefit with a simple heuristic of shunning, the avoidance of the stigmatized object.

Stigma has been shown to have a number of key properties. Laboratory experiments testing these properties have involved dipping a medically sterilized cockroach into glasses of juice and gauging subjects' willingness to drink the juice after the cockroach has been removed (Rozin, 2001). First, stigma shares many of the psychological characteristics of contagion, where contagion is associated with touch or physical contact. For example, while subjects refused to drink the juice if the sterilized cockroach was dipped into the glass, they would drink the juice if the cockroach was just placed near it. Second, stigma appears to be permanent. Subjects refused to drink the juice even if it had been in the freezer for one year. Third, stigma appeared to be insensitive to dose. Reductions in the duration of contact between juice and cockroach had little effect. Any contact was sufficient for subjects to shun the juice. Fourth, the source of contagion is usually unknown. Thus, while shunning may have evolved from an adaptive response to avoid contaminated food, it can be triggered in inappropriate circumstances. For example, subjects who saw sugar water placed in a clean empty jar and then saw a cyanide label placed on the jar still tended to refuse to drink the sugar water. Finally, subjects tend to medicalize the risk, arguing that the stigmatization was the result of a fear of health effects.

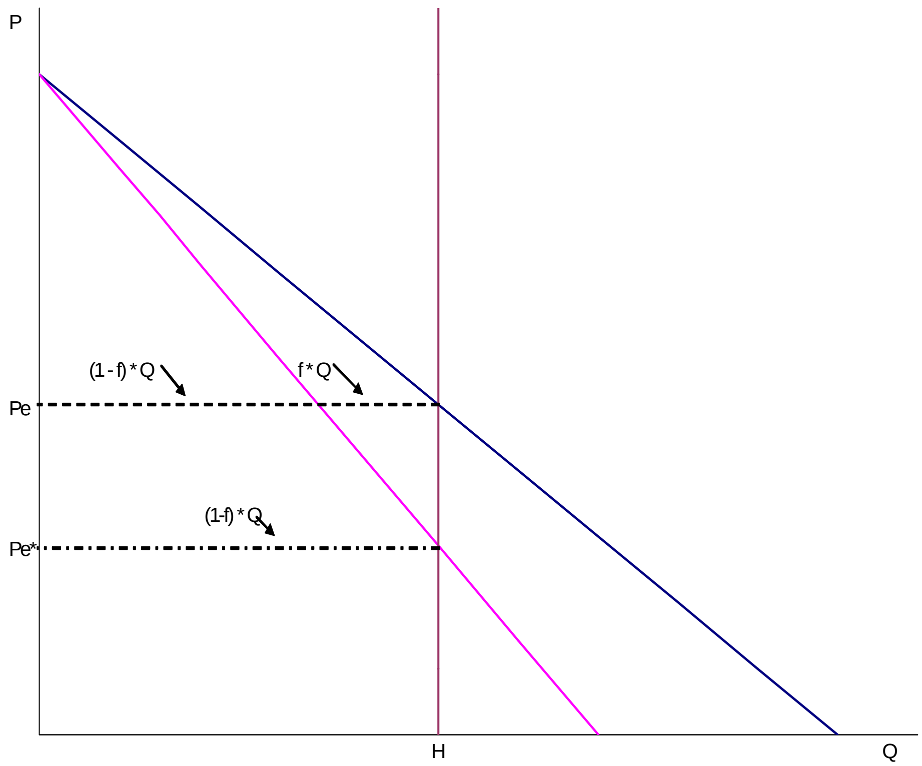
The possibility that Superfund sites might be stigmatized could have a major impact on the prospects for successful cleanup of contaminated sites. If such sites are permanently shunned because, like the "cockroached" juice, they are viewed as permanently stigmatized, property values may not recover immediately once cleanup is in progress (since future improvements should be capitalized into home values) or even when cleanup is completed.

1.5 Stigma and Property Values

The possibility that stigma may cause large losses in property values has been noted by other researchers (e.g., Dale et al., 1999; Adams and Cantor, 2001) and the EPA (Harris, 2004). In contrast to the hedonic approach (Rosen, 1974; and for application to hazardous sites see Bartik, 1998; Harris, 2004; Harrison and Stock, 1984; Ketkar, 1992; Kolhase, 1991; Mendelsohn, et al., 1992; Michaels and Smith, 1990; etc.) where risk is treated as one of many attributes that contribute to a determination of sale price, stigma is likely to effect property values in a rather different and more direct manner. Upon learning of the contamination potentially affecting their community, some current home owners may simply be unwilling to continue to live in their home, and likewise, potential buyers will be unwilling to consider buying a home in that community. If some owners and buyers have lexicographic preferences, the standard hedonic model fails since it relies on a tradeoff between risk and home prices. Rather, shunning by both current owners and potential home buyers will reduce the total demand for housing for a neighborhood near a site as shown in Figure 1.1. Imagine that the total demand for homes in a particular fully built-out neighborhood with H existing homes is Q(P) where Q is the number of desired homes, P is the sale price, and quantity demanded falls with price, $Q' < 0$. If, for example, homes were sold in a competitive uniform price auction, the equilibrium price, P_e, is obtained by solving H=Q(P), so $P_e = Q^{-1}(H)$. Now consider the case where a fraction f of home buyers and owners shun a neighborhood because of a nearby Superfund site. The usual hedonic model cannot handle this phenomenon because the hedonic price adjustment for these individuals, either through very high subjective risk beliefs (assuming conventional values of statistical life) or shunning would give homes a risk deficit greater than or equal to the value of the home. In other words, in either case the perceived costs of staying in the home are greater than the entire value of the home and the observed behavior would be identical. This implies that fraction f of current owners will sell and that the number of potential buyers will be reduced by fraction f as well. As shown in Figure 1.1, since we have defined total demand for the neighborhood to include current owners, the equilibrium price will now be determined by the solving $H=(1-f)Q(P)$, so $P_e^* = Q^{-1}(H/(1-f))$ and $P_e^* < P_e$ for $f > 0$. If f falls with distance from the site, as is likely since perceptual cues decline with distance, then property values will rise with distance, *ceteris paribus*. Of course, relative demand for housing that is more distant from the site will increase, but presumably this increase in demand will fall on a much larger group of homes, resulting in a negligible increase in prices of homes farther from the site.

The next question is, since a hedonic analysis is used to incorporate normal attributes for predicting property prices, how can downward sloping demand be incorporated into the analysis? The answer proposed here is that hedonic models predict an average price based on home and community attributes, but do not take into account individual buyer characteristics, including bidding errors, which will affect the willingness to pay for homes in a particular area. So, for example, relative to a predicted hedonic price, P_h, one particular individual will be willing to pay more because grandmother happens to live in the neighborhood and another particular individual will be willing to pay less because of a random error in bidding strategy. Clearly no hedonic market can exist for such attributes since they are buyer specific, and these sale price deviations will appear as part of the error term in the estimated hedonic equation. Thus, for homes with a particular set of hedonic attributes in a homogenous neighborhood with a mean sale price of P_h, there exists an array of values for homes among potential buyers, V, with a cumulative distribution function of Q(V). Presumably, the H buyers with the highest individual values will own homes in the area.

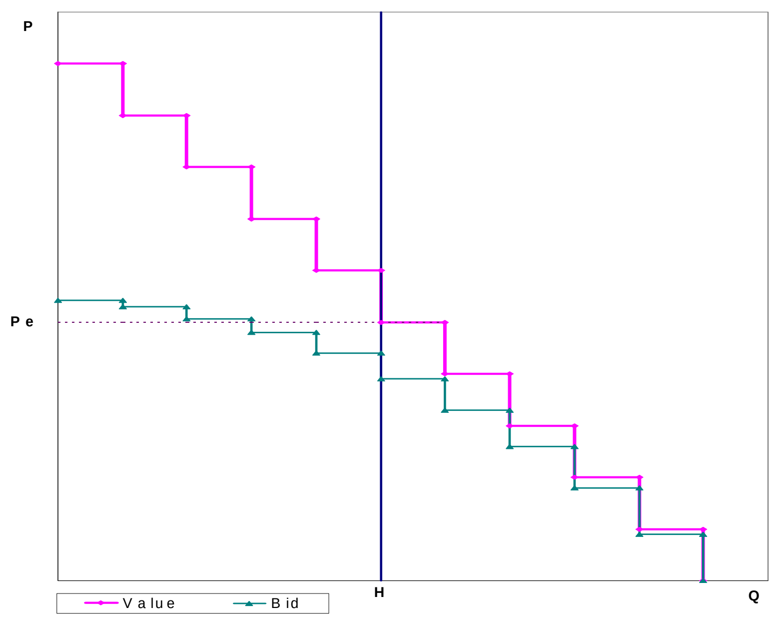
Figure 1.1 The Effect of Stigma on Equilibrium Housing Prices



To further understand the property value market, we model the market itself as a discriminative auction to account for the fact that identical homes in the same neighborhood can, in fact, sell for different prices depending on unobserved individual buyer errors and other attributes (see Cox et al, 1984, for a discussion of the relevant theory and an experimental test of this auction). Approximating the property value market with an appropriate auction where multiple buyers compete for available homes solves the potential problem associated with modeling real estate sales as bilateral negotiations where some sellers potentially have no value. Rather, in a discriminative auction other potential buyers provide competition that maintains the price at a higher level than that which would be predicted by bilateral negotiation. The properties of a discriminative auction are well understood, and this auction provides a reasonable approximation of the real estate market under the special circumstances where homes near a site are stigmatized.

As previously discussed, sellers in our model have essentially no value for the homes they are selling since they shun the site. Thus, any price they can get for the home is acceptable. This corresponds to an auction situation where buyers bid on H homes put up for sale, and the H bidders with highest bids obtain the homes for the prices bid. Figure 1.2 shows this market in the context of total demand where all homes in a neighborhood are potentially up for sale. Note that the bids in a discriminative auction (shown as the lower step function) fall below the true values (upper step function). Note also, that compared to the price that would be obtained in a uniform price auction giving a price, P_e, in a discriminative auction there is a distribution of bids and sale prices around the equilibrium price, since buyers pay accepted bid prices. In a discriminative auction, it is well known that if buyers are risk neutral, the average of the accepted bids will equal the uniform price, so revenue neutrality exists in theory between uniform price and discriminative auctions. Note also that risk aversion will increase bids in a discriminative auction and bring them closer to true values because buyers trade off the gain in consumer surplus of a lower accepted bid against the reduced probability of having their lower bid accepted. The lower bid curve shown in Figure 1.2 assumes risk neutrality and plausibly provides a lower bound for bids in a real estate market.

Figure 1.2 Discriminative Auction Market



With these concepts in mind, we can then turn to the hedonic model used to estimate property values at each of our study sites. The hedonic model estimated to explain property values uses a logarithmic specification and takes the form:

$$(1.1) \qquad SPRICE_{it} = P_t DIST_{it}^{b_{1t}} e^{b_2 A_{iT}} e^{b_e S_{it}} e^{b_4 D_{iT}} e^{\varepsilon_{it}}$$

Here, P_t is an area-wide price index for owner-occupied housing in year t, $DIST_{it}$ is the distance of each dwelling from the Superfund site in question. The coefficient associated with this variable will be allowed to differ across years by interacting the constant distance measure with yearly dummy variables. The vector A_{iT} is property attributes and S_{it} is a vector of (interpolated) time-varying characteristics of the Census tract in which the dwelling is located, and D_{iT} is a vector of the logarithms of the distances from the dwelling to a potentially relevant set of other spatially differentiated local amenities or disamenities, calculated at time T, the end of the sample period, rather than contemporaneously.

Taking the logarithms of both sides of the equation yields a version of this model that is appropriate for estimation:

$$(1.2) \qquad LSPRICE_{it} = \ln P_t + b_{1t} LDIST_{it} + b_{2t} A_{iT} + b_{3t} S_{it} + b_{4t} D_{iT} + \varepsilon_{it}$$

where $LSPRICE_{it}$ denotes the logarithm of the observed selling price, $\ln P_t$ will be captured as an intercept for the first year in the sample and a set of intercept shifters activated by year dummy variables. The variables of key interest are the $LDIST_{it}$, which consist of a vector of logged distances from the dwelling to the Superfund site interacted with yearly dummies in order to permit year-varying elasticities of housing prices with respect to distance to the site. Geographic Information Systems (GIS) techniques were used to measure distances from the homes to the closest Superfund site in the specific year, t, that the sales price was observed and the distance to other local amenities or disamenities as they existed in year T.

An ideal sample of data would consist of transactions data and housing structural characteristics, neighborhood characteristics, distances to all relevant amenities and disamenities, all collected contemporaneously with the time of sale. This ideal data would also include analogous information (except for selling price) about houses that did not sell in these periods, either because they were not for sale, or they did not find a buyer. This would allow the researcher to control for non-random selection into the pool of dwellings actually observed to be transacted.

When a researcher has data like these data over a number of years, it is possible to control for many unobserved housing and neighborhood characteristics that do not vary across time by using the so-called “repeat sales” method. When a house has sold more than once in the observed time period, the difference in the selling price can be explained in terms of differences in any explanatory variables that have also changed over time. This method for eliminating all the time-invariant characteristics from the analysis was first proposed by Bailey, et al. (1963), and has recently been used to analyze the influence of news stories about Superfund sites on housing prices (Gayer and Viscusi, 2002). One disadvantage of this method is that the sample of repeat-sales dwellings over-represents houses with greater turnover and excludes dwellings that have been sold only once during the window of time for which data are available. There is also a problem that any remodeling or updating of the property that is not captured by the quantity variables typically recorded in multiple listing service data will go unacknowledged in the process of dropping all structural characteristics by differencing over time.

In this study, we use a source of data that over-samples houses that have been sold only once over the time period in question. Our data roughly reflect the current status of dwellings. The data are provided, for the most part, by Experian, a company which provides information to direct mail marketers and others. These data are updated at fairly regular intervals, although not simultaneously. Anyone buying these records gets the most recent information available. For each street address in the sample, most records include information on the date when the house was purchased and the price that was paid at that time. For different localities, there are different quantities of structural information in the data set. From the same data supplier, all fields will be available for all localities, but for any given locality, blocks of fields will be blank. Blank fields differ across localities, possibly reflecting different public recording requirements.

In some cases, notably the Eagle County files sought for the Eagle Mine site near Vail, Colorado, the missing data problem was so severe that, despite the appearance of over 5,000 house transactions in the data, there were less than 50 with sufficient data for estimation of a basic hedonic property value model. Part of the problem is that a large share of dwellings is not owner-occupied. In that case, we sought and received data from the Eagle County Assessors office. There were roughly 1,400 observations for owner-occupied units, lying between 2.6 and 19.3 kilometers of the nearest part of the Eagle Mine site. About 57% were owner-occupied but were not single-family dwellings. Other problems existed with this data. For example, the data indicates that there are no current owner-occupied units in the vicinity of the middle school which is only 1,500 feet from a tailings pile. It would have been vastly preferable to have acquired the same assessor's office information for each year during the time span of interest (in this case, from 1976 to 1999). However, data that are "obsolete" from the point of view of the assessor's office are apparently not retained merely for the convenience of researchers who wish to understand time patterns in property values.

An obvious disadvantage of our sample is that in all of our data sets we only observe selling prices for the most recent sale of a house. If a house is in an area where turnover is high, there will be more recent sales and fewer earlier sales. For analytical purposes, it would be preferable to have data on all sales in all years and selling price in those years, but such data do not exist. Data could be purchased from Experian every year, if a future study could be anticipated, but retrospectively, the data are not available. The data are collected primarily for current marketing purposes and records are updated without saving their previous values. Historical modeling is not a use anticipated by the providers of the data. Consequently, there may be some systematic sampling. We observe earlier transactions prices only for houses which are still occupied by the owners who purchased them at that earlier date. We do not observe many early transactions prices for houses in neighborhoods where there has been a lot of turnover. It must be a maintained hypothesis that rates of turnover are uncorrelated with identification and cleanup of Superfund sites. This may be a strenuous assumption, but there are few alternatives. So it will be necessary to speculate upon the types of biases this non-random selection is likely to produce in the effects of distance from a Superfund site on housing transactions prices. Chapter 8 presents a description of the property value approach and data used in the study, while Chapter 9 presents the property value results.

However, a distinct advantage exists of only having one observation for each home in the sample. By only having one observation per house and controlling for area-wide price index with dummy variables, we ensure that each observation is independent. Therefore, the coefficient b_{1t} (the effect of distance from the Superfund site on property values) can be observed over time by looking at the hedonic estimates for each year over the 20-30 years of observations that have been obtained for each of the sites. To dampen noise, we average b_{1t} the coefficients over three-year intervals. To get time trends in property values as affected by the site, we normalize both by the initial three-year period property value effect, t=0, and by distance. Thus, we ask the question, at a minimum distance from the site, $DIST_{\min}$, how do property values compare to price at distance $DIST_{\max}$ (the boundary of the available data), which was chosen to be sufficiently far away such that no effects of the site should be present, and to the magnitude of this effect in the initial period. The relative property value effect, normalized by base period and by property values at a large distance is defined as

$$R_t = \left(\frac{DIST_{\min}}{DIST_{\max}} \right)^{b_{1t} - b_{10}} \quad (1.3)$$

Thus, the index for each site starts at 1.0 (or 100% in the figures below) and either decreases or increases in successive three-year periods from this value. Table 1.2 presents the results for each of the case studies.

Table 1.2 Coefficient Determinants

	Time Period	Average Distance Coefficient	Normalized Value
OII	1970-1972	-0.133	100.00%
	1973-1975	-0.136	100.79%
	1976-1978	-0.086	86.25%
	1979-1981	-0.099	89.65%
	1982-1984	-0.015	68.94%
	1985-1987	-0.039	74.28%
	1988-1990	0.013	63.03%
	1991-1993	0.015	62.65%
	1994-1996	0.015	62.65%
	1997-1999	0.027	60.46%
Montclair (Outside)	1987-1989	-0.022	100.00%
	1990-1992	0.009	90.65%
	1993-1995	0.031	84.81%
	1996-1997	0.064	76.51%
Montclair (Inside)	1987-1989	0.102	100.0%
	1990-1992	0.174	92.9%
	1993-1995	0.094	100.8%

	1996-1997	0.191	91.1%
Woburn	1978-1979	-0.166	100.00%
	1980-1982	-0.115	87.96%
	1983-1985	-0.154	97.01%
	1986-1988	-0.157	97.85%
	1989-1991	-0.134	92.35%
	1992-1994	-0.111	87.12%
	1995-1997	-0.106	86.04%
Eagle	1976-1982	-0.814	100.00%
	1983-1988	2.134	83.88%
	1989-1994	4.815	71.48%
	1995-1999	1.966	84.72%

As can be seen in Figures 1.4, 1.5, and 1.6 presented below, relative property values of the three metropolitan case studies (OII in Los Angeles, Industri-Plex and Wells G&H in Woburn, and Montclair, New Jersey) tend to follow an overall declining trend consistent with the notion of progressive stigmatization of the site as suggested by arguments from psychology. This result is in contrast to a number of earlier studies that examined property values over shorter time periods (Carroll et al, 1996; Kiel, 1995; Kiel and Zabel, 2001).

Our concluding chapter, Chapter 10, attempts to explain the long term downward trends observed in relative property values shown in Figures 1.3-1.5 using a psychological model. If the trend is driven by f, the fraction of home owners and potential buyers who shun homes near the site, a model of the determination of f over time is needed. From the discussion of the psychology of risk perception and stigma, the determination of the fraction of shunners will be driven by media attention and perceptual cues resulting from activity at the site, which are in turn driven by “events” such as EPA announcements, discovery, NPL-listing, and cleanup. Thus, it is plausible that the percentage change between periods in the fraction of the population who shun the site is a linear function of events of type j occurring during the prior interval, characterized by the discrete dummy variable (or index summarizing a number of dummy variables), $E_{j,\,t-1}$, thus

(1.4)
$$f_t - f_{t-1} = \alpha + \sum_j \beta_j E_{j,t-1}$$

So, in a period with no events, $E_{j,\,t-1} = 0\ \forall j$, we hypothesize that α is negative and f will decline, thereby raising home values, because some people who know about the site will leave the area (perhaps because of job opportunities elsewhere) and some new potential buyers will move into the area who will have no awareness of the site. Other events, such as cleanup activities, might, (a) raise awareness and thereby increase the fraction of the population who shun the site, or alternatively, (b) reduce the fraction of shunners by convincing people who know about the site that it is now safe. This latter possibility is unlikely in that the notion that, "once contaminated, always contaminated" is part of the psychology of stigmatization. Note, also, that changes in perceived risk for those who may not shun the site will likely follow a similar model.

There is no available data on f, so the model specified above cannot be estimated directly. However, if one assumes a constant elasticity of demand, $\eta<0$, and risk neutrality, a simple transformation exists between f_t and R_t as defined above: $f_t = 1 - R_t^{-\eta}$. Thus, the equation describing movement in f_t can be rewritten as:

(1.5) $$R_t^{-\eta} - R_{t-1}^{-\eta} = -(\alpha + \sum_j \beta_i E_{j,t-1})$$

Figure 1.4 Relative Property Value over Time for OII Landfill, California

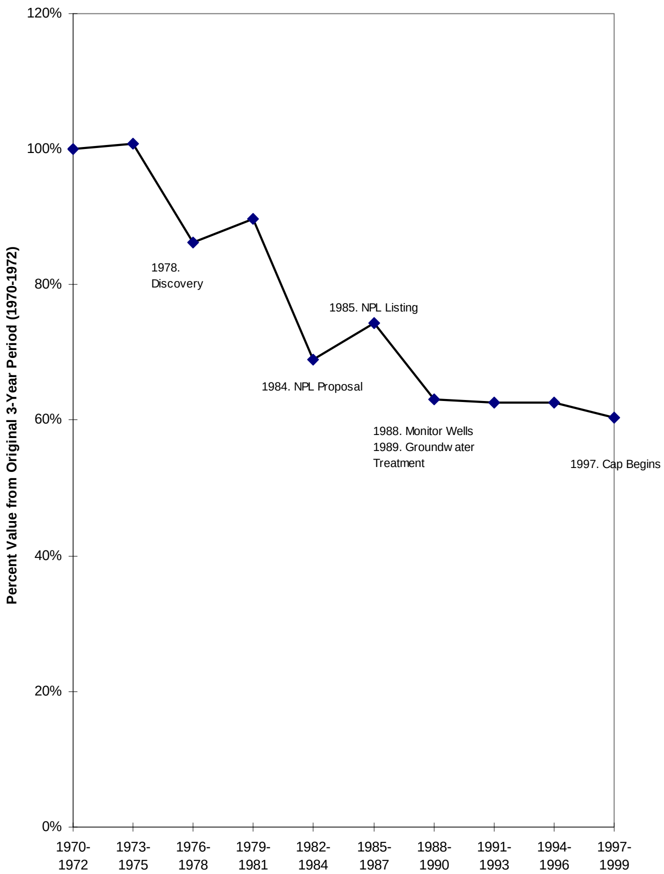


Figure 1.5 Relative Property Value over Time for Montclair, New Jersey (outside of area)

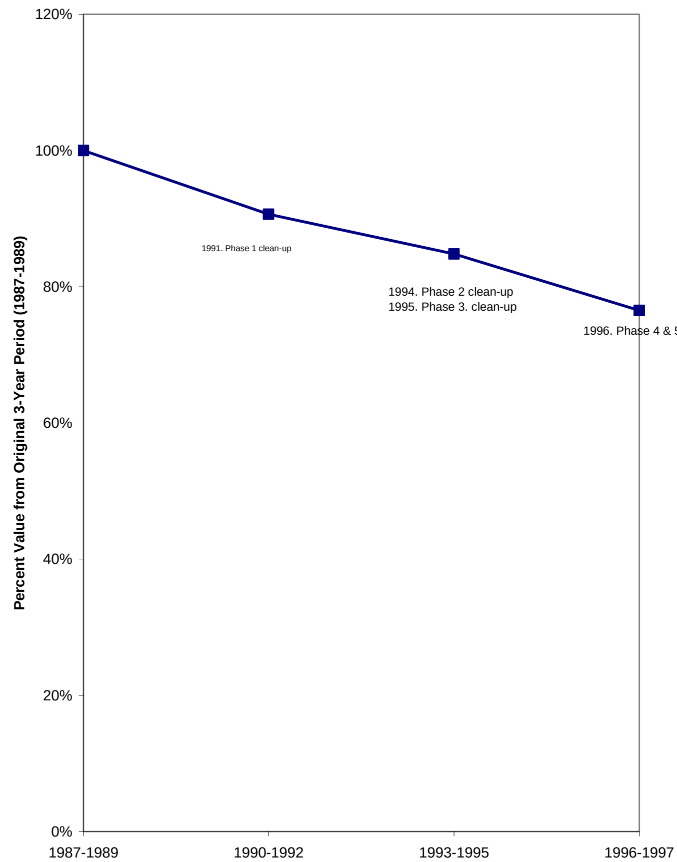
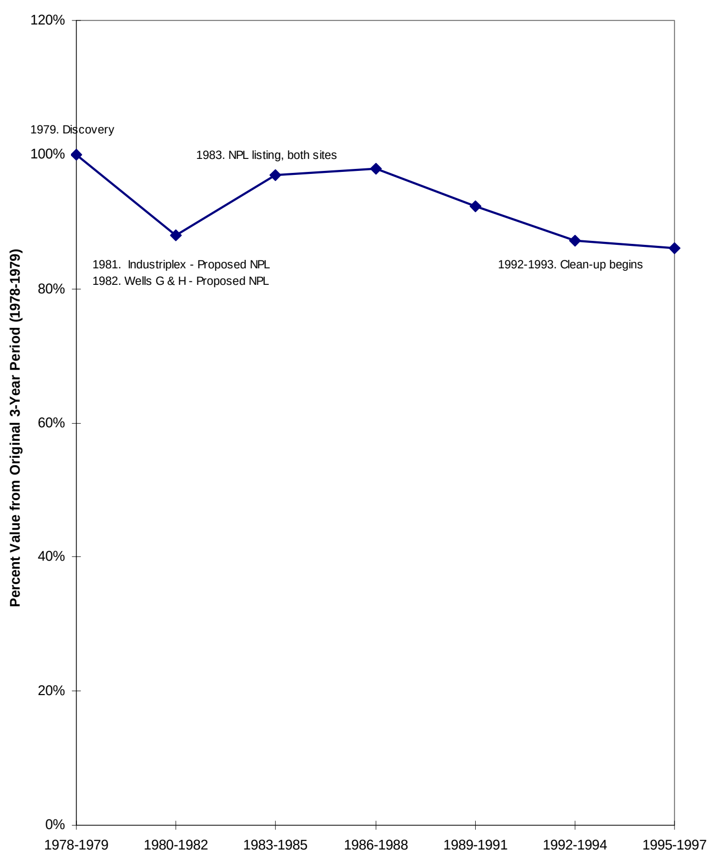


Figure 1.3 Relative Property Value over Time for Woburn. Massachusetts



To employ this transformation we need to know the relevant elasticities of demand that depend on the error distribution in bids. Since we do not have this information, we assume that the elasticities are all -1.0, consistent with a linear approximation of the relationship between f and the change in R over time.

Table 1.3 Number and Description of Events

	Number of Events			
Event Type	**OII**	**Montclair**	**Woburn**	**TOTAL**
EPA Action	11	3	14	**28**
State Government Action	6	1	4	**11**
Local Government Action	10	1	0	**11**
Public Action	2	1	9	**12**
Potentially Responsible Party Action	7	0	0	**7**
Remediation Action	6	4	3	**13**
EPA Announcement	12	3	8	**23**
Site Incident	5	2	12	**19**
TOTAL	**59**	**15**	**50**	**124**

Table 1.4 presents a psychological model using the data shown in Figures 1.3, 1.4, and 1.5 of relative property values over time for the three metropolitan sites. Note, as mentioned earlier, Eagle Mine was excluded from this analysis because the socio-demographic information for the homes were unavailable. Since all of the home sale observations were independent, a simple linear regression could be used with 18 observations of changes in relative property value ($R_t^{-\eta} - R_{t-1}^{-\eta}$) over the three-year periods for the three sites. For Discovery, NPL Listing, and the Beginning of Major Phases of Cleanup, dummy variables were used. The variable "Events" was

derived by summing the number of major announcements and actions described in EPA published reports for the relevant three-year interval for each of the three case studies (Table 1.3). Events are defined as followed:

- **EPA Action –** Includes site investigations, orders, notifications/decisions, remediation, legal actions, and regulations the EPA.
- **State Government Action –** Includes site investigations, orders, resolutions, remediation, lawsuits, reports, and regulations by state agencies.
- **Local Government Action –** Includes site investigations, orders, resolutions, remediation, lawsuits, reports, and regulations by local cities, county, and school districts.
- **Public Action –** Include the creation of public interest groups, major public meetings and protests, lawsuits by the residents, and the hiring of technical advisors for the community.
- **Potentially Responsible Parties Action –** Include site operation and closure, and committees formed. Lawsuits by PRPs.
- **Remediation Action –** Includes containment of contaminations, remediation efforts and site improvements.
- **EPA Announcement –** Includes official Consent Decrees, Record of Decisions (RODs), and announcements of settlements with PRPs.
- **Site Incident –** Includes general site facts, reports and studies regarding the contaminants and occurrences at the site.

The analysis across the three sites shows that discovery, cleanup itself, and the number of events all negatively affect property values by drawing attention to the site and possibly increasing the number of owners and potential buyers who shun the site thereafter (Table 1.4). Thus, the effect of any event, publicity or site information, good or bad, appears to increase the fraction of the current home owners and potential buyers that stigmatize and consequently shun the communities neighboring the sites. In other words, at least within the observed period of the studies, all news is bad news and causes relatively permanent property value losses as an increasing fraction of original owners leave and more potential buyers shun the site. The only good news in the study is that property values did significantly recover for a short period after sites were listed on the NPL. But, it is likely that as soon as it was realized that EPA could not immediately clean up the sites, the process of stigmatization began with consequent reduction in property values. All of these coefficients except the constant are significant at better than 1% level.

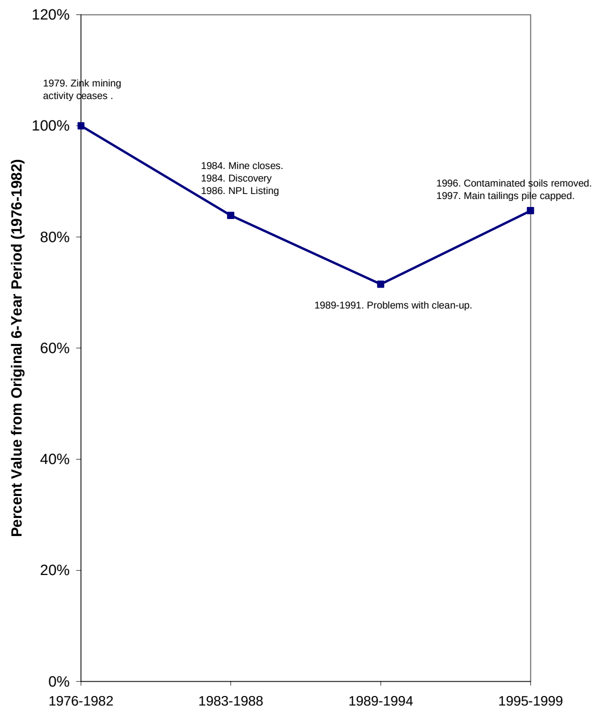
Table 1.4 Psychological Model, Dependent Variable $R_t - R_{t-1}$

Model	**B**	**t**	***p***
(Constant)	0.078	3.578	0.003
Discovery	-0.160	-4.493	0.001
NPL – Listing	0.105	4.097	0.001
Clean-up Begins	-0.096	-4.753	0.001
Number of Events	-0.016	-6.156	0.000

N=18
R^2 = 0.855

Rather than property losses reversing immediately once cleanup has begun, we see no permanent recovery in property values within the time period of our data and speculate that recovery will only occur as the local population gradually moves away, events cease, and perceptual cues and media attention disappear, so more buyers are uninformed. Note that McClelland et al. (1990) found that most buyers were uninformed in spite of reporting requirements. The positive intercept in the psychological model (significant at better than the 5% level) indicates that property values will increase at a linear rate of about 12% every three-years if no actions are taken and no news is generated by the site. Thus, at OII one could expect a complete recovery in about a decade if no news is generated from the site and recovery might occur in about half that time for the other sites.

Figure 1.6 Relative Property Value over Time for Eagle Mine, Colorado



The sites excluded from the model are also of some independent interest. First, although the Eagle Mine (see Figure 1.6) has very different characteristics from the three sites discussed above, it shows a similar pattern in that relative property values decline for most of the period analyzed. Given the small amount of data available along the Eagle River, we are forced to use six-year rather than three-year periods for the analysis but do confirm the general pattern shown above. Second, the “inside” Montclair property value estimates do not use distance as an explanatory variable since the homes themselves are within the Superfund site. Yearly dummy variables averaged over the same three-year intervals used in the outside-Montclair analysis show that, unsurprisingly, cleanup itself does have a positive impact on property values (Figure 1.7). Third, another interesting result in the property value studies is the effect of including socio-demographic variables. As shown in Figure 8, these make a large difference in the magnitude of property losses at the Woburn site. Negative socio-demographic trends, that may be the result of the progressive stigmatization of the site, also take a substantial toll on property values (that are not included in the psychological model), but possibly should be included in any damage assessment. These results suggest a different trend than observed by Kiel and Zabel (2001) which did not account for these socio-demographic affects.

Figure 1.7 Relative Property Value over Time for Montclair, New Jersey (inside of area)

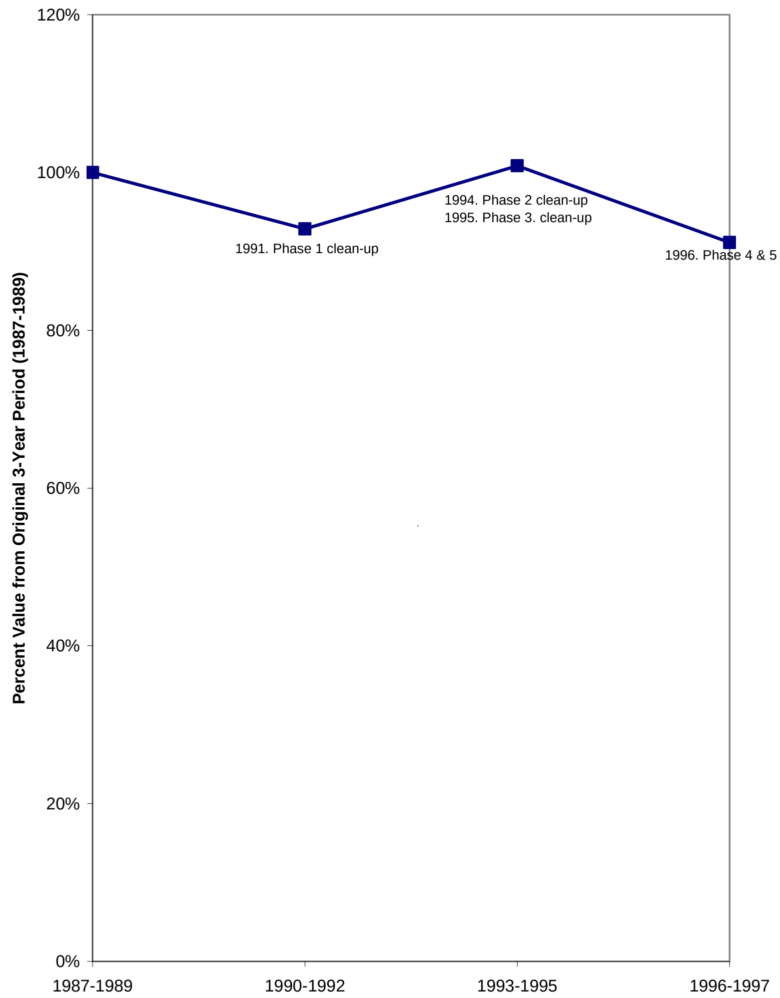
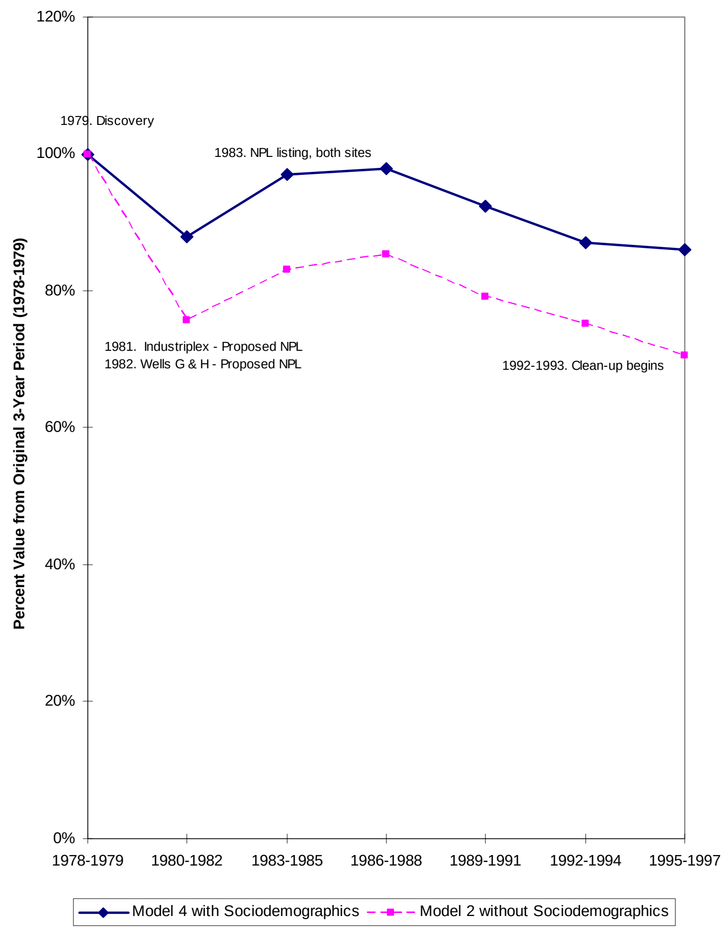


Figure 1.8 Relative Property Value over Time for Woburn, Massachusetts with and without socio-demographic variables.



1.6 Policy Implications

Since economic benefits are based on discounted present value, the benefits of delayed cleanup for homes surrounding sites are likely to be negligible where cleanup takes 20 years and another 5-10 years may be needed after cleanup is complete for property values to recover. The principal policy conclusion becomes evident from the results of the psychological model, which suggest that the promise of a prompt cleanup raises property values, while an increase in the number of events that are the root cause of perceptual cues and media attention decreases property values. Thus, an expedited cleanup should occur as quickly as possible after a site has been determined to be hazardous and this cleanup should be conducted in a way that does not arouse excessive attention. Otherwise the neighborhoods surrounding the site will likely be stigmatized resulting in quasi-permanent economic damages.

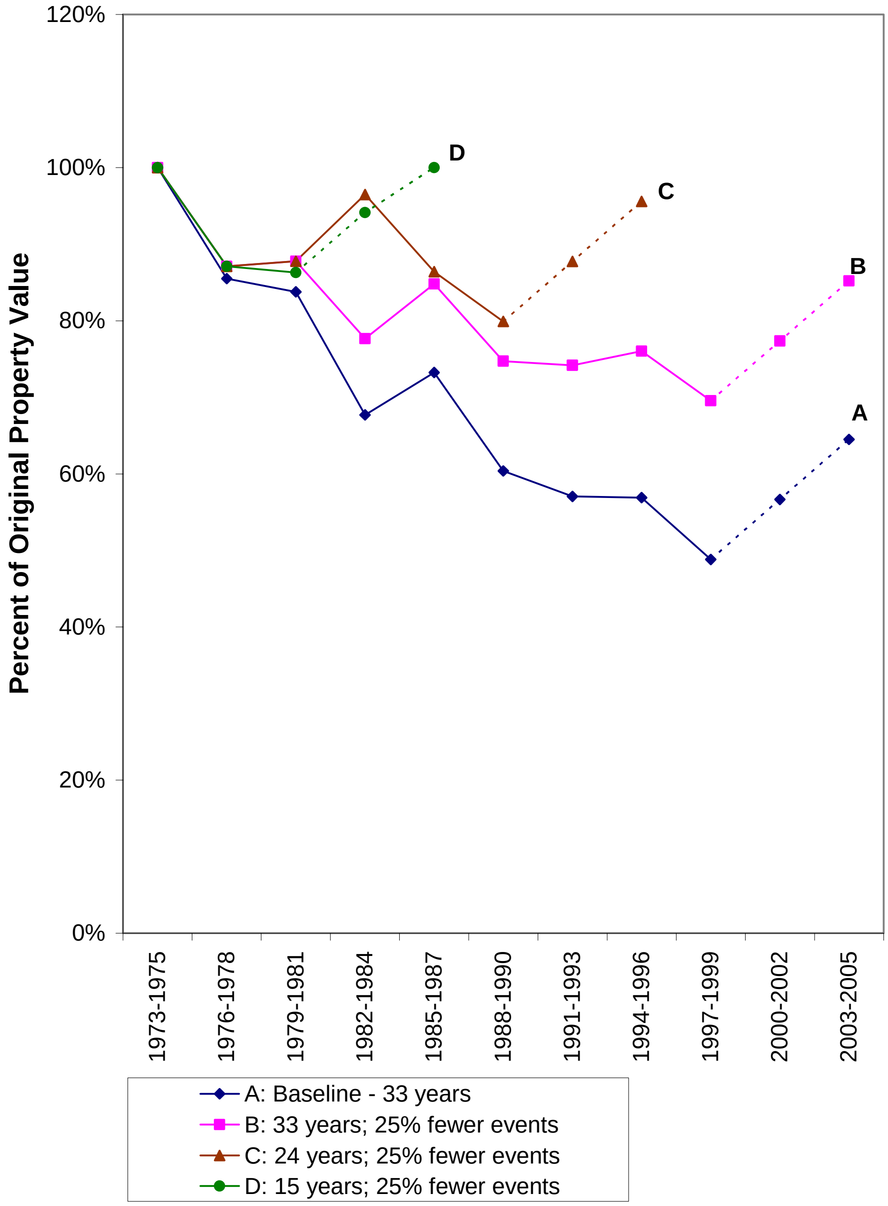
Table 1.5 Cleanup Scenarios

	Time Horizon	Events	Discovery	NPL Listing	Cleanup time periods	Recovery time periods	Final % of Original Value
Scenario A	33 years	All	1978	1985	1988-1990 & 1997-1999	2002-2005	64.5%
Scenario B	33 years	25% Fewer	1978	1985	1988-1990 & 1997-1999	2002-2005	85.2%
Scenario C	24 years	25% Fewer	1978	1982	1985-1987 & 1988-1990	1990-1995	95.6%
Scenario D	15 years	25% Fewer	1978	1979	1979-1981	1982-1987	100.0%

Using the history of the OII and the corresponding dates and events in a simulation, the potential benefits of these policies becomes evident (Figure 1.9). As shown in Table 1.5, this simulation considers four different scenarios and includes an extrapolation of a recovery in property values after cleanup is complete where there are no further events. Given the legislative history of Superfund, some of these scenarios are clearly fanciful, but the results are nevertheless suggestive as to what potential benefits could be obtained by expediting the cleanup process and reducing the number of events that drive perceptual cues, media attention, and social amplification. These results support several of the suggestions made by Kunreuther and Slovic (Chapter 21, 2001) for reducing stigma. In particular, they suggest prevention of the occurrence of stigmatizing events and the reduction of the number of stigmatizing messages and thus reducing social amplification.

Note that these results contrast with those of Gayer, Hamilton and Viscusi (2000) and Gayer and Viscusi (2002) who argue that media attention supports learning that leads to a lowering of public risk perceptions more consistent with scientific evidence for smaller sites. No credible evidence supports a significant long-term health risk to residents living near OII (McClelland et al. 1990). Yet the actual property value losses are enormous. One difference is that this study focuses on prominent sites while the two studies cited above focused on less prominent sites. Note, however, that most potential benefits from cleanup are likely to come from prominent sites. Also, both Woburn and Montclair are associated with demonstrable long-term health risks, yet property losses are much smaller than at OII. Finally, property value losses seem to be greatest when cleanup finishes, when risks should be at their lowest.

Figure 1.9 Policy Simulations Using the OII Landfill History



It is interesting to note that Carol Browner did in fact institute reforms to USEPA policy in 1995 to at least partly attempt to avoid the pattern shown in this study. EPA began to work with PRPs in an attempt to negotiate sufficient cleanup at potential Superfund sites to avoid having sites listed on the NPL. These reforms may, in fact, have represented an optimal response given the difficulty stigma presents for neighborhoods surrounding Superfund sites. It should also be noted that the enormously costly process of litigation and delayed cleanup that has occurred under the Superfund program has provided strong incentives for industry to avoid creating new hazardous waste sites. However, for residents living near very large Superfund sites, as they have often stated, the program has failed in spite of EPA's best efforts. In this regard, it should be noted that when CERCLA was passed, little or none of the work in psychology necessary to understand the phenomena described here had been completed. In fact, much of the relevant work was motivated by Superfund.

This study raises several questions for future research. First, are smaller sites truly different as the work by Gayer, Hamilton and Viscusi suggests? Second, although the psychological model developed here is statistically significant, it is based on data from just three sites. Additional work to incorporate both larger sites, as well as smaller sites, and additional explanatory variables would be worthwhile in our judgment. Finally, more research to understand and prevent stigmatization is warranted.

Chapter 2

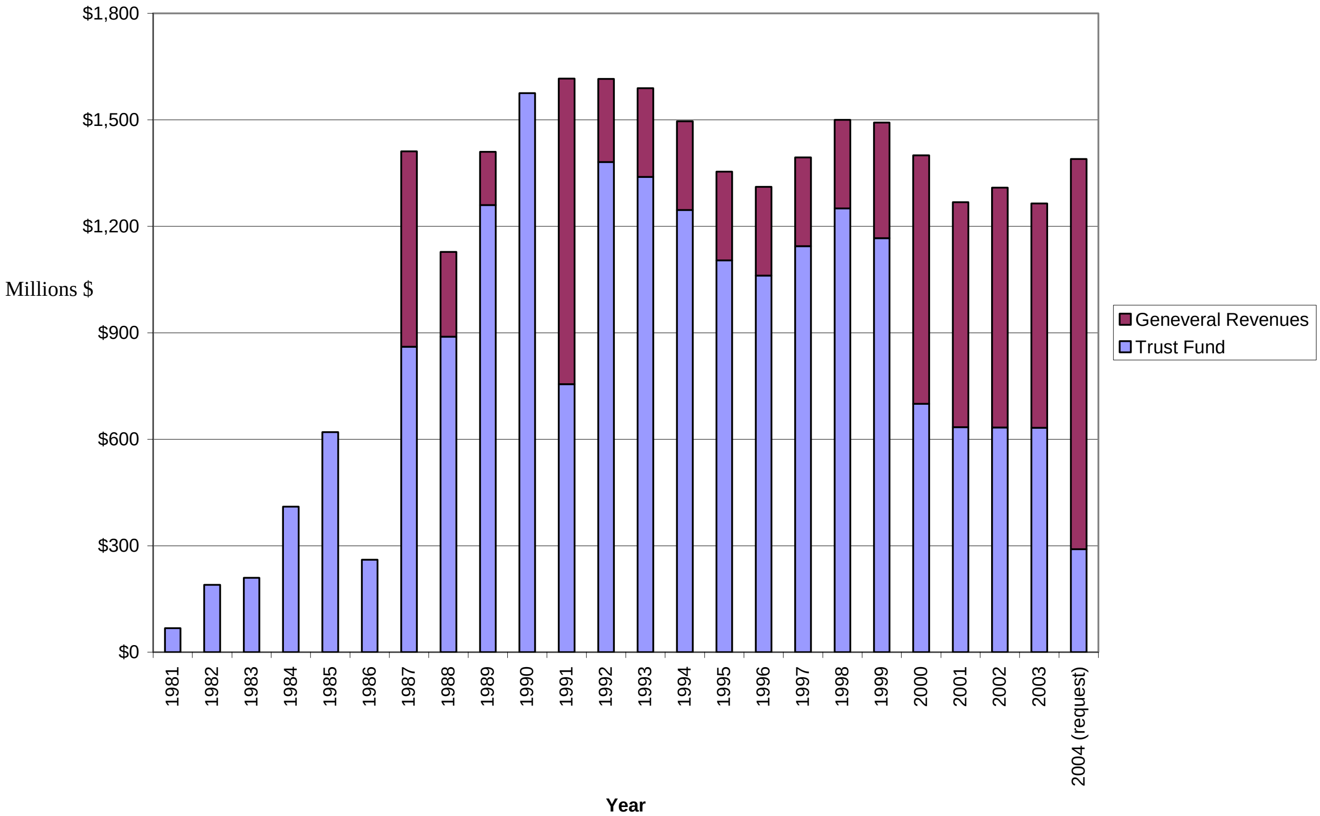
History of Current Superfund Legislation

2.1 Overview of Superfund Legislation

Superfund is one of the most controversial pieces of legislation ever implemented by the EPA, and it has been tainted for years by skepticism and uncertainty. Congress approved the Superfund bill in 1980, despite uncertainty about the number of sites, costs of cleanup, and availability of appropriate technology. The number of sites in need of cleanup and the costs of the program skyrocketed beyond the original expectations of Congress or the EPA, due to underestimates of the extent of the hazardous waste problem. The bill was reauthorized twice, but in December 1995 it was not renewed. The taxing authority of the fund expired in December 1995, leaving only fines, penalties, and interest as working income for EPA's Superfund program.

Since 1995, the Superfund program has been primarily funded by the Trust Fund, and the General Fund that supplements the Trust Fund. Since 2000, an average total of $1.3 billion is appropriated to Superfund each year with more money being allocated from the General Fund than the Trust Fund (Figure 2.1). The Superfund trust is used in cases where responsible polluting parties cannot or will not pay for cleanup. In some cases where the EPA has tapped the Superfund trust for cleanup, EPA cleans up the property itself and then sues the responsible polluting party for triple the damages. The 2004 request is $1.1 billion from the General Fund and only $290 Million from the Trust Fund. Changes in the way the Superfund program and how the EPA cleans hazardous areas are underway. On April 12, 2004, the National Advisory Council for Environmental Policy and Technology released its Final Report on the how the Superfund program could be improved.

Figure 2.1 Superfund Budget (1981-2004)



2.2 Legislative Background

The driving force for Superfund legislation came from 1978 report by Michael Brown, a local reporter for the Niagara Gazette newspaper, on Love Canal, the toxic waste site near Niagara Falls. He described children coming home from the playground with hard pimples on their bodies, women giving birth to deformed and mentally retarded children, and many other horrible consequences of Hooker Chemical and Plastics Corporation's (now Occidental Petroleum) disposal of over 20,000 tons of toxic wastes in an unlined canal (Barnett, 1994). The thought of a country filled with sites similar to Love Canal angered the American public. Shortly after the issuance of Brown's report, Congress began hearings on Love Canal and other waste disposal sites throughout the country.

The Carter Administration favored a new piece of legislation addressing the toxic waste issue because existing legislation, such as the Clean Air Act of 1970 and the Clean Water Act of

1972, regulated the emission of chemical pollutants, but did not consider the impact of chemical pollutants and toxic waste on human and ecological health. A key question in the legislative debate was whether the funds should come from general government revenues or from the financial contributions of both the offending industry and the government. In mid-1979, President Carter spoke in favor of a bill with a $1.6 billion fund, financed 80% by industry and 20% by government imposing strict, joint and several liability on responsible polluting parties (Barnett, 1994). Joint and several liability means that a company, individual, or some combination thereof, can be held responsible for the entire cleanup of a hazardous waste site regardless of the amount of pollution contributed to the site. That is, there is no proportionality with respect to liability. This “deep pockets” principle was highly controversial.

In 1979, several key issues divided the proposed Superfund legislation in the House and Senate. These included the size of the fund and if the legislation should be limited to abandoned hazardous waste sites or also include provisions for oil and hazardous substance spills. The House preferred two separate bills totaling $1.9 billion, while the Senate preferred a $4.1 billion bill that could be used for both emergency removals and more costly, long lasting projects. Both the House and Senate, however, agreed the legislation should be financed primarily through taxes imposed on chemical feed stocks. The chemical industry disputed this overall tax on the industry and advocated financing the fund through the federal treasury, responsible parties, and state contributions. The final Superfund bill did not include other House and Senate recommendations regarding public participation in the siting of hazardous wastes or determining satisfactory levels of cleanup.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (commonly referred to as Superfund) was signed into Public Law 96-510 by President Carter on December 11, 1980. It passed by wide margins in both the Senate (78 to 9) and House (274 to 94). The final Superfund bill passed under several unusual circumstances. The Senate Finance Committee sent the bill forward without a formal recommendation and President Carter pushed for it to be signed quickly, before Reagan took office. The bill, because it was rushed, was not based upon an accurate assessment of the problem, and suffered from a lack of research as well as inaccurate estimates of the potential costs and the number of toxic waste sites. As noted in a 1985 report funded by the Cato Institute, the law "was based upon misunderstandings and distortions of the situation, and zipped through a lame duck Congress in a spirit of vengeance against the polluters" (Delong, 1995).

2.3 Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA created a five-year, $1.6 billion trust fund for the cleanup of active or abandoned hazardous waste disposal sites that posed an immediate threat to public health and the environment or when a responsible party would not take action. Superfund called for two different types of cleanups: (1) Remedial Actions, which ere long-term cleanup for sites on the National Priority List (NPL), and (2) Removal Actions, which are short-term cleanups of immediate threats. Removal Actions did not require listing on the NPL.

The trust was funded by the chemical and petroleum industries, which were required to pay into the fund. The chemical industry ended up paying 85% of the $1.38 billion paid by these two industries. The States were required to contribute 10% of the total cleanup costs, provide long term maintenance at sites, and provide disposal capacity for waste removal (Office of Technological Assessment, 1984). The other component of the Superfund trust included a series of taxes. Specifically, the bill created a $0.79 per barrel tax on US refineries, crude oil and petroleum imports, and domestically produced crude oil. Hazardous chemicals and wastes were taxed at rates varying from $0.22 to $4.87 per ton. After September 30, 1983, there was an additional excise tax of $2.13 per dry weight ton of hazardous waste received at qualified hazardous waste disposal sites (Office of Technological Assessment, 1984). The taxing authority of the CERCLA legislation expired September 30, 1985, though it was reauthorized shortly thereafter.

Under the CERCLA legislation the EPA was required to assess the nation's hazardous waste sites according to the hazard ranking system, which is a numerically based screening system that determines the threat of waste sites to human health. A minimum of 400 of the worst hazardous waste sites were to be placed on the NPL, and each state was given the opportunity to place a site on the list as well. The bill also gave the EPA and the Justice Department legal authority to identify polluting parties, enforce liability, and enlist contributions for cleanup.

Superfund imposed strict, joint, and several liability, and the generators of hazardous waste substances and the owners and operators of waste facilities, past and present, were all liable to pay for the costs of cleanups. The process for cleanup entailed listing a site on the NPL. Then scientists conducted a detailed examination of the site called a remedial investigation. This was followed by a feasibility study, an ascription of the most appropriate cleanup remedies. These two processes are often referred to as the “remedial investigation/feasibility study” or “RI/FS”. Once the appropriate remedies were selected, the EPA prepared, or appointed an agency to prepare specifications and timelines for the cleanup of the site and remediation begins.

2.4 Implementation of Superfund: 1980-1985

The Reagan Administration took office only weeks after the Superfund bill was signed, and it promoted an ideology that was incompatible with many of Superfund’s legislative provisions. The objective of the Reagan Program was to promote economic growth by reducing the size and number of federal spending programs, cutting taxes, and reforming regulatory agencies (Barnett, 1994). Reagan reduced government spending and emphasized *voluntary* compliance with environmental regulations.

Funding Superfund presented an immediate problem. The actual costs of cleanups were much higher than the original estimates of $7 to $10 million (Barnett, 1994). By 1992, 42 of the 50 states lacked adequate resources to fulfill their obligations to pay 10% of the costs of cleanup (Office of Technology and Assessment, 1983). During the first three years of the program, appropriations for Superfund also fell far below those initially authorized by Congress. Of the $960 million authorized in the first three years, $74.4 million was appropriated in 1981, $26.6 million in 1982, and $210 million in 1983. Most funding for the program was devoted to legal battles with polluters as well, and the federal government wrote off $270 million because responsible parties could not be found or were unable to pay (New York Times, 1993). As a result of these funding setbacks, elements of the Superfund program were cut back in 1981 and 1983. The EPA’s total outlays were cut by one third (Shabecoff, 1983), the abatement and control staff declined 21%, the enforcement staff decreased 33%, and the research and development staff declined16% (Crandall and Portney, 1984: 68).

While the funding for Superfund was less than originally anticipated, the number of sites identified for the National Priority List far exceeded expectations. The legislation called for an identification of at least 400 sites to be added to the NPL. The EPA quickly identified 16,200 potentially hazardous sites and placed 546 sites on the proposed National Priority List. The first official National Priority List, released in September of 1983, included 406 sites (Environmental Protection Agency, 1997). The following year, the EPA added 132 more sites to the List bringing the total up to 538 (Environmental Protection Agency, 1997). While the list continued to grow, only 119 site removals and two full cleanups were completed by mid-1983 (Davis, 1983). Various government and private agencies re-estimated the number of sites in need of cleanup. The new figures were much larger than originally anticipated, and ranged from EPA's initial estimate of 2,000 sites to the Office of Technological Assessment's estimate of over 10,000 sites (Office of Technological Assessment, 1985). As of March 31, 2004, 1,239 sites were listed on the National Priorities List (NPL).

To further complicate the bill's implementation, a scandal concerning the manipulation of hazardous waste programs by some EPA officials erupted in 1982. Top officials were charged with using political criteria to determine Superfund spending and making "sweetheart" deals with industry members for partial cleanup, perjury, and the manipulation and destruction of government files. EPA Administrator Anne Burford and 13 other top EPA officials, including Rita Lavelle (head of the Superfund program), were forced to resign in March of 1983. This "Sewergate" scandal dominated the front pages of major newspapers for the first three months of the year, causing the EPA to lose a considerable amount of legitimacy and some of its own morale. This scandal, furthermore, undermined the momentum of the already struggling program.

After the resignation of Administrator Anne Burford, William Ruckelshaus took office in 1983. Ruckelshaus adopted a more aggressive approach to remediation and often used lawsuits to force industry members into compliance. The EPA financed 102 waste removals within the first six months of Ruckleshaus' term and an additional 157 waste removals from 1984 to 1985. The EPA's combined outlays in fiscal years 1984 and 1985 totaled over $600 million, a 261% increase over the $233 million spent between 1981 and 1983 (Barnett, 1994).

2.5 1985: The Expiration of Superfund

Superfund legislation expired on September 30, 1985. Debates about reauthorization of the bill continued for over a year because of uncertainty about how to improve the program's performance. Reauthorization issues included concerns over health and environmental risks at waste sites, questions about risk assessment, frustration with lengthy cleanups, and burgeoning costs. Many cleanup cases were embroiled in legal battles which often expanded into complex webs of multiple party lawsuits, further compounding Superfund’s problems. The public's expectations of the program were initially very high, but they found the rate and success of cleanups disappointing (Office of Technological Assessment, 1984). Changes to the Superfund legislation were imminent and necessary.

The House and Senate proposed different reauthorization bills in 1985. The House was overwhelmingly (391 to 33) in favor of a bill creating a five-year, $10.1 billion dollar program. Revenues would include $3.1 billion from a tax on petroleum companies, $2 billion from a tax on chemical companies, and $2 billion from a tax on toxic wastes. The Senate proposed a five-year, $7.5 billion program. General revenues would provide approximately $1 billion with the remaining $6.5 billion to come from special taxes on manufacturers and processors of raw materials with annual sales of $5 million or more (Shabecoff, 1985). Environmentalists argued that the bill would not raise enough money and was described by the Washington representative of the Sierra Club as "a missed opportunity to build an effective program" (Shabecoff, 1985).

The EPA anticipated that the debate between Congress and the House would continue past the bill's expiration date and began to halt or slow cleanup at 57 sites in August of 1985 (New York Times, 1985). As the authorization debate continued through April, the Agency reduced its response rate to toxic waste emergencies by 80%. Although EPA Administrator Lee Thomas said that $5 billion was the most EPA was capable of spending over the next five years, the House and Senate remained firm in their higher requests of $10.1 billion and $7.5 billion respectively (New York Times, 1985). As a result of the lengthy debates in 1986, appropriations for the program were reduced from the expected $900 million to $206 million (Shabecoff, 1986).

2.6 Superfund Amendments and Reauthorizations

A conference committee finally approved a plan on July 31, 1986 for a five-year, $9 billion fund. The bill included $500 million for regulating leaky underground storage tanks; created a new, broad based tax on corporations earning more than $2 million a year; and increased taxes on oil products (Shabecoff, 1986). Other provisions imposed new regulations throughout all EPA offices with respect to deadlines and cleanup standards, increased public involvement by requiring industry to provide local residents with information about chemicals used, and required the EPA to provide technical assistance grants to communities proximate to NPL sites.

President Reagan signed this bill known as the Superfund Amendments and Reauthorization Act of 1986 (SARA) on October 17, 1986. After the expiration of Superfund's taxing authority, the CERCLA legislation was extended two more times: first for a four-year period at which time $5.1 billion was authorized for the program and second through December 1995.

The 1986 reauthorization failed to solve many of the Superfund's problems. The EPA still lacked adequate financial resources to cleanup many waste sites due to difficulties collecting money from responsible parties. The liability scheme caused funds to be tied up in legal battles. The EPA spends approximately 15-18% of the Superfund budget on the legal enforcement of its cleanup mandates. There were often over 100 PRPs at large sites, creating complex webs of lawsuits (Barnett, 1994). Responsible parties found it worthwhile to litigate in hopes of spreading costs among many responsible parties (as opposed to settling) because the average cost of cleanup at a site was approximately $30 million. A 1993 report funded by the Cato Institute indicated that, in 1989, insurance companies spent an average of $470 million on costs related to the Superfund program, $410 million of which went to defending their policy holders (New York Times, 1992). According to a RAND Corporation survey in 1994, legal fighting over prior liability was costing a total of $1 billion a year, while fewer than 200 of the most serious 1200 sites had been cleaned up (Quint, 1994).

To help remedy inefficient spending on legal fees, the Congressional Budget Office (CBO) studied the costs of repealing prior liability, a provision in the Superfund legislation that holds a company legally responsible for cleanups when the waste was dumped before Superfund was enacted. The CBO found that repealing prior liability would reduce transaction costs and increase efficiency of the program. It might also, however, reduce the speed of cleanup or require lowering cleanup standards. Additionally, federal government spending on Superfund would need to increase by $1.6 billion per year and the government would incur an additional one-time cost of almost $7.5 billion for PRPs' ongoing expenses plus $6 billion for past costs (Committee for the National Institute for the Environment, 1997). Consequently, many government officials remain opposed to the repeal of prior liability. They believe that the general public should not have to pay for the costs of hazardous waste cleanup and that tax money should be reserved for orphan sites and emergency actions.

Other challenges with the Superfund program remain as well. Cleanup times were criticized as being too slow. According to the General Accounting Office (GAO), the average time to cleanup a site increased from 3.9 years in 1986 to 10.6 years in 1996 to 11.5 years in 1999. The time it took from discovery of a problem site to its final listing increased from 5.8 years in the 1986-1990 time period to 9.4 years in 1996 (GAO, 1998). The GAO concluded that these increases are due to the legislation's ambiguous cleanup requirements (GAO, 1998). The structure of the program was fundamentally flawed because it neither provided contractors with incentives for cost effective remediation nor encouraged innovation. Responsible parties were reluctant to try new technology because they feared inadequate results and the possibility of having to conduct a second costly remediation. The legislation also required copious amounts of paperwork and authorizations. Critics also were concerned about the EPA's risk assessment procedures, claiming that the true risks of most people living near sites are overstated, resulting in costly remedies and little gain in risk reduction. Polluters and their insurance companies are dissatisfied with the law's retroactive provisions, requirements to reach "gold plated" cleanups, and disregard for cost when selecting cleanup remedies (Center for Hazardous Waste Management, 1997).

In December 1995, Superfund lost the ability to tax, and this taxing authority has not been renewed. Since taxes on the industry could not finance the Superfund Trust Fund, it began to rely heavily on appropriations from general revenue. Other income also included fines, penalties, and cost recoveries. Since 1995, there have been several bills debated in Congress, yet none have been approved.

Reauthorization was a top environmental priority for the 105th and 106th Congresses, according to Congressional leaders, but action on Superfund legislation never materialized. President Clinton toured a Superfund site in Wallington, NJ in March 1996 to show his concern about Superfund's shortcomings. Reauthorization issues include the size of the fund, broad liability scheme, high contractor costs, and slow pace of cleanups. Most Republicans, and some Democrats, continue to support repealing prior liability (Government and Commerce, 1997). There are also disagreements over who should be required to pay for cleanups, the stringency of cleanup currently required by the law, whether cleanup results in too few benefits for the costs, and whether or not to limit the National Priority List. Another issue that has gained more attention recently is the damage to natural resources, such as rivers, caused by hazardous wastes (Government and Commerce, 1997). The Senate proposed to allow the addition of only 90 more sites (30 annually for three years) to the National Priority List. The House proposed to allow 125 sites over an eight-year period, declining from 30 sites in the first year to 10 sites in each of the last three years.

2.7 Superfund Reforms and Successes

Under the leadership of Carol Browner, in 1995, the EPA implemented three series of more than 45 administrative reforms designed to strengthen Superfund by targeting its problems with cleanups and enforcement. The reforms sought the goal of being "faster, fairer, more efficient" and were similar to provision of the 1994 reauthorization legislation that died in the previous Congress. These reforms expanded beyond the scope of the reforms in the reauthorization of 1986 and have been even more successful than originally anticipated (Nakamura and Church, 2003).

While the federal government maintains control of determining appropriate remedies for hazardous waste sites, states have recently taken on more responsibility for the cleanup of Superfund sites. States have developed the capacity and technical expertise necessary for successful remediation of Superfund sites. Currently, the federal government enters into cooperative agreements with states, on a site-by-site basis, which authorizes the states to conduct cleanup activities.

In 1995, the EPA also implemented a new "brownfields" economic redevelopment program. Brownfields are sites contaminated with hazardous waste that are possible candidates for the National Priority List. These sites often remain abandoned for long periods of time because they are undesirable to lenders and developers who fear that they will assume liability or that the land will remain undervalued. To date, the brownfields program has been highly successful and helps states, communities, and other stakeholders work together to safely and efficiently cleanup and reuse brownfields (Environmental Protection Agency, 1997).

The Superfund program has been much more successful in recent years as a result of the aforementioned reforms. As of 2004, more than 82% of the sites on the final Superfund NPL were either undergoing or had completed cleanup (NACEPT, 2004). Furthermore, the number of sites added to the National Priority List is currently declining, while the number of sites deleted is increasing. Only 12 sites were added in 2003, as opposed to 162 additions in 1986. The total number of sites listed as possible National Priority List sites also decreased over the past years. In 1988, there were 378 sites on the proposed list. In 2003, 54 sites were on the list. As of 2003, the total number of sites on the National Priority list is 1,572 while 274 sites have been deleted from the NPL list. Deletion from the NPL list means that the remedial goals had been achieved even if operation and maintenance of the site continues (NACEPT, 2004).

Responsible parties were also paying a higher percentage of the cleanup costs than in the past. Polluters were now contributing more than 75% of long term cleanup costs compared to 37% in 1987 (EPA, 1997). This has saved taxpayers a total of over $12 billion and resulted in the EPA obtaining over $7.00 in private cleanup commitments for every $1.00 spent in Superfund enforcement. The EPA also reached settlements with more than 14,000 smaller polluting parties (such as small businesses and municipal governments) and gave over $457 million in compensation to responsible parties willing to negotiate long-term cleanup settlements (Superfund Administrative Reforms, 1996). Moreover, the Justice Department collected $790 million for cleanup activities from responsible parties in 1996. As a result, the EPA was able to preserve the Superfund budget for sites where responsible parties could not be identified.

In July 2001, the Superfund Subcommittee of the National Advisory Council for Environmental Policy and Technology was formed to evaluate the Superfund Program. In April 12, 2004, the Final Report was released which recommend improvements to three main areas:

what types of sites should be listed on the NPL, how to measure performance, and what to do about “mega sites” (cleanup costs greater than $50 million).

2.8 Conclusion

Superfund has been controversial since its inception. Many of the problems with the program, such as high legal costs, inadequate funding, slow pace of cleanups, and high contractor costs, plagued the program from the outset because it was developed in response to an emergency situation of uncertain proportions. However, Superfund did have some success in the 1990s. As of 2004, over 82% of the sites on the final Superfund NPL were either undergoing construction or have completed cleanup. Responsible parties are paying more of the costs of cleanups, allowing the EPA to conserve its budget for orphaned hazardous waste sites. In the next chapters, detailed site histories are provided for the six “mega-sites” examined in this study.

Chapter 3

Operating Industries, Inc. Landfill

3.1 Overview

The Landfill covers 190 acres and is located 10 miles (16 kilometers) east of Los Angeles between the communities of Monterey Park and Montebello, California (Figure 3.1). The Pomona Freeway (Route 60) divides the site into two parcels, one 45-acre area lies north of the freeway and the other 145-acre parcel lies south of the freeway (Figure 3.2). The landfill is in the city of Monterey and the city of Montebello borders the southern end and portions of the northern section of the landfill. Throughout its operating life, from 1948 to 1984, the landfill received 30 million cubic yards of residential and commercial refuse, industrial wastes, liquid wastes, and a variety of hazardous wastes. The EPA determined that approximately 4,000 different parties sent waste to the landfill at one point or another. In October 1984, the landfill was closed and proposed for listing on the National Priority List (NPL). In June 1986, the landfill was officially listed as a NPL Superfund site, and experts estimated that the cleanup could take as much as 45 years and more than $600 million to complete. As of 2002, the EPA had reached settlement with more than 1,250 parties to pay for the cleanup work, with the total settlements reaching more than $600 million.

Figure 3.1 OII Landfill Vicinity

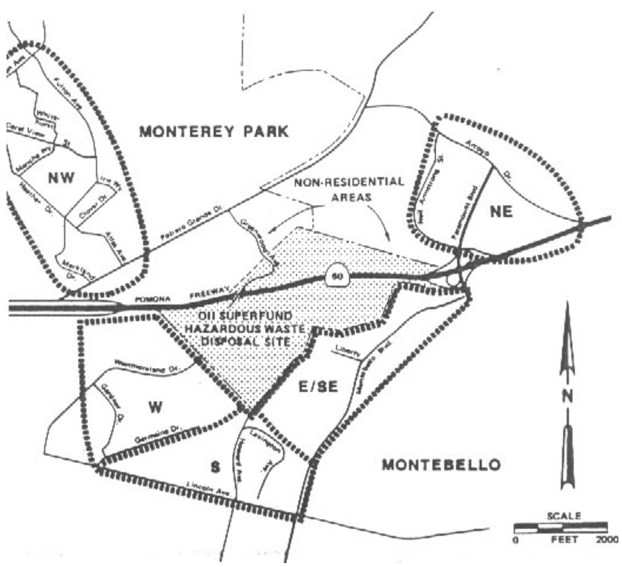
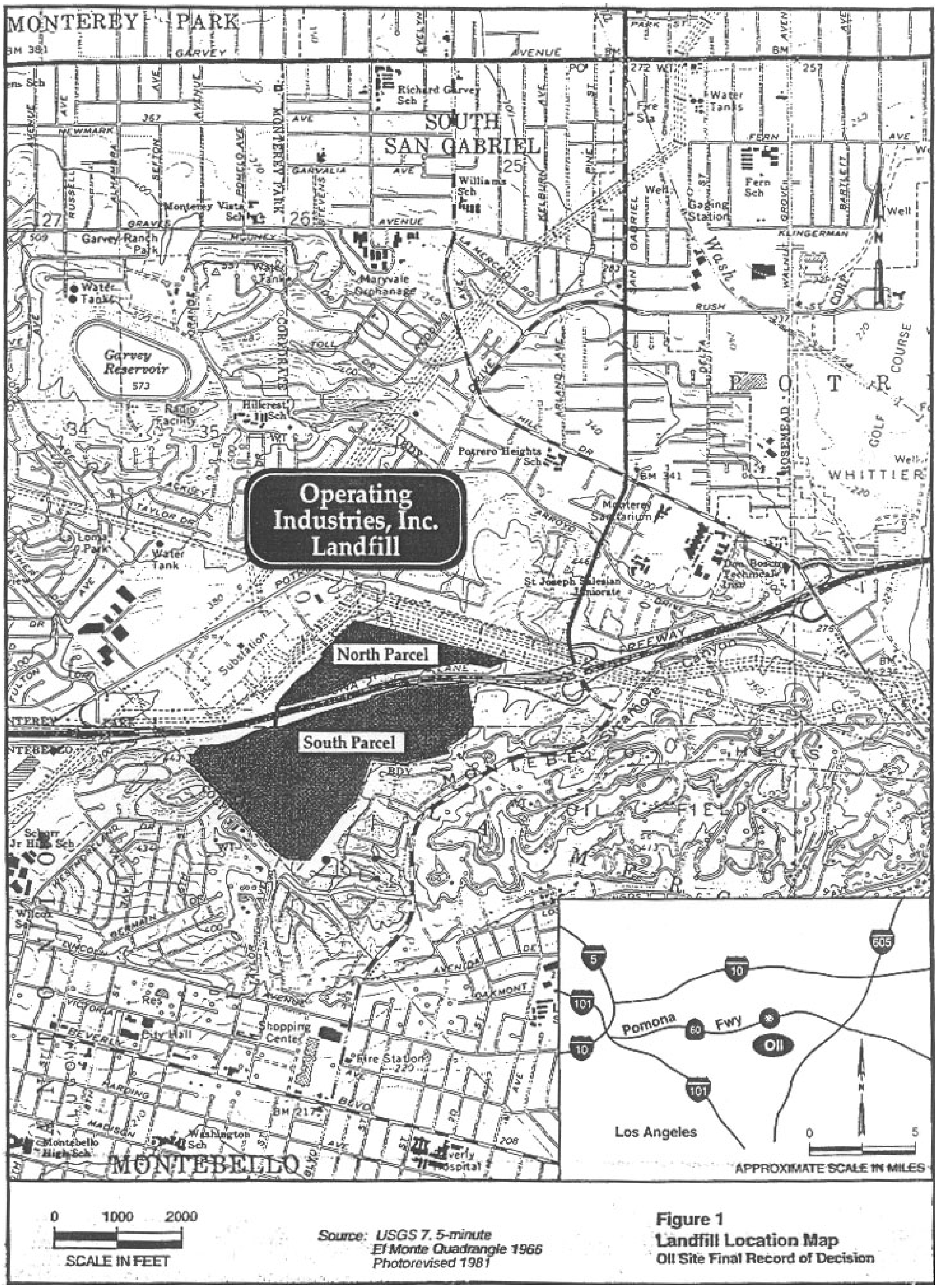


Figure 3.2 OII Landfill



The landfill remains a particularly prominent feature of the area, towering more than 300 feet above the surrounding community.

On the road to completion: OII's final landfill cover along the Pomona Freeway.

According to Katherine Shrine, assistant regional counsel for the EPA Region 9, "This site is basically a 300-foot-tall, 190-acre mountain of every kind of disposable item in the world." Residents say the landfill is so large that it interferes with television reception. Approximately 53,000 people live within three miles (4.8 kilometers) of the sites, 23,000 within one mile (1.6 kilometers) of the site, and 2,150 within 1000 feet (0.3 kilometers) of the landfill. Three schools are located within 1 mile (1.6 kilometers) of the landfill. The area consists of heavy residential development and mostly middle income and multi-racial neighborhoods.

OII Landfill and Neighboring Community.

3.2 History of the Landfill

Before 1970

In 1948, the Monterey Park Disposal Company began municipal dump operations in a former stone and sand quarry. At this time there was very little development neighboring the site. Operating Industries, Inc. (OII) purchased the site four years later in January 1952. OII continued municipal operations, but began accepting industrial wastes at the site as well.

1970-1972

In the early 1970’s, the population of southern California blossomed and development pressure in areas surrounding Los Angeles increased dramatically. To help alleviate this pressure, the land surrounding the landfill was approved by Montebello for residential use. Promised closure of the landfill by the city and proposed development of a golf course on the site prompted rapid development of the area.

1973-1975

The Pomona Freeway was built in 1974 and intersected the 190-acre landfill. Soon the middle income communities of Monterey Park and Montebello encircled the OII Landfill. Landfill activities were restricted to the larger southern area (South Parcel) of the landfill, closest to Montebello. In compensation for the closure of the North Parcel, the city increased the height limits on the South Parcel of the landfill.

1976-1978

The increase in the height limit on the South Parcel led to increased erosion, mudslides, and ultimately exposed refuse. Starting in 1978, leachate seepages were observed periodically on the slopes of the South Parcel of the OII Landfill. The leachate contained both organic constituents (such as volatile organic compounds, semi-volatile organic compounds, oil, and grease) and inorganic constituents (such as metals, ammonia, chloride, and high levels of total dissolved solids). Large amounts of landfill gas, generated by the natural decomposition of organic and hazardous wastes, were also reported at the site. Tests of the landfill gas found its primary components to be methane, nitrogen, carbon dioxide, and volatile organic compounds (approximately 0.05 percent). Threats of contamination at OII stemmed from exposure to toxic compounds (such as trichloroethane and toluene) and carcinogenic compounds (such as vinyl chloride, benzene, trichloroethylene, and carbon tetrachloride) via air, groundwater, soil, and leachate.

Before the EPA's involvement, numerous state, regional, and local agencies were involved with the OII site. The earliest government intervention began in March 1978 when the South Coast Air Quality Management District (SCAQMD) issued an order requiring OII to follow proper maintenance and disposal procedures. One year later, OII hired Getty Synthetic Fuels to collect methane gas generated by the landfill. Getty Synthetic Fuels then removed the methane gas from the site and refined it for commercial purposes but these activities, including drilling, exacerbated odor problems

1979-1981

In 1980, the Los Angeles County Department of Health Services (LACDOHS) realized that the original methane gas collection system by itself was insufficient and directed OII to institute a second gas control system.

Residents near the landfill formed Homeowners to Eliminate Landfill Problems (HELP) to address increasing odor and potential health problems at the site, as well as specific issues such as leachate seepage, methane gas buildup, declining property values, and land use after closure of the site. This organization, comprised of 460 dues-paying families, was an essential force in the eventual closing of the landfill. According to testimony from Montebello Councilwoman Norma Lopez-Reid:

> "… residents living near the Operating Industries Landfill came home each evening to an area filled with migrating gases, that made them suffer from headaches, nauseating odors, and grass-less yards due to the hazardous liquid waste, called leachate, that seeped out of the ground. These difficult circumstances made the quality of life in this bedroom community decrease considerably, we couldn't even open our windows on hot summer nights. Little did our residents know the extent to which companies, large and small, had been allowed to dump incredible amounts of hazardous waste, including carcinogens, into the landfill that was only supposed to contain regular trash."

In the early 1980's, community council meetings became volatile as residents protested the "assaulting stench" of the air. "We could never open the [house] windows," said Montebello resident Phyllis Lee. As another resident stated, "Some nights I wake up coughing at two, three, four o'clock in the morning. The methane gas is so strong that I have a hard time breathing."

On March 5, 1981, the Montebello School District passed a resolution objecting to the landfill odors and ordering an investigation of potential health risks. Later that year, county health officials cited OII for not controlling the migration of potentially hazardous gasses. The OII Landfill was ordered to temporarily shut down.

1982-1984

Despite resident complaints, heavy criticism from state health and air quality officials, possible $1,000 per day operating fines, and the previous temporary order to shutdown, OII reopened and continued to operate. Finally, in January 1983, OII ceased accepting hazardous liquid waste. In April, they stopped accepting any liquid waste. Also in April, offsite levels of vinyl chloride gas (a known carcinogen) were measured at 19 parts per billion (the state regulated level at that time for vinyl chloride was 10 parts per billion), however, in a random sample of 12 homes elevated levels of vinyl chloride gas were not detected. In June, a buildup of methane within the landfill caused several underground fires. Potentially explosive levels of methane were also discovered underneath city streets adjacent to the landfill. Levels of air-borne vinyl chloride in excess of EPA and state health standards were also detected around the site. However, the LA County Department of Health released a 1983 study showing no pattern of school absence and that there was not excess mortality around the OII Landfill compared to other areas of Los Angeles.

In January 1984, the State of California placed the OII Landfill on the California Hazardous Waste Priority List.

In August 1984, the LACDOHS cited OII for allowing landfill gas concentrations which exceeded the lower explosive limit (5% methane in air) to migrate beyond landfill boundaries. That same month, California Department of Health Services (CADOH) also issued its first Remedial Action Order against OII. It required OII to completely phase out the on-site disposal of leachate and to provide plans for implementing leachate collection and treatment systems, site characterization and groundwater monitoring programs, landfill gas collection and monitoring programs, and slope stability corrective measures.

In October 1984, after four years of legal battles, public hearings, and tremendous community public hearings, SCAQMD issued a second order of abatement requiring the landfill to close permanently, thereby ending the disposal of all solid wastes. This order also instructed OII to install a landfill gas emission control system, a permanent leachate control system, and also to perform specified landfill maintenance. Soon after the closure of the landfill, the owner of OII declared bankruptcy.

Also in October, the EPA proposed OII for the federal Superfund NPL, making it eligible for federal Superfund money. Likewise, the California Regional Water Quality Control Board (RWQCB) issued its own abatement order requiring that the on-site disposal of leachate be phased out.

In December 1984, the EPA dug six wells around the OII site to test for possible groundwater contamination. The test results showed organics and trace mineral contamination in three of the wells, but no pesticide contamination. Fortunately, the drinking water used by the neighboring residents of the landfill came from a number of municipal water companies, which did not operate any wells located on or near the site. However, based on their initial tests, the EPA decided to conduct further testing to determine the specific location and potential movement of the groundwater contamination. The EPA installed an additional 24 wells around the perimeter of the site, which tested positively for soil and groundwater contamination.

1985-1987

In April 1985, while the OII Landfill awaited its final federal NPL listing, the EPA began its Remedial Investigation/Feasibility Study (RI/FS) which assessed and prioritized remedial actions for the site. This did not, however, assuage state concerns about the site. One month later, the California Waste Management Board (CWMB) joined the CADOHS and filed a joint suit against OII for not complying with the CADOHS's first Remedial Action Order issued in August 1984.

In June 1986, the EPA placed the landfill on the NPL of Superfund sites and assumed responsibility for all remedial activities at the site. Shortly after the NPL listing of the site, the California Department of Health Services conducted an extensive epidemiological investigation comparing health symptoms of residents near the site with those of control communities (Satin et al., 1986). The results indicated no significant differences between the health of local residents and that of control communities.

The EPA began its search for OII's PRPs concurrent with the NPL listing. Because of the nature of landfills, the EPA estimated that as many as 4,000 companies were potentially liable for dumping hazardous waste at the OII Landfill during its operable years. Although not all of these PRPs contributed to the cleanup of the landfill, the first of several cleanup agreements was signed in May 1989 between the EPA and over 110 polluting companies. Valued at approximately $66 million, this First Partial Consent Decree required site control and monitoring activities and construction of an interim leachate treatment facility. In return for their immediate cooperation and financial contributions, the Consent Decree released from future liability several large national corporations including Mobil, Exxon, and General Motors. A group of PRPs then organized the OII Steering Committee, of which OII was not a part, to handle legal and environmental issues at the site. This committee eventually formed a corporation called the Coalition Undertaking Remedial Efforts, Inc. (CURE), which would remediate leachate at the site according to the established leachate management plan.

The EPA signed its first Record of Decision (ROD) for the OII site in July 1987, authorizing short-term control and management activities to prevent further contamination and exposure to potential health risks. One such action included fencing the site and posting a guard at the entrance to ensure that no trespassers come into contact with the contaminants. Other emergency measures included gas migration control measures, slope stability, leachate control measures, erosion control, and runoff and drainage improvements.

Once these emergency measures were in place, the EPA signed the second ROD, in November, for control and cleanup of leachate at the site. The EPA proposed several alternative plans and submitted its draft plan for public review. As it often did for area residents, the EPA extended the 30-day public comment period to allow ample time for all interested parties to respond. Based on these public comments, the EPA decided to replace the system of off-site leachate treatment with an on-site treatment plant because it found this alternative to be more acceptable, more cost effective, and more protective of public health and the environment. While the surrounding communities were supportive of this decision, they were greatly concerned that the plant might be used to process liquid wastes from other sites as well. The EPA assured local citizens that only liquids generated from the OII site would be treated at the on-site plant, and then preceded with its remedial plan. The plant would treat 43,200 gallons of OII leachate per day, test it for compliance, and then discharge it into the Los Angeles County Sanitation District sewer system. Natural attenuation and degradation of contaminants would also help reduce groundwater contaminant levels beyond the site boundary, and the EPA agreed to routinely monitor groundwater under and near the site.

1988-1990

Landfill gas migration was the second major problem the EPA addressed at the OII Landfill. The EPA's third ROD for OII called for special gas migration and treatment studies so that gas control systems could be improved prior to the final site cleanup. The results of these studies called for the design and construction of a new gas flare facility (thermal destruction facility), new gas piping and extraction wells, use of existing extraction wells until they are no longer functional, discontinuing use of the air dike system, construction of additional gas monitoring probes, and the installation of gas extraction wells on the North Parcel. Fifty gas wells were also installed in the South Parcel to help control gas and liquid migration. During this time, the EPA notified residents that workers wearing protective gear and loud drilling noises would be present at the site for several months. The EPA estimated that with these improvements 70% more of the landfill gas would be collected, but that the landfill still would not reach the EPA's goal for surface emissions until the final landfill cover was put into place.

The cost of the leachate treatment facility was estimated to be $1.6 million, with annual operation and maintenance cost of $700,000. Although the plant was originally scheduled for construction in the summer of 1988, it was delayed almost a year because of the lack of appropriate funding and the long processes of public comment and facility design and finalization. Likewise, plant operation, scheduled to begin in early 1989, did not begin until August 1994.

In 1989, a Consent Decree was signed by the EPA and more than 100 companies that disposed wastes during the operation of the landfill. These companies formed a committee to examine the issues facing the cleanup effort. Also in 1989, over 100 businesses and public entities filed a lawsuit against other PRP's to share in the cleanup costs.

As part of the gas control system, the EPA amended the ROD to add a landfill cover that sought to better control gas emissions and improve surface water management. The existing cover was highly variable in its thickness and ability to limit surface emissions and odor. A new landfill cover would make gas control remedies more effective and efficient, reduce the amount of gas escaping into the atmosphere, and facilitate the cost effectiveness of the final site remedy. The new landfill cover sought to keep water and oxygen out of the landfill and prevent erosion and run-off from the landfill's slopes. The cover also was designed to improve the appearance of the site. Vegetation has been planted, whenever possible, over the cover. The EPA estimated that the construction of the landfill cover would cost between $61 million and $116 million dollars.

1991-1993

In 1991, the EPA extended the settlement offer to another 154 PRPs, which resulted in a Second Partial Consent Decree similar to the first. In August, 63 of the 154 companies signed the Second Partial Consent Decree worth $8.5 million. Those that did not sign the agreement denied the charges, asserted that they dumped only non-hazardous materials at the site, or maintained that their refuse dumping records didn't exist or were unrecoverable. A third settlement between the EPA and approximately 178 PRPs was reached in December 1991. It required the defendants, later organized into a corporation called the New CURE, to implement major portions of the gas control and landfill cover remedies, improvements worth $130 million.
In addition, the EPA sent letters to more than 50 additional PRPs informing them of their liability at the site. During this time, several private companies brought suit against nearby communities to make them liable for contaminants dumped at the landfill. To recoup legal costs resulting from these accusations, one city raised trash collection rates and several other cities sued trash haulers.

In November 1991, the EPA installed another 21 wells beyond the perimeter of the site, which determined that groundwater contamination had not spread beyond the boundaries of the landfill. In total, the EPA constructed 75 wells and conducted six major hydrologic investigations over the course of 28 years.

In April 1992, Judge Mariana R. Pfaelzer of Montebello, California, enforced the previous $130 million agreement. The EPA also entered into another Consent Decree with a variety of contributing companies to begin the initial cleanup activities related to gas control and landfill cover as designed by the EPA.

Implementation of gas control remedies began in 1992. The construction, operation, and maintenance of these remedies were estimated to cost $73 million over a 30-year period. From 1993 to March 1994, during the construction of the new gas flare facility, low levels of vinyl chloride escaped into the atmosphere because the temperature of the old gas flare treatment system was insufficient to incinerate the gas. Although they had no way of monitoring emissions, the EPA maintained there was no problem with air quality. However, the EPA still tested 197 Montebello homes for vinyl chlorine. Four percent of the homes tested positively and the EPA installed gas management systems to aerate the homes and prevent further the contamination from entering the houses. The EPA is required to monitor these homes for ten years.

1994-1996

In 1994, the leachate treatment facility began operations. A settlement was reached in 1994 that resolved the 1989 lawsuit filed by 137 businesses and public entities that had already contributed more than $200 million to the cleanup efforts.

In April 1995, a Fourth Partial Consent Decree was reached between the United States, the State of California, several private companies, 14 cities and municipalities that disposed of municipal waste at the landfill, and those who transported municipal waste to the landfill. The agreement provided $51 million for the Final Remedy and construction of a Thermal Destruction Facility on the North Parcel.

In March 1996, thirty companies signed a final Fifth Partial Consent Decree to pay $18.7 million for interim site costs and the Final Remedy. In total, over $270 million had been collected from almost 400 different entities for the cleanup of the OII Landfill. This estimate represents only private money contributed to site cleanup. An additional estimated $165 million of public dollars will be spent for site remediation.

In September 1996, the fourth OII ROD for Final Site Remedy was signed. The EPA agreed to evaluate and monitor the site and the success of their cleanup efforts every five years after the remedial action plan is implemented. The EPA also decided to replace the gas flare disposal system with a new landfill gas thermal destruction facility, which would be used to treat or destroy landfill gas produced at the site.

1997-1999

In mid-February, 50 new testing wells were installed on the southern and western perimeter of the former OII Landfill near Montebello. These wells were designed to better control gas and liquid migration from the landfill. The EPA advised residents to not interpret the workers protective clothing as an indicator of a “hazard for the neighborhood”. Additionally they emphasized that during the drilling process “**there will be no contamination hazard to nearby residents during these activities**” (emphasis in original).

Additionally, construction of the landfill cover began. The EPA mailed out a special notice to residents informing them of the upcoming constructions and possible disturbances that may result. Construction of the cover involved moving six million cubic yards of soil. The old dirt on the landfill was removed and was replaced with a six-foot-thick “monocover”of clean soil. A variety of native vegetation including grasses and shrubs was added to the slopes of the landfill and the flat top of the landfill was covered by a multi-layer “geosynthetic clay liner” (a system of woven matting and clay). The objective of both covers was to prevent rainwater from entering the landfill and to stop gas from escaping.

In March 1997, the EPA issued a universal administrative order requiring seven more companies, which collectively dumped six million gallons of hazardous substance into to the OII Landfill, to contribute to OII’s remediation. Specifically, these companies are responsible for maintaining the on-site leachate treatment facility until December 1999, which will cost a total of approximately three million dollars.

In 1999, the EPA reached a settlement with 327 parties which allegedly disposed small amounts of waste at OII. These parties contributed between 4,200 and 110,000 gallons of waste.

After 1999

In 2000, the landfill cap and the new gas control systems (Thermal Destruction Facility) were essentially completed, gas flares were replaced and the treatment of groundwater commenced. Development of a shopping center at the North Parcel of the landfill began. This North Parcel was not significantly affected by the hazardous waste and is one of the largest pieces of undeveloped property in the Los Angeles area.

In December 2001, a $340 million settlement was signed with 161 PRP's. This was the eighth settlement since 1986. Settlements up to this point had totaled over $600 million.

Also in 2001, the construction of the ground water remedy was completed and the EPA ended its in-home monitoring and random sampling programs after it found no evidence of a problem in any of the houses for several years.

The eighth Consent Decree was approved in May 2002, which outlined the final cleanup remedies.

Chapter 4

Woburn, Massachusetts

4.1 Overview

Woburn is a historic city (founded in 1640) of about 35,000 people located 12 miles (19.3 kilometers) northwest of Boston (Figure 4.1). The community is predominantly blue-collar because of its industrial heritage. It is also the location of two large Superfund sites: Wells G & H and Industri-Plex. Together the sites cover almost 600 acres of land in the 14 square mile (36.3 square kilometer) community. Both sites are located in the section of Woburn east of Main Street, a low, swampy area that includes many streams and the Aberjona River (Figure 4.2). This section of Woburn, referred to as East Woburn, is a mix of industrial and residential areas. For the Industri-Plex site, homes are located within 1,000 feet and 13,000 households are within a two mile (3.2 kilometer) radius. Approximately 34,000 people live within three miles (4.8 kilometer) of both sites. While the two sites are distinct from each other, the pollution problems at both sites were discovered within a few months of each other. Both sites were evaluated by the EPA and added to the NPL in the early 1980s.

Figure 4.1 Woburn Vicinity

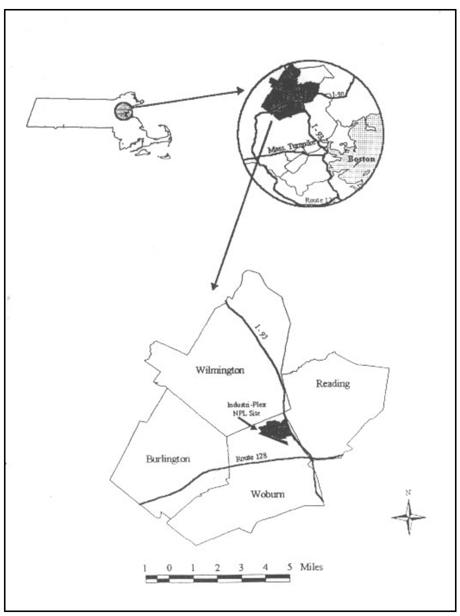
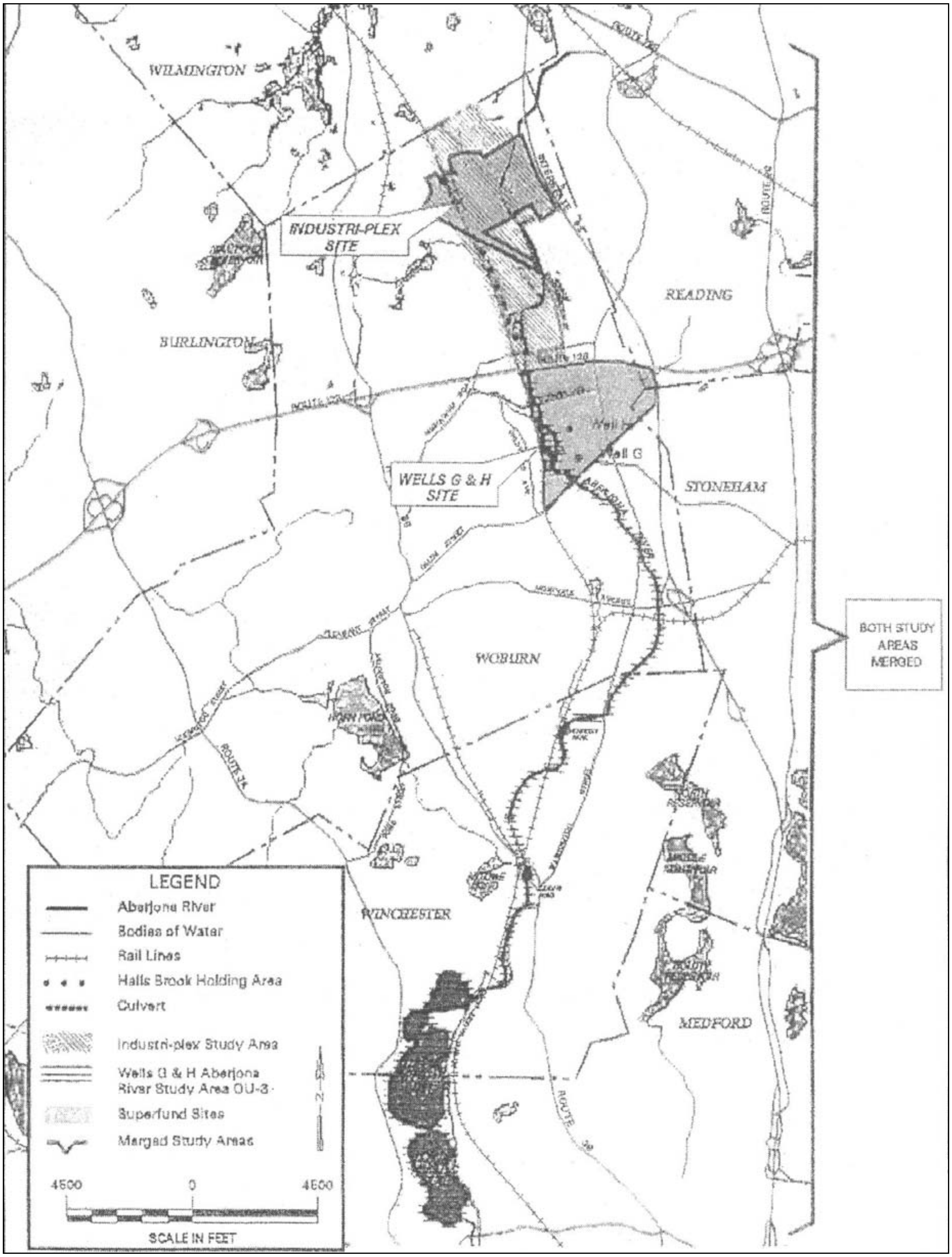


Figure 4.2 Industri-Plex and Wells G&H Sites



Throughout Woburn’s history, more than 100 companies used the Aberjona River, which flows through the city, for industrial waste disposal. Companies dumped wastes on land, into lagoons and ponds adjacent to the river, as well as directly into the river itself. From 1853 to 1931, compounds and chemicals such as acetic acid, sulfuric acid, lead, arsenic, chromium, benzene and toluene were dumped behind buildings, used as fill for low spots, and included in construction material for dikes and levees. Woburn has a long history of public health problems, including elevated rates of kidney and liver cancer, colon-rectal cancer, child and adult leukemia, male breast cancer, melanoma, multiple myeloma, and brain and lung cancer.

The 330-acre Wells G & H site is located near the Aberjona River, about one and a quarter miles (2 kilometers) downstream (south) of the Industri-Plex site. It once ranked as the tenth worst site on the EPA’s NPL list. The site is the location of two drinking water wells for the city of Woburn, which were built in 1964 (Well G) and 1967 (Well H). These wells were located near an automobile graveyard, an industrial barrel cleaning and reclamation company, a waste oil refinery, a tannery, a dry cleaner, and a machinery manufacturer. Despite public complaints about the water from these wells, Woburn continued to use the wells, especially during the summer. Both wells were finally closed in 1979 after testing showed that the water was contaminated. Soil and groundwater at the site are contaminated with volatile organic compounds (VOCs), such as trichlorethylene (TCE) and tetrachloroethylene (also called perchlorethylne, PCE, or ‘perc’). Land in this area is zoned for industrial and commercial use, with some areas for residential and recreational use.

The Industri-Plex site, the location of Woburn’s most intensive industrial activity since the 1850s, consists of 245 acres in an industrial park and once ranked as the fifth worst site on the EPA’s NPL. This area is located one mile (1.6 kilometers) northwest of the intersection of Interstate 93 and Route 128 and is bordered by the communities of Wilmington and Reading. Two tributaries of the Aberjona River flow through the Industri-Plex site. Of the 245 acres at the site, one-third was contaminated and 60 acres were used for commercial purposes throughout the remediation of the site. Contamination at the Industri-Plex site includes heavy metals and hydrocarbons. In the soil, the contamination was primarily arsenic, lead, and chromium and in the water the contamination was primarily benzene, toluene, arsenic, and chromium.

Additionally, hydrogen sulfide gas emanating from buried animal hides from the tanneries and wastes once permeated the air.

Redevelopment plans are now underway for the Industri-Plex site and consist of a Regional Transportation Center (train station, park and ride), a recycling center, highway interchange, an office park, and retail space. This development is expected to yield between 12,000 and 16,000 jobs by 2010, relieve traffic congestion in Woburn, and help the Boston area come into compliance with EPA air emissions standards by enhancing public transportation in the area. However, as of 1999, the City of Woburn estimated that the number of permanent jobs at the redeveloped site was 4,315.

Groundwater remediation and monitoring now constitute the bulk of the remaining work to be done. As of December 1998, three groundwater treatment plants operating at the site had pumped and treated more than 150 million gallons of water. In addition, all the contaminated soil has been removed (approximately 150 tons) and 1,360 pounds of VOCs have been destroyed. Although major strides in the remediation of the property have taken place, according to EPA lawyers, complete cleanup of the site will cost approximately $80 million and could take another 20-30 years because of the site's extensive groundwater contamination.

4.2 History of Woburn and its Superfund Sites

1600-1700's

Woburn was incorporated as a town in 1640 and shortly thereafter became a center of manufacturing in New England, because its location was ideal for industry because of its accessibility to major transportation throughways (roadways and seaports) and proximity to the consumer market of Boston. In 1648, the first tannery opened in Woburn.

1800's

In the mid-1800s, Woburn became known for shoe manufacturing. Local manufacturing activity later shifted from shoes to leather production, and Woburn became a leader in the U.S. tanning industry by 1865. By 1884, Woburn was home to 26 large tanneries that employed approximately 1,500 employees and produced $4.5 million worth of leather. At the peak of

Woburn's tanning industry, from 1900 to 1934, an estimated 2,000 to 4,000 tons of chromium was dumped directly into Woburn's water resources, as well as 65 to 140 tons of copper, 85 to 175 tons of lead, and 40 to 75 tons of zinc.

Numerous chemical manufacturing firms occupied the Industri-Plex land, which is upstream from water Wells G & H, for almost 150 years. In the 1800s, several firms operated on the site, producing chemicals for the local tanning, textile, and paper industries. In 1863, theMerrimac Chemical Company (Merrimac) became the leading industry on the site.

1900's

From 1863 to 1931, Merrimac produced lead-arsenic insecticides, TNT and other explosives, dyes, and organic chemicals such as phenol, benzene, and toluene. Between 1900 and 1914, Merrimac was one of the largest producers of arsenic insecticides in the country. In 1915, as part of the war effort, industry in Woburn began to diversify to include munitions, chemicals, and insecticides. (Until the war, Germany had been the major source of these chemicals.) By 1917, Merrimac had grown into the largest chemical manufacturer in New England.

1920's

The City of Woburn built a sewer due to concerns about pollution of the Aberjona River and Upper Mystic Lake. Monsanto acquired Merrimac in 1929 and moved the chemical operations off the Industri-Plex site in 1931.

1930's

In 1934, Monsanto sold the Industri-Plex land. Between 1934 and 1968, the companies that occupied the Industri-Plex site manufactured glue and gelatin by extracting collagen from animal hides and chrome-tanned leather. Wastes generated by these processes included animal hide residues and metals such as arsenic, lead, and chromium. These wastes were generally deposited on top of existing waste deposits. Waste piles, including the animal hides, covered tens of acres and reached heights of 40 to 50 feet above the natural grade.

1950's

In the 1950s, East Woburn began discussing the need for additional water supplies for the city's expanding population. In 1958, the city hired an engineering consultant to examine the possibility of utilizing the Aberjona River water for drinking. Although the consultant concluded that the water was too heavily contaminated to be safe for drinking, the city began constructing two new wells, Wells G & H.

1960's

Water Wells G & H, located on the east side of town, began operating in 1964 and 1967, respectively, to provide Woburn's growing population with drinking water. At that time, these two wells supplied 30% of the city's drinking water. The 330-acre Wells G & H site contains five contaminated properties bounded by Route 128 to the south, Interstate 93 to the east, the Boston and Maine Railroad to the west, and Salem Street to the south. The Aberjona River also flows through the site, through on-site wetlands found immediately adjacent to both sides of the river, and into the Mystic Lakes. The Mystic Lakes are a popular recreational destination including swimming and fishing.

Shortly after the installation of the two wells, residents of East Woburn complained that the water smelled and tasted funny, corroded their pipes, discolored their dishwashers, and stained clothing and fixtures. Prompted by citizen complaints, city officials tested the water from the two wells. Test results only revealed high levels of salts in the water and officials downplayed citizen's concerns about the water.

In 1967, the Massachusetts State Department of Health (MSDH) recommended that Well G & H be closed because of concerns about bacteria and only recommended their use in conjunction with continuous chlorination. Soon residents reported concerns about their water tasting like "bleach". In the spring and summer of 1968, residents complained about their "red water," but city officials claimed it was due to the city's unlined old cast iron pipe. MSDH gave the city permission to add sodium hexametaphosphate ("Calgon") to Well G & H to remedy the problem and to adjust the water's pH content. In an attempt to find a long term water supply solution that did not involve the use of Wells G & H, the Woburn City Council authorized the Mayor to negotiate with the Metropolitan District Commission (MDC) about joining its water system with the neighboring town of Stoneham. Starting in February 1969, the City of Woburn increased the chlorine feed at Well G by 50%. Due to resident’s complaints, Well G was closed for the winter starting in October.

At Industri-Plex, Stauffer Chemical Company (Stauffer) bought the last of the glue manufacturers in the 1960s and ceased operation in 1968. In 1968, Mark Philip Realty Trust (MP Trust), a real estate developer, bought the Industri-Plex land from Stauffer to develop it as an industrial park. MP Trust began preparing for construction of a shopping mall and an industrial park. In 1969, the project started illegally without a permit, though a permit was obtained a year later. The construction at Industri-Plex involved moving piles of waste accumulated over 130 years and filling in low-lying areas and wetlands.

Early 1970’s

Throughout the early 1970s, despite the repeated reassurances from city and state officials, the citizens of East Woburn continued to express concerns about the water from Wells G & H. In response to public pressure, Well G was frequently turned off in the winter when water was more abundant only to be called into service again during hot, dry summers. Voluntary water restrictions were put into place in 1972 and 1973 to avoid use of the wells, while the city continued to work with MDC to provide a long-term water solution. In the summer of 1974, water shortages forced the city to consider activating both Wells G & H, which caused a “storm of protest” from residents. In 1975, a fire destroying the MDC pumping state at Spot Pond in Stoneham interrupted construction of the water main connecting Woburn and MDC.

In 1975, as part of the development of the south end of Industri-Plex, 20 acres of animal hide piles and animal glue waste were disrupted releasing hydrogen sulfide fumes into the air. This "rotten egg" smell, extremely potent at times, elicited numerous complaints from citizens of Woburn and the neighboring Town of Reading, downwind of Industri-Plex. Citizens and the media referred to the omni-present stench as the “Woburn odor.” This odor at times prevented children from playing outside during noon recess at school and residents of affected areas claimed that they could not use their yards. When the odor was strong, citizens working outside complained of nausea, burning eyes, and difficulty breathing. Residents even mentioned that the airborne chemicals caused the exterior paint on their houses to peel. Large open-air pits of waste at the site allowed humans and animals to come into direct contact with the contaminants.

According to one Woburn mother, "It was only a five-minute walk and you see the open pits filled with chemicals. We used to go blueberry picking where they found the arsenic."

The Massachusetts Department of Environmental Quality Engineering (MDEQE) [now the Massachusetts Department of Environmental Protection] issued MP Trust numerous violation notices, orders to halt construction, and requests to cleanup wastes at the Industri-Plex site. In 1977, MDEQE and the Town of Reading filed a lawsuit against MP Trust demanding that MP Trust be prohibited from disturbing the two parcels where the glue waste was buried. However, MP Trust continued its construction because it had the permission of Massachusetts Department of Health (MDOH) (which was responsible for hazardous waste management at that time) to excavate and dispose of hazardous wastes on the site. "It [remediation] would make the land too expensive to develop. It [the waste] can stay there as far as I'm concerned," said William D'Annolfo, owner of MP Trust.

1978-1979

The major pollution problems at both of Woburn's Superfund sites were discovered within six months of each other.

Abandoned 55-gallon Drum with the Entire Side Corroded; Found Near Wells G & H.

Wells G&H. In May 1979, construction workers discovered that 184 55-gallon barrels of waste had been dumped near the Wells G & H. Immediately after this discovery, the MDEQE tested the wells for possible contamination. These tests revealed high concentrations of several VOCs, known carcinogens in animals, but indicated that the barrels were not the source. Officials were particularly concerned about TCE and perc in the well water because TCE levels tested as high as 267 parts per billion and VOC levels tested as high as 100 parts per billion. (The EPA considered anything more than 27 parts per billion and 5 parts per billion, respectively, to be hazardous.) Additionally, river sediments were found to be contaminated with polycyclic aromatic hydrocarbons (PAHs) and heavy metals such as chromium, zinc, mercury, and arsenic. Adjacent soils also contained PAHs, poly-chlorinated biphenyls (PCBs), VOCs, and pesticides. Anyone coming into contact, swallowing, or ingesting this groundwater, soil, or river sediments would be at risk.

Although the EPA discovered these problems with Wells G & H in July of 1979, Woburn officials and residents were not notified of the problem by the EPA, COE, or MDEQE until an enterprising reporter released the information in a local newspaper story. The problems described in the news story and the lack of notification by the official organizations involved, generated much outrage and distrust on the part of local citizens. Likewise, contamination at Industri-Plex was documented in federal and state COE and EPA records in August 1979, but local officials were notified of the contamination not through official channels but, again, by a local newspaper article reporting the results of EPA investigations conducted earlier that summer.

Industri-Plex. At Industri-Plex, the Massachusetts Department of Environmental Protection (MDEP) asked the Army Corps of Engineers (COE) to investigate alleged wetlands violations and help control the activities of MP Trust. After conducting a preliminary survey of the site, the COE solicited the help of EPA. In late 1979, based on their discovery of illegal filling of wetlands, the EPA and the U.S. Attorney’s office (on behalf of the Army Corps of Engineers) obtained a court order against MP Trust to stop development at the Industri-Plex site. Additionally, the EPA discovered pits of buried animal hair and barrels of slaughterhouse waste. In December, regional EPA officials requested funds for the installation of a permanent air monitoring station for North Woburn.

Groundwater was contaminated with arsenic and VOCs, including benzene and toluene, and soil was extensively contaminated with arsenic, chromium, and lead. Benzene has been proven to cause leukemia. In fact, EPA investigations revealed a football field-sized arsenic pit that rose 40 feet into the air. Arsenic was used in the production of lead-arsenate, an insecticide that was replaced by DDT in the 1940s. Arsenic is a known human carcinogen and can cause skin tumors when ingested, and lung tumors when inhaled. Arsenic is also linked to chromosomal damage in humans and animals. Measured arsenic concentrations in this pit reached as high as 1,100 parts per million (ppm) and debris from the pit was detected on the slopes of Route 93, a half-mile away (0.8 kilometers). Although EPA officials were uncertain about when the arsenic was dumped, they believed it dates between 1899 and 1934, meaning that the arsenic has been in Woburn soil for 85 to 100 years. Other contaminants permeated the site as well. Recorded levels of chromium reached 3,000 ppm in one place and 78,000 ppm in another. The concentration of lead was as high as 1,200 ppm. At the time, the standards for both of these contaminants were 0.05 ppm.

Community Reaction. The discovery of two major hazardous waste problems in one town prompted strong media interest as well as the active response and involvement of Woburn's residents. Area newspapers and TV stations ran multi-part stories about Woburn, alluding to it as a "toxic wasteland." Local newspapers and magazines featured articles with headlines such as: "Lagoon of Arsenic Discovered in North Woburn" (*The Daily Times,* September 10, 1979), "Chasing A Radioactive Ghost" (*The Daily Times*, October 16, 1979), "Deaths From Cancer Increase in Woburn" (*The Daily Times*, December 12, 1979). In particular, *The Daily Times* published two notorious articles about Woburn's hazardous waste contamination, which reported higher rates of adult and childhood leukemia, bone and skin cancer, prostate cancer in men, and breast cancer. However, the estimates quoted in the article were not confirmed by MDOH until the following spring. Interestingly, in its final report, the MDOH used the same statistics reported in *The Daily Times* months earlier.

One east Woburn resident, Anne Anderson, began to suspect a link between the well water and her son's leukemia. "From the time we moved here, the water was bad in the summer. It had an unpleasant odor and a terrible taste," she later recalled. "My mother brought jars of MDC water when she came to visit. The kids used to always ask for 'Nana water.' It was like a mother's milk, for God's sake. She still brings it when she visits." Anderson began recognizing some of her neighbors at the hospital, who were also there with children suffering from leukemia. "I just don't see where all the leukemia cases in our area aren't correlated," she said. "It seems they have to be. The thing that strikes me is there are two neighbors off of Pine Street who have children with leukemia. A year later people on the other side of the street had their child diagnosed and two people we know personally were diagnosed." Her husband continued, "Before, in all of my life, I knew of only one child with leukemia. But these are all in Woburn." Anderson had requested that city officials test the water, but she was informed that it was not standard procedure to perform such tests on the basis of one individual's request. Unsatisfied with this response, Anderson, with the help of her minister Reverend Bruce Young, convened a meeting in September 1979 for parents of children with leukemia. Attendees of that meeting counted the number of local leukemia cases and mapped the homes of the sick children—eight leukemia cases were clustered within one square mile (1.6 square kilometers) in East Woburn, six in a six-block square served by Wells G & H.[1] Sparked by these findings, the citizens of Woburn formed the group For A Cleaner Environment (FACE) in October 1979. Two months later (December), FACE and the doctor treating Woburn children with leukemia convinced the Woburn City Council to contact the Centers for Disease Control (CDC). After examining the situation, the CDC found that Woburn's childhood leukemia rate was two to three times that of the national average and four times the average of other communities the size of Woburn. As CDC described it, Woburn had the most persistent leukemia cluster it had ever seen.

Later that December, MDOH released a preliminary report on the second five-year study[2] of the health effects of Woburn's drinking water, which contradicted the clustering of leukemia in East Woburn and the pronouncements of CDC. It stated that Woburn had a higher than normal incidence of many cancers but that there was no "association between environmental hazards and the incidence of childhood leukemia." (As later determined, the state had used in its calculations, a population estimate for Woburn, taken from the 1970 Census, which was much greater than Woburn's population at the time the study was conducted.) When MDOH corrected this inaccuracy, its calculations revealed several statistically significant rates of cancer and leukemia.

1980-1982

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[1] Between 1964 and 1997, 28 leukemia cases were diagnosed in Woburn. Of these 28 cases, 16 resulted in death. (The last case of documented childhood leukemia in Woburn was reported in 1986.)

[2] Dr. Robert Tuthill and Dr. Leslie Lipworth, of the University of Massachusetts, conducted the first five-year study, which found a slightly elevated but statistically insignificant increase in Woburn's rates of cancer and leukemia.

Wells G&H. Initial EPA investigations of potential contamination at Wells G & H began in 1981. Per these investigations, the EPA divided the site into three areas, or “operable units”, and identified five likely sources of pollution. The operable units included five properties inside the site boundary, the area immediately surrounding the wells, and a segment of the Aberjona River and adjacent wetlands. Three of the sources of pollution that EPA identified were W.R. Grace, UniFirst, and the John J. Riley Tannery (Riley) which had been purchased by Beatrice and then again purchased by Wildwood Conservation Corporation. Grace operated an equipment manufacturing plant located about 2,500 feet northeast of the wells; the firm used solvents at several points in the manufacturing process. The Riley Tannery, and an adjacent 15 acre property, was bought by Beatrice in 1978 and sold back to Riley in 1983, but Beatrice retained legal liability for environmental matters at the tannery property. UniFirst, located about 2,000 feet north of the wells, used perc as part of its industrial dry-cleaning business. The other two sources of contamination were New England Plastics and Olympia Nominee Trust. Final testing conducted in September 1988 confirmed that groundwater contamination emanated from pollution at these properties. On December 30, 1982, the EPA proposed adding Wells G & H to the NPL.

Installation of a groundwater monitoring well near Wells G & H.

Industri-Plex. In 1980, the EPA allocated $150,000 for an investigation of the Industri-Plex site, which revealed major pollution problems. In May of 1980, a judge ordered MP Trust to halt construction until it designed, with the help of MDEQE, an appropriate cleanup plan for the site.

Also in 1980, MDEP placed a latex cover over the inorganic wastes at the site. At that time, the site contained streams, ponds, remnant manufacturing, buildings, a warehouse, office buildings, and waste piles.

The EPA began negotiating remediation with the primary polluting parties. On October 23, 1981, the EPA proposed the Industri-Plex site for inclusion on the NPL. The EPA installed chain link fence. This fence was subsequently damaged by ATVs and was not permanently fixed until 1986. During this time period, illegal dumping occurred at the Industri-Plex site.

Unlike the lengthy lawsuit with MP Trust over the Industri-Plex site, negotiations with Stauffer were expeditious. In May 1982, Stauffer signed a Consent Decree with the EPA and MDEQE to undertake a remedial investigation and feasibility study (RI/FS) for the site.

Community Reaction. In May 1980, the CDC and the National Institute for Occupational Safety and Health initiated a more detailed study of Woburn's rates of leukemia, which confirmed the presence of elevated levels of kidney cancer and childhood leukemia. However, the final report stated that the results of the study were inconclusive because of the lack of data prior to 1979. It also failed to attribute elevated levels of leukemia to hazardous wastes, "The information gathered thus far fails to provide evidence establishing an association between environmental hazards and the incidence of childhood leukemia…in Woburn." The public was outraged and felt betrayed by this persistent stonewalling from governmental agencies. According to local residents, state and city health officials worked to preserve public health in theory only. The media continued to document concerns about the sites including "Workers Near Waste Site Complain of Headaches, Fatigue" (*The Daily Times*, July 2, 1980), and "Toxic Waste: One Year Later, Still No Answers" (*The Daily Times*, August 1, 1980).

The reports fueled community activism and led FACE to question the validity of the reports. Seven months after their initial meeting, FACE convened a group of state and federal agency representatives to discuss the plight of Woburn residents. At that meeting, the EPA agreed to investigate the wells. An EPA report released later that year confirmed what the public already knew, that high levels of contamination were present in groundwater, particularly in the areas of Wells G & H. This was the first of FACE's many victories, as the group was instrumental in the remediation of both the Wells G & H and the Industri-Plex sites.

In 1982, eight Woburn families filed a highly publicized $400 million lawsuit against several industries alleging that they had contaminated the aquifer for the two wells, and that this contamination caused the high rate of childhood leukemia and other health problems in Woburn. While the court case proceeded, FACE continued its grassroots advocacy work and held numerous public meetings to mobilize community leaders and local residents. Two professors studying the clustering of disease heard of FACE's struggles and invited activists Anne Anderson and Reverend Bruce Young to present the Woburn case at the Harvard School of Public Health (HSPH). As a result of this presentation, the HSPH and FACE collaborated on a more detailed study of environmental contaminants at Woburn. The HSPH designed and administered a public health survey of the area with the help of FACE, which coordinated 235 volunteers to implement the survey. Between April and September, 54% (3,257 households) of all Woburn residents answered the survey. The results revealed a clear linkage between leukemia, fetal and newborn deaths, birth defects, and childhood illnesses within the neighborhoods that received most of their water from Wells G & H. The survey also found that the well water caused ten times the expected rate of stillborn births. As Reverend Young described the situation, "For seven years we were told that the burden of proof was upon us as independent citizens to gather the statistics…. All our work was done independent of the Commonwealth of Massachusetts. They offered no support, and were in fact one of our adversaries in this battle to prove that we had a problem."

Millions of dollars and several years were devoted to the Woburn court case which commanded front-page national media attention. The book describing the lawsuit, *A Civil Action*, was published in 1996 and became a bestseller. In 1999, the book was made into a movie starring John Travolta.

1983-1985

Wells G & H. On September 8, 1983, Wells G & H were officially listed on the NPL. In 1983, the EPA issued its first order requiring Grace, Beatrice, and UniFirst to begin initial investigations on the contamination at their properties affecting Wells G & H. In 1985, the EPA's second order mandated that Wildwood Conservation Corporation fence its property and hire a 24-hour guard to prevent any additional human contact with the contaminants present on that property. An EPA Technical Assistance Grant, awarded to FACE, allowed the community to hire a consultant who could interpret technical information and reports about the site. FACE heavily utilized the expertise of their consultant, providing community members the opportunity to actively participate in the development of the Record of Decision (ROD) and final remediation guidelines for the site.

Industri-Plex. On September 8, 1983, the EPA placed the Industri-Plex site on the NPL. Stauffer completed the RI/FS in April 1985 and found that arsenic contamination was even greater than initially suspected. Stauffer's investigation also revealed that the northeast section of the property would require only groundwater monitoring and might be appropriate for future development. Finally, the report concluded that although Wells G & H and Industri-Plex were hydraulically connected, contamination present at Wells G & H is the result of pollution dumped not at the Industri-Plex site, but at a location south of Route 128. The EPA ordered a full-blown investigation of the entire 330-acre Wells G & H site. Stauffer chemical signed a consent order with EPA to pay for its apportioned share of the remediation efforts. In May 1985, the parties approved decrees requiring MP Trust to investigate and cleanup the site, but MP Trust never undertook these activities citing financial concerns.

1986-1988

Wells G & H. In 1986, after five years, the $400 million lawsuit filed by the eight Woburn families went to trial. The initial trial lasted only 80 days and none of the surviving plaintiffs ever took the witness stand to talk about their loss resulting from contamination at Wells G & H. Woburn residents were embittered by the results of the verdict:

- UniFirst Corporation (UniFirst) settled for $1.05 million prior to the trial without admitting any wrongdoing.
- Although a jury found Grace & Company (Grace) negligent, a district judge dismissed the ruling because of inconsistencies in the evidence. Grace eventually settled for $8 million without admitting any wrongdoing. After lawyer's fees, each family received approximately $300,000.

- A jury dismissed the charges against Beatrice Foods (Beatrice), but the judge reopened the case because of legal misconduct on the behalf of Beatrice's lawyers.

In 1986, an EPA administrative order required Olympia Nominee Trust to remove all drums and debris from the western portion of its property. Additionally, in 1987, EPA issued an administrative order requiring UniFirst to install monitoring wells and remove contaminants near Wells G & H. Also in that year, the U.S. Geological Survey reports that approximately 50% of the water for Wells G & H originated, from the polluted Aberjona River. In 1988, the EPA conducted a detailed investigation showing the groundwater contamination from the five properties near the wells.

Industri-Plex. Also in 1986, to restrict access to the Industri-Plex site, the EPA ordered the fence to be fixed and a 10,000-foot extension. A year and a half after the RI/FS was complete, in September the ROD was finalized; the EPA published its ROD describing the remedies selected for the Industri-Plex site. The remedy consisted of five elements:

- The "soil remedy" called for installation of a permeable cap over 105 acres to prevent physical contact with soils and sediments contaminated with high concentrations of lead, arsenic, or chromium.
- The "air remedy" called for placement of an impermeable cap over five acres of the site to prevent water infiltration and gas release, and installation of a gas collection and treatment system.
- Interim groundwater treatment of a benzene/toluene "hot spot" on the site to reduce concentrations and limit migration of the chemicals.
- Investigation into and development of a plan for treatment of groundwater and surface water.
- Implementation of institutional controls to limit the future use of the site because available cleanup technology could not provide the safety necessary for unrestricted use.

The total cost of site investigations and remedial actions was estimated to be $50 million. Although cleanup remedies for the Industri-Plex site were identified in 1986, actual cleanup activities did not begin in until 1993.

The fence around the Industri-Plex site was completed in 1988, but shortly thereafter dirt bikes and ATV riders again destroyed a section of the fence, and several barrels of waste were dumped illegally at the site. Three months after the repair, the fence and posted warning signs were demolished by vandalism.

1989-1991

Wells G & H. In 1989, the EPA granted Woburn a Technical Assistance Grant enabling the community to hire a technical advisor to help them better understand the technical aspects of the contamination and remediation efforts and take an active part in decision making processes for Wells G & H. On September 14, after incorporating issues mentioned in the public comment phase, the EPA released its final ROD. The ROD addressed the properties contained within the site, the accompanying groundwater contamination, and the subsequent investigations of the other two operable units of the site.

In July 1991, after only four months of negotiation, the EPA finalized a "record-breaking" settlement with four of the five PRPs for the Wells G & H site (Grace, UniFirst, Beatrice, and North Eastern Plastics). At the time, it was the most expensive Superfund settlement ever achieved in New England. Although an agreement with the fifth PRP, Olympia Nominee Trust, was never reached, the comprehensive cleanup of the G & H Wells site began immediately upon the closing of this multi-million dollar deal. The settlement stipulated that the companies would:

- Clean up their own properties simultaneously, at a collective cost of approximately $68.4 million,
- Provide funding for EPA's oversight of cleanup activities, valued at $6.4 million,
- Conduct a risk assessment of the area immediately surrounding Wells G & H, and
- Reimburse the EPA for its investigation studies, which cost approximately $2.65 million.

Due to the amount of contamination present at the site, agency officials knew long-term remedial plans for the site would be critical and remediation of groundwater resources would be extensive. These plans included excavating and incinerating 2,100 cubic yards of contaminated soils, extracting toxins from soil vapors (this entailed, literally, suctioning the toxins out of soil), and pumping groundwater from the underground aquifer and returning it after treatment.

Although the problems at both the Wells G & H and Industri-Plex sites were identified in 1979, local citizens grew increasingly frustrated by the 14 year delay in remediating Industri-Plex and the 13 year delay in remediating Wells G & H.

Industri-Plex. Trespassing on the Industri-Plex site ceased after the Industri-Plex Site Remedial Trust (ISRT) established its office on the site in 1989 and posted 24-hour security guards.

After five years of arduous negotiation, MP Trust signed a Consent Decree to investigate contamination at the site and resolve wetland infilling violations. Unable to comply with terms of this agreement, MP Trust filed for bankruptcy. A Consent Decree was signed for Industri-Plex site in April 1989, Monsanto, Stauffer-ICI (ICI Americas, Inc, purchased Stauffer in 1987), and twenty smaller other PRPs established the Industri-Plex Site Remedial Trust (ISRT) to implement the agreement. In addition to forming a remedial trust, this Consent Decree allowed Monsanto and Stauffer-ICI to create a Custodial Trust which would technically own title to contaminated areas of the Industri-Plex property, protecting Monsanto and Stauffer-ICI from liability relative to the site, attempt to avoid conflicts among PRPs, and set-up a mechanism to sell the land after completion of the remediation of site. A key feature of this agreement required that the recently bankrupt MP Trust sell all of its Industri-Plex holdings to fund its share of remediation of the toxic contamination and in return to have no additional liability.

1992-1994

Wells G&H. One year after signing their multi-million dollar agreement with the EPA, in September 1992, UniFirst and Grace began groundwater remediation, and Wildwood and New England Plastics began soil excavation. This progress was viewed as a mixed blessing. Government officials applauded the PRPs for ultimately accepting responsibility and then acting expediently, but residents felt betrayed. According to Gretchen Latowski, director of FACE, "The Woburn experience is the ultimate failure of Superfund. It took 12 years since the problems at the wells were first identified before anything was done or any responsibility taken."

Excavation of contaminated soil near Wells G & H.

Industri-Plex. Although cleanup remedies for the Industri-Plex site were identified in 1986, actual cleanup activities did not begin in until 1993 when construction began on the permeable and impermeable cap for Industri-Plex site. By the summer of 1994, EPA had approved 100% of the remedial design. Also in the early 1990's the EPA and the ISRT amended the groundwater remedies listed in the Industri-Plex ROD (Element 3) because of unanticipated contamination, advancing technology, and cost efficiency. As a result of this change, groundwater was treated by a pilot oxygenation and bioremediation process as opposed to the original remedial prescription to pump groundwater, strip it of contamination, and return it to the aquifer.

Industri-Plex during remediation: site with cap on contaminated soils.

1995-1997

Wells G & H. On April 27, 1995, Jeffery Purvis, Chief of the Community Assessment Unit of the Bureau of Environmental Health Assessment, reported on the status and conditions of Wells

G & H. Though not clearly identified, the well field was easily accessible and a No Trespassing sign was posted. However, the area was not fenced and rolls of fold fencing and piles of concrete piping lay in the area. The site did not appear to have been accessed recently, though trash, including clothing, furniture, tires, and other debris, littered the site. In 1995, the UniFirst Corporation and W.R. Grace and Company installed UV-oxidation systems to treat groundwater in area bedrock.

The bestselling book, *A Civil Action*, was published in 1996.

After extensive but fruitless efforts to bring Olympia Nominee Trust to the table, the EPA in 1997 agreed to remediate that part of the site with money from the Superfund trust. Initial tests of the Olympia Nominee Trust property began in September 1997.

Industri-Plex. By 1997 the soil and air “remedies” ordered in 1986 for Industri-Plex were in place (Elements 1 and 2), the groundwater treatment to reduce the benzene/toluene “hot spot” was only partially implemented (Element 3), and the instructional controls to determine future use of the site were still not finalized (Element 5).

1998 and later

Wells G & H. In 2000, North Eastern Plastics completed the remediation of the soil and water contaminants related to Wells G & H. In 2003, six years after reaching agreement with the other four responsible parties, EPA reached an agreement with Olympia Nominee Trust, the fifth source of pollution for Wells G & H. The EPA entered into administrative order by consent with all parties this year to address PAH and PCP contamination.

Phase II investigation of the groundwater contamination, beyond the five sources continues. As part of Phase III, which focuses on the Aberjona River, the EPA prepared a risk assessment.

Industri-Plex. At the Industri-Plex site, the gas collection and treatment system were completed in December 1998. Groundwater remediation and monitoring constitute the bulk of the remaining work to be done. As of December 1998, the three groundwater treatment plants operating at the site had pumped and treated more than 150 million gallons of water. In addition, all the contaminated soil was removed (approximately 150 tons) and 1,360 pounds of VOCs had been destroyed. Although major strides in the remediation of the property have taken place, according to EPA lawyers, complete cleanup of the site will cost approximately $80 million and could take another 20-30 years because of the site's extensive groundwater contamination. An investigation of groundwater contamination at the Industri-Plex site began in 1999. Initially it was expected to be completed by early 2000; however, it was not finished until 2003.

State and local governments and EPA officials have been successfully working together to promote commercial redevelopment of the Industri-Plex site. For example, with the support of state and local officials, the EPA pursued prospective purchaser agreements which limit the liability of property purchasers and, in some cases, offered previously contaminated properties at reduced rates. Plans included having Home Depot and Target serve as anchor stores of the 110 acres of commercial development at the site, with 35 acres being devoted to a regional transportation center, and 100 acres being preserved as wetlands and open space. As one development engineer recently observed, foxes and snapping turtles now frequent Industri-Plex wetlands.

Industri-Plex after remediation: regional transportation center.

Though soil data was collected in 1995 and 1997, additional sediment and surface soil sampling was conducted in 2000 and 2001 to fill in data gaps of the Human Health and Ecological Risk Assessments. In 2002, sediment and soil samples were collected along the

Aberjona River to evaluate the potential impacts from the river, including on the cranberry bog, on flood source soil conditions, and on areas the City of Woburn was interested in developing in the future.

Chapter 5

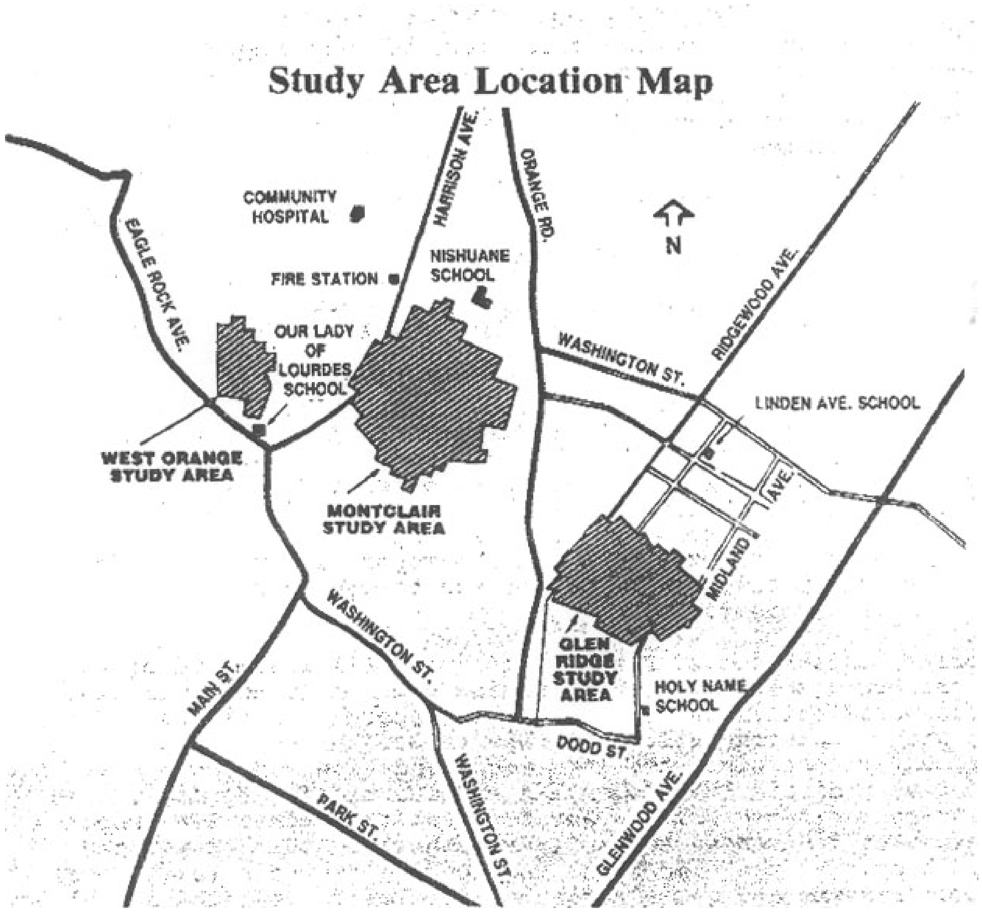
Montclair, New Jersey

5.1 Overview

Montclair, Glen Ridge, and East and West Orange Townships are located about eight miles (12.9 kilometers) from Newark Airport in northern New Jersey. These towns are densely populated, and are located in one of the most densely populated regions of the United States. The Montclair/West Orange Radium Superfund site consists of 366 residential properties on 120 acres in Montclair and West Orange (Figure 5.1). The Glen Ridge Radium Superfund site is comprised of 306 properties on 90 acres of residential land in Glen Ridge and East Orange. The soil at both sites is contaminated with radium, a naturally occurring element which can result in high levels of radon gas and gamma radiation in nearby homes. The Center for Disease Control (CDC) and the New Jersey Department of Health (NJDOH) declared these sites to be a public health hazard due to concerns about lung cancer. Montclair/West Orange and Glen Ridge were listed on the NPL for Superfund sites in 1985 because of their proximity to radium waste generated by radium processing. These plants had operated in the area after the turn of the 20th century, and an estimated 200,000 cubic yards of contaminated material were placed on private and public areas in the communities.

Initial attempts to remove the contaminated soil were hampered by the lack of suitable waste depository, resulting in 4,902 drums and 33 containers of soil being stored for nearly two years on the yards of partially excavated properties in Montclair. In 1999, nearly 20 years after the initial identification of the problem and 12 years after being put on the NPL, cleanup activities continued to occur as the streets are replaced and the EPA continued to investigate the possibility of additional groundwater contamination. By 1998, a total of $175 million had been spent to remediate over 300 houses and remove 80,000 cubic yards (or 5,000 large truck loads) of contaminated soil. In 2004, estimates of total cleanup exceeded $200 million.

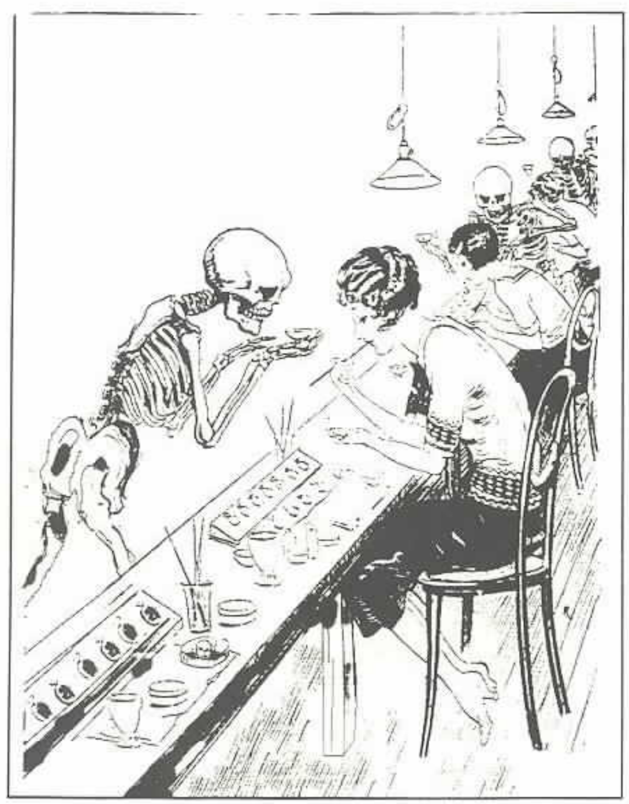
Figure 5.1 West Orange, Montclair, Glen Ridge Sites



5.2 Timeline and History

1915-1926

Northern New Jersey was a center for radium processing and the dial-painting industry in the 1900’s. Several plants occupied the area, the largest of which was the U.S. Radium Corporation (formerly the Radium Luminous Materials Corporation) which operated between 1915 and 1926. Because of its luminescent properties, radium was added to the paint that was used for numbers on watch dials and instruments, which became especially popular during World War I. At various times, U.S. Radium Corporation employed between 100 to 300 young women as watch dial painters. Corporate supervisors instructed the painters to lick the tips of their brushes to create the fine point needed for the detailed work. As a result of this process, the dial painters ingested a significant amount of radium. Since clothes were often speckled with this luminous paint, many of the dial painters glowed in the dark by the time they returned home from work. Women sometimes painted their fingernails, buttons, or eyelids with the paint for its special glow-in-the-dark effects. One worker reportedly painted her teeth with the luminous paint in preparation for a date after work one evening. Because of their exposure to radium, some of the workers developed bone diseases, such as necrosis of the jaw, anemia, and cancer. Many factors, including health problems and the discovery of richer uranium ore in the Belgian Congo led to the closing, and eventual destruction, of New Jersey's radium plants.



"POISONED! -- as *They Chatted Merrily at Their Work*

Painting the Luminous Numbers on Watches, the Radium Accumulated in Their Bodies, and Without Warning Began to Bombard and Destroy Teeth, Jaws and Finger Bones. Marking Fifty Young Factory Girls for Painful, Lingering, But Inevitable Death"[3]

[3] Source: Hearst Sunday supplement *American Weekly*, February 28, 1926.

The U.S. Radium Corporation extracted and purified radium from carnotite ore found in New Jersey soils. It processed approximately one and a half to two tons of ore each day, and generated large amounts of radium contaminated waste. This waste was stored temporarily on-site, and then transported and dumped on nearby rural areas.

1930's

During the 1930's, the contaminated soil was used as fill to prepare approximately 200 acres of low-lying areas in Essex County, New Jersey, for residential development. Contaminated soil was also mixed with cement for foundations and sidewalks. An estimated 200,000 cubic yards of contaminated material is believed to have been disposed of on private and public lands within the communities before the area was fully developed. This area, contaminated by radium infill, eventually gave rise to the townships of Montclair, Glen Ridge, and East & West Orange.

The Montclair site was almost entirely residential with some small businesses and a park nearby. Within a half-mile (0.8 kilometer) of Montclair were five schools, a hospital, one health care facility, and a nursing home. West Orange was also predominantly residential with some businesses located on the north/northeast side of the site. Located within one half-mile of the West Orange site were two schools and one hospital. The Glen Ridge site was primarily residential, and encompassed a park and had several small businesses nearby. No hospitals were located near the Glen Ridge site, but three schools exist within a half-mile.

A USEPA contractor takes gamma radiation measurements in Montclair.

Pre-1987

The New Jersey Department of Environmental Protection (NJDEP) discovered radium contamination in these communities in 1979 during an investigation of the former radium processing facilities. In 1981, the NJDEP requested EPA funding to perform an aerial gamma radiation survey of 12 square miles (19.3 kilometers) of Essex County to identify possible contamination from offsite disposal of radium processing waste. This survey identified three distinct areas of elevated radiation in the townships of Montclair, Glen Ridge, and West Orange.

The NJDEP conducted additional screening surveys and ground readings in Glen Ridge in July 1983, and in Montclair and West Orange in October 1983. As part of this screening, 17 homes in Montclair and 10 homes in Glen Ridge underwent additional testing for radiation, 19 of which were found to exceed federal safety standards for radium (13 in Montclair, 6 in Glen Ridge).

NJDEP officials were planning to notify local government officials and residents of their findings in early December 1983. However, despite a request by NJDEP officials to hold the story until official notification had been made, a November 30th television news report broke the story early. According to the *New York Times* (October 16, 1984) article published one year later, "[Many] residents of the three communities – Montclair, West Orange and Glen Ridge – were not told about the problem until…technicians, wearing protective gear began taking soil and air samples in and around their homes." Within a few days of the television news report, New Jersey Governor Kean convened a news conference to make an official announcement about the radium contamination. That month, local newspapers reported extensively on the areas of radium contamination in their communities. Response to the announcement of radium contamination was immediate, widespread, and occurred at many levels from local neighborhood residents to federal agencies. With this heightened public concern, the EPA immediately installed temporary radon ventilation systems in 38 homes and gamma radiation shielding in 12 homes.

A combined federal and state task force formed in December 1983 to devise a comprehensive sampling plan that would better define the areas of contamination and provide a benchmark for remedial action. This plan included an initial screening of "grab" samples which showed above background radon levels. Long term units for continuous sampling and monitoring were later installed. Technicians in protective suits performed surface gamma radiation surveys on the properties surrounding affected homes. Soil samples were also collected. In response to local citizens' and officials' concerns, two schools in Montclair were tested but no contamination was found.

At the local level, community members received different messages from different agencies about the health risks involved. NJDEP Commissioner Hughey portrayed radon as strictly an environmental problem. A New Jersey Department of Health (NJDOH) representative said that the only known health risk was lung cancer, and a NJDOH representative was made available to meet with affected families for advice. According to the EPA, risks associated with radon were equivalent to the risks associated with cigarette smoking. A couple of news reports, however, referred to the radium contamination in New Jersey as "another Love Canal," since both residential areas were built on contaminated soil. Even EPA officials expressed great concern, among themselves, about this case, because it identified the first residences built directly on contaminated ground. In response to this mixed information, the Montclair Township Council formed its own task force in December 1983, which held its first organizational meeting that month. Montclair residents from the contaminated neighborhoods also formed a Radiation Ad Hoc Committee in December 1983.

Within a month of the November 30, 1983, news report, three bills to aid the affected communities were introduced into the New Jersey state legislature. One bill requested cleanup funds, another victim compensation, and the third would require the NJDEP to investigate any potentially affected homes at the owner's request and provide a certificate of clearance if the property was not contaminated. The latter bill was passed in January 1984, and by July 20, 1984, some residents received certification that their homes had been tested and were clean.

The EPA began field investigations in Glen Ridge and Montclair in January 1984 to determine the boundary of the contamination and to quantify gamma radiation and radon levels in the affected areas. Residents were asked for permission to collect samples and were then provided with the results for their homes. Field investigations continued throughout the fall of 1984. By the end of the year, the EPA had completed all radon source characterization surveys in the three townships.

The NJDOH conducted an epidemiological assessment of the three radium sites and found a possible, but not statistically significant, increase in lung cancer among white males at these sites. As a result of this study, the CDC and NJDOH declared these sites to be a public health hazard. The Centers for Disease Control (CDC) released a Public Health Advisory for Glen Ridge and Montclair which quantified health risks and recommended appropriate remedial actions. The CDC divided homes into four categories based on their levels of contamination and the actions necessary to reduce human exposure contamination:

- Level I homes required remedial action within two days and restricted smoking and time spent in high radon level areas of the homes.
- Level II homes necessitated remedial action in 1-3 months.
- Level III homes necessitate remedial action within 1-2 years.
- Level IV homes required no action.

Prescribed actions included the installation of remedial systems such as dilution air fans, air filtration systems, and sealing foundations. The plan also suggested additional studies to determine the boundaries of the contaminated areas, locate and characterize the source of the contamination, and assess the potential for groundwater and vegetation contamination.

All this testing and EPA attention prompted local realtors to gather at a Task Force meeting to discuss the potential impact of radon on the housing market. Reactions were mixed. Some realtors reported that there was no decrease in the number of homes sold. However, other realtors reported, anecdotally, a decrease in the selling prices of the homes *if* the homes were known to be in affected areas. Fearing lower property values, local residents felt strongly that they should not have to pay full property taxes on their homes. In response to these concerns, the Essex County Board of Taxation granted to petitioners in 1984 tax relief on 39 properties in Montclair: 20% relief if there was soil contamination and 50% relief if radon levels required installation of ventilation systems. The County also granted tax relief for 22 properties in Glen Ridge, but the town appealed this in State Court. In West Orange, tax relief was granted for eight properties – including some adjacent to contaminated properties.

In June, the media agitated already deepening concerns with a spate of negative publicity which included local newspaper articles and several special news features on major television stations. Residents and officials of Montclair grew more concerned, and decided to hire a private consultant, David Rosenbaum, a former EPA official. Many of Rosenbaum's views were published in the local newspaper, including: 1) levels of radiation are the highest ever determined in a dwelling in the U.S.; 2) residents in these homes were exposed to "some of the highest concentrations of any carcinogen ever recorded"; and 3) "Affected residents are in considerably more danger than the people who once lived in the Love Canal region in NY." Rosenbaum concluded that the contaminated soil should be dumped in the ocean and that the EPA could approve this solution (*Montclair Times*, October 11, 1984). Residents of Montclair, Glen Ridge, and West Orange filed suit against the U.S. Radium Corporation. The 7-year legal battle went to the State Supreme Court and ended in 1991 when 237 residents received a $4.2 million settlement (average $18,000/house) from remnants of the U.S. Radium Corporation.

The entire backyard of this property in Montclair was excavated during cleanup.

A joint EPA/NJDEP task force identified 12 homes in the three communities for a proposed pilot study involving soil excavation and removal. The EPA decided to postpone the pilot study until the completion of the requisite feasibility study, scheduled to begin later that year. The NJDEP, however, planned to proceed with the pilot study on its own. The search for an acceptable disposal site stalled progress of the pilot program and ultimately generated a great deal of public anger and distrust of the NJDEP. In August, the NJDEP proposed to temporarily store contaminated soil from the pilot study at the National Guard Armory in West Orange. Residents of West Orange strongly opposed this plan and the proposal was withdrawn. The Montclair Township Council was then asked to help locate a disposal site in Montclair for the radioactive waste. In response, the Council passed a resolution stating that the Township would under no circumstances comply with the request because: 1) complete cleanup was the only acceptable alternative; 2) high population density and development pressures excluded the possibility of local storage sites; and 3) securing a disposal site was a state and federal responsibility.

As the search for a suitable storage site for the contaminated soil became a major problem, the NJDEP considered several other options, but significant resistance from people living in or near the potential sites caused each of these possibilities to be abandoned. For example, protests and demonstrations were held to prevent storage of contaminated soil at a dump site on the Montclair State College campus. During this time, questions were raised about the desirability of a pilot project. Those in favor of the project said that it would shorten the time it would take the EPA to start cleanup because the project would demonstrate the feasibility of the cleanup approach.

In the fall of 1984, the NJDEP and federal officials considered simply buying and fencing-off the contaminated properties. This option deeply concerned the townships, which soon deemed it the least desirable alternative because it would transform whole neighborhoods into “radium dumps.” Finally, in September 1984, the Montclair Township Council and community task forces announced their intention to undertake legal action against the EPA and the NJDEP to facilitate timely removal of contaminated soil.

The Montclair/West Orange and Glen Ridge sites were added to the proposed NPL in October 1984, and the EPA began its Remediation Investigation/Feasibility Study (RI/FS) the following month. Three months later (January 1985), both sites were added to the final NPL. In April, the EPA finalized its RI/FS and submitted it to the public for final approval.

Also in April, the New Jersey Governor signed a bill appropriating eight million dollars for the pilot study (this was later increased to $15 million). With this money, the NJDEP was able to locate a storage site in Beatty, Nevada, and the pilot study began with four homes in Glen Ridge in June of 1985. In August, five Montclair families were temporarily moved from their homes for an expected two months and excavation of the contaminated soil began. Prior to its shipment to the permanent storage site, approximately two-thirds of the contaminated soil excavated for the pilot project (9,500 drums and 51 containers) was stored in Kearny, New Jersey, and the remainder of the soil (4,902 drums and 33 containers) was stored in the yards of the partially excavated properties in Montclair.

Immediately preceding the completion of the pilot project and soil shipment, the state of Nevada revoked the NJDEP’s disposal permit. In October 1985, the U.S. Supreme Court directed the NJDEP to look for a disposal site within the state. Once again there was no place to store the contaminated soil from the complete remediation of four homes in Glen Ridge and the partial remediation of five homes in Montclair. Consequently, almost 5,000 containers of contaminated soil remained in the yards of the partially excavated Montclair homes.

In July 1986, the NJDEP made plans to ship the excavated soil to an abandoned quarry in Vernon, New Jersey, where it would be blended with clean dirt to bring radium levels down to acceptable levels. Thousands of Vernon residents vigorously protested against this plan by obtaining temporary restraining orders and demonstrating with chants of “Hell no, we won’t glow.” Several state and federal lawsuits were also filed against the NJDEP, and the NJDEP dropped the plan in November. As the search for a storage site dragged on, the plight of the relocated Montclair families continued to be the subject of media attention. Three hundred people from Montclair and surrounding communities rallied in support of the indefinitely displaced families.

1987 – 1989

The NJDEP made several offers to buy these five properties from their owners at market value -- as if the homes were not contaminated -- and to pay relocation costs, but these offers were refused. The NJDEP also offered to bury the contaminated soil more deeply in the yards and install filtering systems. This offer was also refused. The Township of Montclair again filed suit in State Supreme Court to force the NJDEP to remove the barrels. Judgment was passed in March 1987 requiring the NJDEP to start removing the barrels by May 15, 1987.

Eventually, the EPA negotiated a disposal site, and in December 1987 the NJDEP spent almost four million dollars to ship the barrels of soil to Oak Ridge, TN where the soil was mixed with radioactive waste from power plants and shipped to a storage site in Washington State. Likewise, the soil stored at Kearny, NJ was shipped out of state in the summer of 1988.

An excavator removes radium-tainted soil from Barrows Field in Glen Ridge.

In April 1989, the EPA released its draft remediation plan and held public meetings for discussion and comment. The EPA's $53 million action plan called for a five-tiered approach to remediation based on the level of contamination found in the homes. In June, the first Record of Decision (ROD) was signed. It established five classifications related to the level of contamination and subsequent required remediation:

Tier A (23 homes):	Complete soil removal and replacement of the most contaminated areas.
Tier B (75 homes):	Covering of contaminated soil and installation of radon control systems in homes with very high radiation levels.
Tier C (65 homes):	Installation of anti-radiation devices in less severely contaminated homes, which would also be subject to deed restrictions and other controls.
Tier D (296 homes):	Monitoring homes with low levels of radon.
Tier E:	The homes had no evidence of radium contamination and would receive no further action.

The public staunchly opposed this plan and all proposed remedial efforts short of complete removal of contaminated soil. In response to public concerns, the EPA installed a fence around two of the sites to prevent the public from coming into contact with hazardous materials. They began removing soil at the most contaminated homes and extended the comment period on the plan, while deferring decisions on the less contaminated homes.

In 1989, Dr. William Kinnard of the Real Estate Counseling Group of Connecticut, Inc. was retained to conduct a market research study of all single-family residential property sales within the three radium Superfund site areas. This analysis identified, reported, and measured the actual market sales behavior of homebuyers and sellers using a total of 1,423 housing sales in three different locations from July 1, 1980 to June 30, 1989. In one location, Dr. Kinnard found a statistically significant decrease in property values and volume of housing sales after the public announcement of contamination discovered at these sites. In the other two locations, the rates of property value appreciation and housing sales volume increased more slowly than in locations without Superfund sites. Evidence from Kennard's study also suggests that the housing market response to a known Superfund site is a direct function of the speed, proximity, and apparent effectiveness of any remediation or cleanup efforts.

1990 - 1992

In January 1990, the twice-extended public comment period ended and by June, the public agreed to a revised $250 million plan and the second ROD was signed. This plan included removal of the first 15 feet of contaminated soil from approximately 400 homes in the three towns. Cleanup efforts would be spread out over a maximum of 10 years, and radiation-ventilating devices would be installed in homes in the interim. As part of this plan, the EPA would also replace existing radon units with higher efficiency radon units.

In 1991, as discussed above, after seven years of litigation, 237 residents received a $4.2 million settlement (average $18,000/house) from the remnants of U.S. Radium Corporation.

While the pilot study involving a limited number of affected homes started in 1984, the major cleanup activities of other areas began in 1991. The cleanup was divided into seven phases based on the severity of contamination, owner access agreements, and location. Radon mitigation systems were maintained in almost 40 homes throughout each phase of the cleanup and until remediation was complete. Each phase of the remedial plan required access to properties to perform a design survey, which included gamma radiation surveys, installation of radon and alpha detectors, and soil sampling and drilling. If the survey found no evidence of contamination, the property owner was given the results of the test, and a follow-up radon test was conducted one year later. If the follow-up test confirmed the lack of radium contamination, the property owner was given a final report summarizing all results. If contamination was present in the initial or any of the follow-up surveys, the EPA remediated the property. After remediation was complete, monitoring and sampling were done for one year to evaluate the success of the cleanup. Once the property was cleared of all contamination, a detailed summary package was provided to each homeowner, which included details of excavation and results of the testing. Over the course of cleanup, approximately 100 families were temporarily relocated.

The cleanup process was highly disruptive to the neighborhood as it involved, in some cases, the installation of building supports and the use of large machinery to remove contaminated soil. The Pilot Phase and Phase I entailed the cleanup of 56 properties, temporary relocation of 22 families, and removal of over 15,000 cubic yards of contaminated soil. After the cleanup was complete, houses, property, driveways, and sidewalks were restored to at least their original condition and in many cases were improved by enhanced landscaping and sidewalk and/or garage replacement. Additionally, the amount of radon remaining in the soil at these locations after remediation was well below the natural level of radon contained in most New Jersey soils

1993-1995

In 1993, Phase IIA was underway, which included the cleanup of 26 additional properties. In 1994, Phase IIB started which called for the remediation of 53 properties. During this time period, EPA had still not made a final decision regarding remediating the three communities’ streets. Phase III was completed in 1995 and consisted of remediation of 54 homes.

1996-1997

Phase IV and Phase V were completed in 1996, and included the partial demolition and rehabilitation of 55 homes. Phase VII of the cleanup began in the summer of 1997, which included continuing remediation of properties with post excavation radon levels above normal and beginning remediation of six additional homes. Remediation at 441 properties complete at Montclair/West Orange, but 20 additional properties were discovered to need remediation.

After 1997

By 1998, a total of $175 million had been spent to remediate 300 houses and remove 80,000 cubic yards (or 5,000 large truck loads) of contaminated soil. In the fall of 1998, a two-year remediation plan for the streets finalized and began in 1999, as part of Phase VI. Also, an additional 30 homes were rehabilitated and 35,000 cubic yards of soil were removed as part of Phase VI, which was completed in 2001. In 1999, the EPA began testing groundwater for possible contamination, and a January 2003 Remedial Investigation Report revealed that elevated levels of radon were found in the groundwater. Phase VIII was completed by the end of 2003. Three additional properties require remediation and are included in Phase IX, currently scheduled for completion in January 2005.

Chapter 6

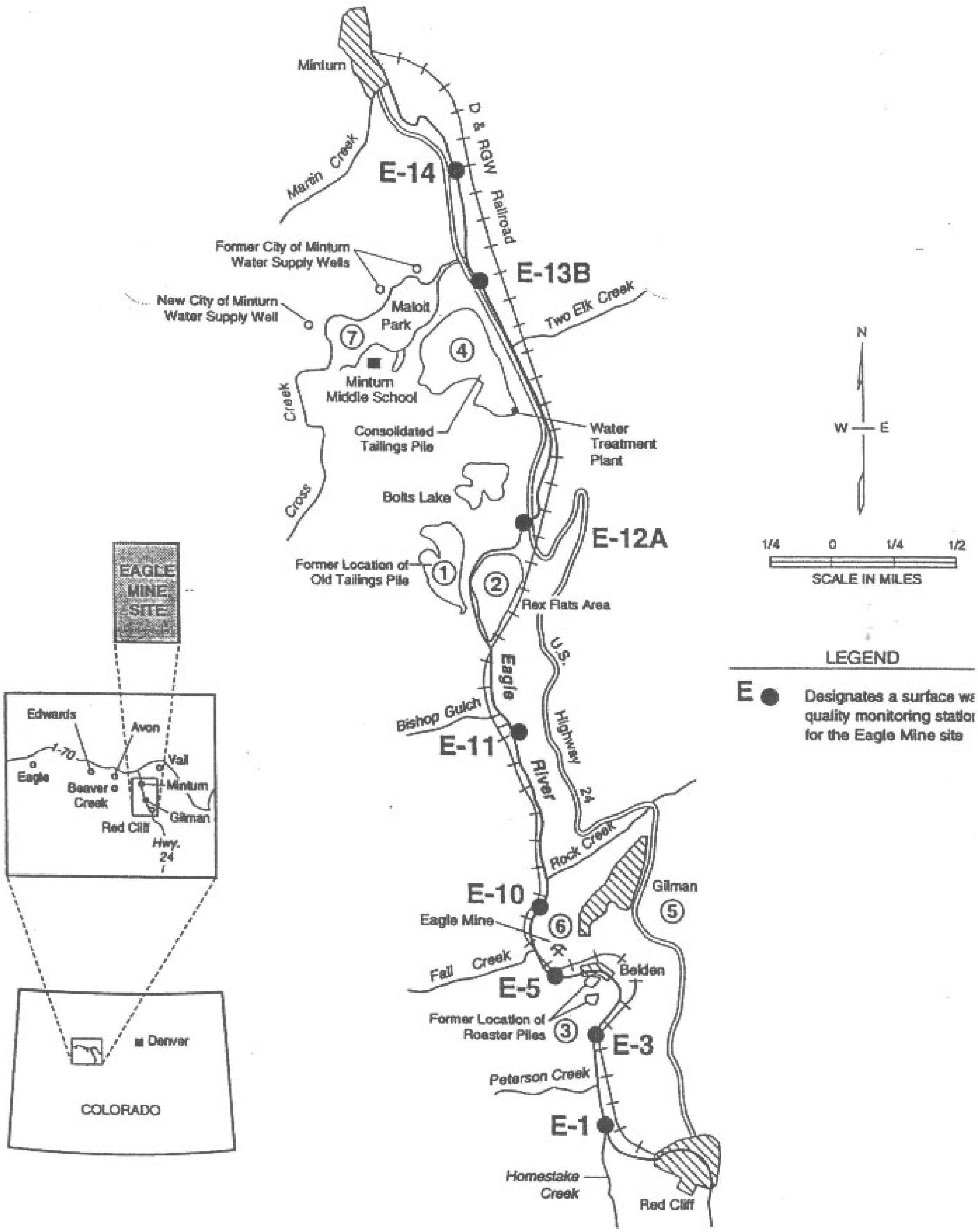
Eagle Mine, Colorado

6.1 Overview

Eagle Mine is centrally located between Vail and Beaver Creek ski areas, approximately 100 miles (160 kilometers) west of Denver, Colorado and about 14 miles (22.5 kilometers) southeast of Vail, Colorado (Figure 6.1). Once one of the nation's top producers of zinc, the mine lies between the small towns of Minturn and Red Cliff, just off U.S. Highway 24. The property consists of approximately 6,000 acres, 340 of which are contaminated with toxic waste. Most of the contamination originates from areas located along the Eagle River, and includes: the abandoned mining town of Gilman located on a cliff just above the mine, the old Eagle Mine processing plant in Belden, two ponds containing wastes from the smelting of ore, Maloit Park, Rex Flats, various waste rock and roaster piles, and an elevated pipeline. The Eagle River (a major tributary of the Colorado River), Cross Creek, and several other tributaries run through the site.

The Eagle Mine site is contaminated with eight to ten million tons of hazardous substances including arsenic, nickel, chromium, zinc, manganese, cadmium, copper, and lead. The main cause of Eagle River contamination came from acid mine drainage, which occurs when sulfide minerals, such as pyrite, are exposed to oxygen and water and then oxidize. This process creates sulfuric acid, which contaminated soil, groundwater, and surface water surrounding Eagle Mine, producing water with low pH levels. Acid drainage at Eagle Mine resulted from precipitation flowing through the waste piles that accumulated from nearly 100 years of mining. As Eagle Mine acid drainage seeped into ground and surface water, it killed aquatic life and vegetation growing along the water's edge and contaminated the river with zinc, lead, manganese, and cadmium. Not only did this contamination threaten brown trout, the most populous fish in this segment of the river, but it also permanently stained the rocks in and along the river bright orange, providing Minturn and Red Cliff residents with a constant reminder of the contamination at Eagle River.

Figure 6.1 Eagle Mine Site



Eagle River across from CTP, stained rock.

State studies conducted in 1984 revealed dangerously high levels of cadmium, copper, lead, and zinc in local water resources. Minturn, with a population of 1500, is the closest town and draws drinking water from Cross Creek and two wells located within 2000 feet of the mine tailings[4]. While Eagle Mine had a history of environmental problems dating back to 1957, the majority of the problems arose after the mine closed in 1984. Eagle Mine was placed on the national Superfund priorities list (NPL) in June 1986.

6.2 History and Timeline

Mining in Colorado began with the discovery of silver-lead and gold-silver in 1879, and played an important role in the economic development of many Colorado mountains. In the mid 1890s, a new ore was discovered in Battle Mountain, and the bulk of mine extractions shifted from gold and silver to zinc. Zinc extracted by independent miners was shipped off site until 1905, when a zinc ore processing plant was built near Belden, approximately a half-mile (0.8 kilometers) southeast of Gilman. The plant heated the ore to extreme temperatures and then extracted the zinc using magnets, a process called roasting. After the roasting was complete, a

[4] Most mine tailings are disposed of in an on-site compound, and are typically comprised of 40-70% effluent liquids used in the mining process and 30-60% solids.

tramway transported roasting wastes across the Eagle River and dumped them into three piles on the west side of the canyon in direct sight of Gilman. In addition to these piles, two more waste piles were located on the east side of Eagle River.

North face of Gilman and waste rock pile.

Around 1912, the Empire Zinc Company began buying small independent mines. By 1915, the company had consolidated the small independent operations into one business which it named the Eagle Mine. Gilman became a company town and, at its peak, was home to over 400 residents.

The New Jersey Zinc Company constructed an underground flotation mill to process the zinc ore from Eagle Mine. The ore was ground into a powder and then mixed with water and treated with chemicals to bring the zinc to the surface of the mixture. The waste from this process consisted of slurry, which was transported north via an underground pipe and dumped in the Old Tailing Pile (OTP) and Rex Flats areas just west of the Eagle River. In 1928, the zinc operation ceased due to falling prices resulting from the Great Depression. Mining of gold and silver ore continued, but the ores were shipped off-site for processing.

Ownership of the Eagle Mine Superfund site is quite complex. In 1938, Empire Zinc Company merged with the New Jersey Zinc Company, making it the new owner of Eagle Mine. Later in 1966, New Jersey Zinc Company merged with Gulf & Western Industries, Inc., which later changed its name to Gulf+Western, Incorporated.

Because it was used to harden steel, a valuable commodity during the war, zinc production resumed in the early 1940s. Once again the tailings were deposited at the Old Tailing Pile (OTP). By 1946, the pile had reached capacity and a New Tailings Pile (NTP) was established one-half mile (0.8 kilometers) northeast of the OTP, near the confluence of Cross Creek and the Eagle River, just south of Minturn Middle School and Maloit Park. Approximately, 75,000 tons of waste, covering 15-20 acres, were dumped at this site.

Long before Eagle Mine was listed on the NPL of Superfund sites, state officials expressed concern about the amount of hazardous pollution originating at the site. In fact, a March 17, 1957 *Denver Post* article reported that a zinc mine in Gilman, CO was asked to pay $15,000 for 75,000 trout that suffocated in the Eagle River due to an oil fuel spillage. Another *Denver Post* article (October 20, 1974) reported that the New Jersey Zinc Company paid "$3,308 for trout and other fish which died July 19 after 12,000 gallons of liquid wastes and 100,000 pounds of mill tailings polluted the Eagle River".

Peter Seibert and Bob Parker founded Vail ski resort in 1962 less than 14 miles (22.5 kilometers) from Gilman and the Eagle Mine. The resort opened for business on January 10, 1963 and 12 skiers bought lift tickets. Within two years, more than 14,000 skiers visited the resort. Vail's reputation blossomed in the mid 1970s when Gerald Ford became president. Ford had lived part-time in the Vail area since the 1960s, and during his tenure as president, the resort became known as the "Western White House". Starting in the 1970s, Vail experienced explosive growth and building construction. Golf courses, tennis courts, and other sports activities attracted summer tourists almost as plentiful as Vail's winter tourists.

1976-1982

Zinc production continued until 1977 when, due to falling zinc prices, the operation was shut down again and more than 150 mineworkers were laid off. Most families moved out of Gilman at this time.

By 1981, one million tourists visited Vail resort annually.

1983-1988

On September 1, 1983, Glenn Miller, a Colorado businessman, bought the Eagle Mine property for $17.5 million with the intention of developing it into a ski resort. Unable to finance this venture, Miller sold to Battle Mountain Corporation (BMC) 1,400 acres of the property including Rex Flats, the tailings ponds, 70 homes, a bowling alley, and several business offices.

In December 1983, the State of Colorado filed a lawsuit against Gulf+Western and New Jersey Zinc for contaminating the Eagle River. At this time, the State also initiated a preliminary risk assessment of the site. As the State and PRPs were unable to come to an out-of-court agreement, the complaint evolved into a court-ordered negotiation regarding who was responsible for the $80 million cleanup of the 7.5 million tons of tailings at the site.

In 1984, while the State of Colorado’s lawsuit awaited settlement, the new owner of the site, Glenn Miller, lost his financial backing and lost the balance of the property due to nonpayment of taxes. These lands were sold at Eagle County tax sales.

Copper-silver ore mining continued sporadically until 1984 when all mining operations at the Eagle Mine halted. At that time the mine began to fill with water because of the many fissures and cracks inside the mine. The Colorado Department of Public Health and Environment (CDPHE) estimated that approximately 250 gallons of water per minute entered the mine. If the mine flooded, the water would come in contact with transformers in the mine which contained an estimated 3,000 pounds of the known-carcinogen polychlorinated biphenyls (PCBs), which could then potentially seep into local water supplies.

In June, the Public Service Company of Colorado informed the EPA that it was going to turn off the electric power supplied to the Eagle Mine because Mr. Miller was unable to pay the mounting electric bill, which was in excess of $90,000. This posed a problem because the mine was being pumped to prevent it from flooding and coming into contact with PCBs. The EPA intervened and agreed to pay approximately $1,000 a day to keep the power on, until they could perform an emergency removal of the PCB-laden transformers. Before the end of the month, the EPA drained PCBs from all three of the transformers. The transformers remained in the mine, however, to help prevent the mine from collapsing. The EPA also built dikes inside the mine to divert water from entering the Eagle River.

In October 1984, the EPA added Eagle Mine to the list of proposed NPL sites. However, action was delayed because Congress was unable to garner support for additional Superfund funding. The State proceeded by developing a cleanup proposal for the site.

In March 1985, Ray Merry, the Eagle Mine Environmental Health Officer, ordered the 14 families remaining in Gilman to leave the site because of potential human health hazards. By July, all families had left the area and Gilman became a ghost town. A gate prohibiting entrance to the town read “Town for Sale.” In December, the Colorado Department of Health conducted a Remedial Investigation/Feasibility Study (RI/FS).

Warning sign at the entrance to Rex Flats & OTP.

The EPA placed Eagle Mine on the National Priority List on June 10, 1986. The EPA then formally designated the State of Colorado to act as lead agency for the cleanup of the site, but both agencies retained the right to take independent actions.

In 1986, the State of Colorado filed $50 million lawsuit against Paramount (owner of Gulf+Western and now Viacom). The lawsuit was resolved in 1988 and the parties entered into a Consent Decree and Remedial Action Plan (RAP). It was estimated that the cleanup would cost $150 million and take ten years to complete. The agreement drafted by Colorado State health officials set acceptable zinc standards and pH levels for the river and relevant soils and required:

1. Plugging the mine portals to stop the production of acid mine drainage;
2. Removal of the roaster piles and reprocessing of the tailings;
3. Collection and treatment of mine water and groundwater;
4. Revegetating the waste removal areas and the Consolidate Tailings Pile (CTP); and
5. Long-term monitoring of the site.

1989 - 1994

As the cleanup began, public concern about the possibility of adverse human health effects intensified. In March 1989, fearing that no assessment had been conducted, federal EPA officials conducted their own investigation of potential contamination at Minturn Middle School, located 400 yards from the mine. A *Vail Daily* article (July 18, 1989) reported on this investigation and indicated that "Richard 'Dick' Parachini [CDPHE Project Manager] told the governor that dust levels [from the cleanup] are 'right on the break point' of what is generally considered environmentally safe. Breathing the heavy metals present at the Minturn site, in high enough levels and over a period of years, is expected to greatly increase cancer risks." This news generated alarm among local residents because the school was located less than one mile (1.6 kilometers) from the 70-acre CTP, which was used for waste dumping until 1977. The EPA convened a well-attended public meeting regarding the issue. Approximately 1,000 irate citizens attended this meeting, which EPA officials characterized as a "lynch mob". At this meeting, the state agreed to amend its RAP to include the construction of a permanent waste water treatment plant that would reduce the level of zinc in the river and raise the pH level of the river. This plant would be operable by July 1, 1990. Additional plugs were installed in the mine to stop water from pouring directly out of the mine and into the river. Unfortunately, the volume of waste water needing treatment exceeded the capacity of the new plant, allowing contaminated water to seep into the river. Viacom was forced to begin construction on a second water treatment plant.

In the interim, the local school board hired a private environmental consultant, Leonard Slosky, to evaluate air quality and dust emanating from the roasting piles. Slosky installed 15 air monitoring stations in and around the school and enlisted the help of several school teachers as well. Every day for six weeks, select teachers wore small compact devices that resembled portable headphone stereos. At the end of each day, a field technician analyzed the filters for toxic residue. Slosky confirmed the presence of heavy metals in and around the school, but concluded that the amount of metals present fell far below hazardous levels. For example, arsenic found at the site presented the greatest potential health risk, but Slosky likened the children’s chance of developing arsenic-related cancer to that of smoking eight cigarettes in a lifetime.

Although the EPA chose not to endorse the state’s RAP because it was skeptical of the plan’s long-term effectiveness, the State forged ahead with the cleanup of the Eagle River site fearing the worsening of public health and environmental damages that might result from continued acid mine drainage. However, the State’s decision to pump tailings pond water back into the mine, using the mine as a holding tank, proved to be disastrous and caused even more pollution to infiltrate the Eagle River. A dry winter caused mine seepage to make up most of river water, and the river turned orange. As a result, fish populations declined dramatically. Samples taken from the river that fall revealed zinc levels were 255 times higher than fish tolerance thresholds. No fish lived in the river, and contamination was turning the Eagle River various colors.

Media headlines reinforced the environmental and health related fears of local residents: “Eagle ‘cleanup’ casts doubt on state” *Denver Post* April 20, 1990; “Eagle River fish population smaller than expected” *Denver Post* April 24, 1990; “Fish fading in river polluted by mine” *Rocky Mountain News* April 27, 1990; “Mine cleanup again called inadequate” *Denver Post* July 13, 1990; “Polluted water flows to Minturn wetlands” *Rocky Mountain News* July 13, 1990; and “More problems foul cleanup of zinc mine -- mine’s toxic metals pollute Eagle River” *Rocky Mountain News* August 28, 1990. The cleanup was obviously failing, and local citizens felt state and federal agencies were shirking their responsibilities. In an article published in the *Rocky*

Mountain News on April 18, 1990, a letter from the Minturn town council to Governor Roy Romer stated, “Our river continues to run from murky green to sickly red…Above the mine the river is crystal clear. The town of Minturn believes that we are being held hostage to a bureaucratic nightmare. Minturn is a small town with very limited resources. We find ourselves unable to get any action from our state officials who are supposed to be acting on our behalf.”

In April, Paramount’s new facility began to treat polluted water. State and PRPs amended RAP to add a chemical water treatment plant and install additional mine plugs. Colorado Department of Wildlife began monitoring the fish and macroinvertebrates populations in the Eagle River on an annual basis. At the start of this process, virtually no fish were found in the Eagle River.

In September, a newly formed Eagle County Oversight Committee citizens group, joined by Trout Unlimited, Eagle River White Water, Inc., and the Gore Creek Flyfisher, filed a $300 million class action suit against Paramount Communications, Inc. for water, air, and soil contamination originating from the Eagle Mine property. The organizations claimed that Eagle Mine seepage was contaminating the Eagle River as well as the Minturn Middle School. They added that faulty water treatment plans were causing as much as 40 gallons of contaminated water per minute to be dumped into Maloit Park wetlands. From Paramount, the plaintiffs sought damages for potential health risks, compensation of economic harm due to lower property values, funds for removal of the tailings, and “exemplary damages for wanton and reckless disregard” of residents’ rights. Cindy Cacioppo, a member of the Committee, said “We decided a lawsuit was needed for people to recover damages because there’s nothing in Superfund that allows citizens to recoup.”

In 1991, the EPA became increasingly concerned about the site and notified the State of Colorado that Paramount was in violation of six different aspects of the Clean Water Act because of the mine seepage and discharge from the waste piles that had contaminated the river the previous year. The water treatment plant was replaced and the EPA conducted a risk assessment for PCBs.

Remediation efforts removed five piles of waste materials from the ore roasting plant near Belden. This waste was relocated to the CTP, and former waste piles were revegetated.

During this time period, Vail Associates started silently acquiring options to buy portions of Eagle Mine property.

In June 1992, the EPA decided to conduct a Feasibility Study Addendum, which found that the Eagle River ecosystem continued to suffer severely from heavy metal contamination. Part of the study included additional risk assessments that resulted in a more comprehensive investigation of the health of fish and other natural resources. Additional soil studies and risk assessments of ground water quality were conducted in Maloit Park, Minturn Middle School, and the town of Gilman. The Feasibility Study Addendum identified the following activities to supplement the State's RAP: collect additional seepage from the Rock Creek drainage; monitor former roaster pile areas and waste rock piles; continue operation of the Water Treatment Plant; collect additional groundwater from CTP and treat it at the Water Treatment Plant; and cleanup Maloit Park wetlands area. Risks to human health were also reviewed, but no appreciable threat to drinking water was found, and heavy metals in soil and dust were found to be well within acceptable standards.

Regardless of these findings, Viacom later moved Minturn's drinking wells upstream of their old location. Finally, the EPA concluded that the potential risk of PCB ingestion from the 15 pounds of PCBs remaining in the transformers was low. The EPA agreed to continue to monitor for potential PCB contamination, which has never been found. In June of 1992, the EPA proposed a second and preferred remedial plan for the site, which included an alternative cleanup for each of the individual areas contributing metals to the Eagle River. Cleanup activities focused on removing the 150,000 tons of tailings deposited at Rex Flats and the one million tons of tailings deposited at the Old Tailings Pile (OTP). All of these tailings were relocated to the consolidated tailing pile (CTP). After the removal of the tailings, revegetation efforts were undertaken. Restrictions were put into place to restrict the use of groundwater below the OLP. Efforts were made to control seepage, surface water drainage, and groundwater flow in Rock Creek Canyon. The seepage and drainage were collected for treatment.

In 1992, recognizing an opportunity for even more expansion, Vail Associates covertly funded Turkey Creek, LLC's payment of three years of back taxes on over half of the Eagle Mine site. Payment of these back taxes guaranteed Turkey Creek LLC and Vail Associates a first bid option on the Eagle Mine property.

In March, 1993, the EPA issued a Record of Decision (ROD) that required additional site investigations and remedial actions to be implemented. The ROD included modifications of the established remediation standard, proposed monitoring of additional metals, collection of additional groundwater seepage, monitoring runoff, accelerating the capping of the CTP, removal of the contaminated material from the Maloit Park wetlands, development of a monitoring plan, and implementation of an inspection and maintenance plan.

The 1993 risk assessment determined that soils in Maloit Park Wetlands contained elevated levels of arsenic, cadmium and lead. In June, the State amended the remedial plan for the third time. Viacom was to permanently remove pond water from the top of the CTP, implement a sludge dewatering system, and construct a sludge disposal cell.

In the summer of 1994, the EPA issued a unilateral administrative order that consisted of additional monitoring and testing of the site, which was amended again in 1995 to add a work plan for Maloit Park waste removal and restoration.

1995 – 1999

By 1995, more than 2.1 million tourists visit the Vail Valley annually.

In August, 1995, the State of Colorado, US EPA, and Viacom agree to a Three-Party Consent Decree and Statement of Work to implement the 1993 Record of Decision. The agreement called for sampling of water quality, along with assessments of the aquatic insect and fish populations in the Eagle River to determine the effectiveness of the cleanup actions. Additionally, the three parties agreed to investigate the adaptation of biological-based cleanup standard for the site.

In addition to the actions taken in 1992, more efforts were made to control seepage, surface water drainage and groundwater flow in Rock Creek Canyon.

At Rex Flats and OLP, more than 800 cubic yards of zinc concentrates were removed and moved to the consolidate tailing pile. To prevent ground water contamination, remediation efforts involve intercepting and diverting 100-200 gallons of clean water per minute from the Eagle Mine.

In 1996, the contaminated soils in Maloit Park Wetlands were removed. Clean soil was used to cover the previously contaminated area and revegetation efforts were undertaken.

On February 21, 1986, 32 cars of an 82-car train derailed on the Tennessee Pass heading towards Minturn. Two crew members on the train were killed and another was injured. According to the EPA, four tank cars ruptured, spilling approximately 54,000 gallons of sulfuric acid. Five to six acres of nearby trees and vegetation were blackened by the sulfuric acid that went over an embankment and across the two lane highway. Other contaminates spilled including Triethylene glycol (antifreeze) and small amounts of diesel fuel. However, the overall environmental damage appeared to be less than originally feared. Tests of the Eagle River revealed no significant levels pollution in the river or other water sources.

By 1997, the main tailing pile was capped. Residents reported increasingly better water quality in the Eagle River. In August, the EPA awarded "Environmental Achievement Awards" to both the Eagle River Environmental and Business Alliance and Viacom. The Eagle River Environmental Business Alliance was acknowledge for their efforts in the successful cleanup of the site by "keeping area residents informed, providing technical input, and discussing with people their concerns about a hazardous waste cleanup in their neighborhood." Viacom was lauded for their cleanup efforts that had "gone beyond legal requirements, furnishing the town of Minturn with a safe water supply, voluntarily cleaning up large amounts of hazardous materials, planning to intercept clean water flowing onto its site and keeping a skeptical public informed about the cleanup."

In 1998, the EPA issued a final ROD ensuring it would provide ongoing monitoring of the site. In 1999, state and federal authorities formally sought to change the cleanup agreement to include pumping of groundwater to keep it from filling the mine and complicating treatment of contaminated water from the mine.

Although they denied their intentions for years, Vail Associates revealed, under oath in March, its intention to buy and develop the Gilman property. By April, Vail was already 93% built out, so it turned its eyes on neighboring communities. While the remediation and bankruptcy proceedings for the Gilman property progressed, Vail filed suit against Minturn for its under-utilized water rights, which it would use for its controversial back bowl ski trail expansion. Much to the dismay of Minturn residents, Vail won the rights to 4.76 cubic feet per second of running water during the driest months from October to April. The value of these water rights is estimated to be $14 to $16 million. The enormity of the Vail resort, as well as the wielding of its political power, caused a tremendous amount of animosity between Vail Associates and the small nearby communities. In June, six environmental groups sued the US Forest Service over the expansion of Vail resort and its threat to wildlife.

With its option to purchase portions of the Eagle Mine property, as well as an easement from the Forest Service and entitlement to some of Minturn's water supply, Vail Associates began construction of its controversial 885-acre back bowl expansion in July 1999. The expansion opened in the 2000-2001 ski season and brought skiers within a mile (1.6 kilometers) of the Gilman property. Local residents feared that surroundings communities were destined for yet another Vail-controlled real estate expansion similar to that of Bachelor Gulch where ski-in, ski-out homes were sold for $750,000 each. According to local residents, such a surge in housing and rental rates would threaten the stability of the blue-collar families and communities already struggling to afford Vail Valley's ever-increasing cost of living.

However, in November, Vail Associates announced its plan to protect some of Eagle County's last remaining open space, the Eagle Mine property. Some in the Colorado environmental community viewed the announcement as public relations effort. According to Ted Zukoski of the Land and Water Fund, "We're going to be watching this very closely to make sure this isn't just a green-washing effort to make people feel warn and fuzzy about a big development. It's potentially a step in the right direction, but we're going to have to wait and see how far it goes."

2000 and Beyond

According to the first 5-Year Review completed in October, 2002, the cleanup of the Eagle Mine site, both the federal and the state portions, were essentially complete. The review concluded that public health risks had been removed and restoration of the Eagle River had progressed significantly. Eight million tons of waste rock, tailings, and roaster debris were moved to the Consolidated Tailings Pile, and the CTP was capped and revegetated. The tailings from Rex Flats and the Old Tailings Pile adjacent to Rex Flats had been removed, and the area was revegetated. The roaster piles that were directly across the canyon from Gilman had been moved to the CTP. Maloit Park wetland had been cleaned and a barbwire fence was constructed around it.

Rock Creek no longer flowed directly into the Eagle River; its water continues to be treated at the water treatment plant before being released. Also, approximately 250 gallons per minute (gpm) of water from the mine is being treated before being released into the river. In total, the water treatment plant treats about 360,000 gpm every day. In October, 2001, *The Denver Post* reported that as a result of the 14-year effort and a cost of $70 million that the Eagle River once again ran clean enough for a healthy fish population. Groundwater remediation efforts would continue in order to cleanup an estimated 700 million gallons of contaminated groundwater in the 70 miles (113 kilometers) of tunnels within the mine. The annual cost will be approximately $750,000.

The only indication of past contamination is permanent oxidized manganese and iron stains, which give the rocks along the river's edge a rusty brown "bathtub ring". The results of the annual biological assessment of the Eagle Mine site show dramatic improvements in the Eagle River aquatic community such as higher numbers of fish and macroinvertebrates.

Chapter 7

Expert Error and the Psychology of Risk and Stigma

7.1 Expert Error

Gayer, Hamilton and Viscusi (2000) argue that residents living near Superfund sites judge risks to be of a magnitude consistent with EPA expert opinions and that these judgments are reflected in property values. The research presented here suggests quite the opposite. However, the sites studied here are much larger and likely to attract more attention. This section documents many cases of expert error to help explain why expert opinion plays a limited role in explaining residents' risk beliefs. Thus, the judgments of experts are only one component of the mix of news media stories and perceptual cues received by the typical citizen. Even if statements by scientific experts were accepted as credible, they would compete with a mix of the other signals and perceptual cues. As simply one component, such statements are unlikely to be the primary determinant of individual risk beliefs. Thus, risk beliefs determined largely by media stories and other perceptual cues are unlikely to be easily changed by the pronouncements of a few scientists (Fischhoff, 1989).

Furthermore, it is unlikely that statements by scientific experts will be accepted as completely credible. Even when different experts are in essential agreement, the news media often focuses on those aspects where experts disagree (Wilkins and Patterson, 1990), thus lowering the perceived credibility of experts. In a study examining news coverage of Three Mile Island and Chernobyl, Rubin (1987) found that news stories tended to dichotomize events rather than blend a continuum of information to recipients. The result is that the public discredits information it receives from experts because it appears that experts cannot agree among themselves and, therefore, do not really know the risk that a site presents.

Despite the ideal that science discovers absolute truths, for every health or environment related article there appears to be a corresponding article that rejects the tenets of the previously publicized claim. Numerous famous examples exist, which are described in detail below, where experts from academia, government, and industry have made errors and misestimates:

- Soil contamination at Love Canal, Niagara, New York

- Dioxin contamination in Times Beach, Missouri
- The defective Dalkon Shield for birth control
- The false discovery of Cold Fusion
- The failures at Biosphere 2
- The near nuclear meltdown at Three Mile Island
- The Union Carbide Accident in Bhopal, India

These examples are not just relegated to the past, as the costly search for weapons of mass destruction in Iraq, to date, has yet to support early claims by intelligence experts. Each of the short descriptions below serves to illustrate the characteristics and media attention that such failures attract.

7.1.1 Love Canal, Niagara, New York

Love Canal is permanently etched in the collective conscious of America, and these words were synonymous with hazardous waste contamination, cancer, and distrust of authorities. Love Canal brought about a new understanding of the potential health effects of hazardous waste as well as Superfund legislation designed to deal with chemical disposal sites.

Located in Niagara Falls, New York, Love Canal is named for William Love who began digging a canal in 1896 for a proposed hydroelectric power plant. Love abandoned the project when he declared bankruptcy, and in 1920 the city of Niagara Falls purchased the site for use as a landfill. In 1942 Hooker Chemicals and Plastics Corporation (now Occidental Chemical Corporation) purchased the landfill for their own disposal purposes. From 1942 to 1953, Hooker dumped into Love Canal 21,800 tons of toxic waste including more than 400 different chemicals, 11 known carcinogens, PCBs, dioxins, pesticides such as DDT and lindane (both of which have been banned in the United States), heavy metals, and multiple solvents. Three years after Hooker's dumping began, an internal memo from an engineer foreshadowed the disaster to come, "[Love Canal is a] quagmire which will be a potential source of lawsuits."

Once the site reached capacity, Hooker covered the 16-acre toxic waste site with a 40-acre clay seal to prevent chemical seepage. (A 1981 EPA report confirmed that Hooker's waste disposal techniques required only minor adjustments to come into compliance with the hazardous waste disposal standards in place at the time.) Under threats of acquisition by eminent domain and extreme pressure from the city school board, Hooker reluctantly sold the site to the New York State Department of Education for $1.00, on the condition that Hooker would be indemnified from any future liability concerning the site. Because of the potential dangers associated with the site, Hooker insisted that deed restrictions accompany the property transfer and repeatedly warned the school board of potential health hazards at the site. Hooker also stressed that under no circumstances should the land be excavated or the clay cap be jeopardized. Despite these warnings, the city constructed a school on site and sold the remaining parcels of land to real estate developers. The community of Love Canal was born.

Love Canal residents first began complaining of chemical odors and residues in the 1960s. By 1976 chemical seepage had infiltrated neighborhood creeks, sewer lines, sump pumps, and soil – even the air inside several Love Canal homes. That year, the New York Department of Environmental Conservation initiated the first environmental testing of Love Canal which found contaminated groundwater, soil, and air. Once the results of that research were released, local and national media responded quickly: "Vapors from Love Canal Pose Serious Threats" (*Courier Express Niagara*, May 15, 1978), "Toxic Exposure at Love Canal Called Chronic" (*Courier Express Niagara*, May 25, 1978), "Wider Range of Illnesses Expected" (*Courier Express Niagara*, August 4, 1978), "Upstate Waste Site May Endanger Lives" (*New York Times*, August 2, 1978), and "The Devil's Brew in Love Canal" (*Fortune*, November 19, 1979). Heightened alarm among community members and media attention prompted the New York State Department of Health to test Love Canal homes close to the disposal site for environmental contamination. Two years later, the State Department of Health declared a state of emergency, ordered the school to be closed, and recommended an evacuation of the 239 homes that tested positive for environmental contamination. This news spread rampantly throughout the community causing a widespread panic and loss of property values of homes adjacent to and outside the immediate canal area. Fearing for their health, the lives of their children, and their futures, the remaining 660 families pressured both New York State Governor Hugh Carey and President Jimmy Carter to expand the evacuation area.

One year later, in February 1979, Dr. Beverly Paigen, a biologist with Roswell Park Memorial Institute in Buffalo, conducted a study which revealed that between 1974 and 1978:

56% of the children born at Love Canal had birth defects; miscarriages had increased 300%; urinary tract disorders had increased 300%; and the frequency of asthma, epilepsy, suicide, and hyperactivty had increased. Dr. Paigen also claimed to have evidence that these conditions subsided once residents moved away from Love Canal. These findings fueled the Love Canal panic, even though Dr. Paigen's research was not a scientific controlled study but, instead, based on anecdotal evidence from personal interviews with Love Canal residents. Dr. Paigen's research was thoroughly discredited at that time by the NY Department of Health. A governor's panel charged with reviewing her work found that, "[Dr. Paigen's research] falls short of the mark as an exercise of epidemiology. She [Dr. Paigen] believes fervently that her observations prove the existence of multiple disease states directly attributable to chemical pollution, but her data cannot be taken as scientific evidence for her conclusions. The study is based largely on anecdotal information provided by questionnaires submitted to a narrowly selected group of residents. There are no adequate control groups, the illnesses cited as caused by chemical pollution were not medically validated…. This panel finds the Paigen report literally impossible to interpret. It cannot be taken seriously as a piece of sound epidemiological research…."

However, two studies conducted in 1980 by the EPA initially seemed to confirm portions of Dr. Paigen's research and found chromosomal irregularities and nerve damage among Love Canal residents. Upon release of these findings, chaos broke loose at Love Canal and two EPA officials were involuntarily detained. That evening, Lois Gibbs, a member of the Love Canal Homeowners Association, phoned the White House to inform them of their hostages. Pressured by the unfavorable findings of the research and extreme political pressure from local residents, the President issued orders on May 20, 1980, to permanently relocate all families that wished to leave. In total, approximately 950 families (2,500 residents) evacuated the area, leaving the government with $3-5 million in relocation costs. These relocations eventually became permanent costing the government over $30 million.

The integrity of the two 1980 EPA reports as well as the validity of their findings have since been questioned by the Center for Disease Control (*Morbidity and Mortality Weekly*, May 1983), American Medical Association (March 1984), National Research Council, and New York State Department of Health on the basis of the lack of control group (adjusted for by comparing Love Canal results with a control group from a previous unpublished experiment), incorrect statistical analysis, small sample sizes, inadequate experimental methodology, report release prior to peer review, and drawing conclusions that in some cases were not supported by the evidence. For example, the chromosome study actually found a lower rate of chromosomal damage among Love Canal residents than the control group. According to a 1981 *New York Times* article, “it may well turn out that the public has suffered less from the chemicals [at Love Canal] than from the hysteria generated by flimsy research irresponsibly handled.”

Research conducted in 1982 by EPA found no unusually high levels of contamination outside the area immediately surrounding the canal, confirming the results of several previously conducted reports. This EPA report was considered to be highly controversial and was eventually dismissed. (However, another EPA study conducted in 1987 confirmed the results of the 1982 study.)

Despite the lack of evidence to support such an action, Love Canal was declared a national Superfund priority on September 1, 1983. Federal and state remediation activities were expensive and highly intrusive. Fences were erected around the site and bulldozers demolished the abandoned homes and school within. Leachate treatment plants, high temperature incineration, excavation and off-site disposal of contaminants and hydraulic cleaning of sewers and culverts removed wastes and hazardous toxins from the site. Although twenty thousand tons of waste currently remains at the site, the area was declared “habitable” in September 1988. Initial redevelopment of the site was difficult because local banks were hesitant to grant home mortgages for fear of being held liable for environmental contamination. Although the value of the homes was approximately 20% lower than comparable markets, 239 of the 240 homes in the Love Canal neighborhood, now called Black Creek Village, have been successfully rehabilitated and sold. Approximately 30% of the purchasers are original Love Canal residents.

In 1991, the Committee on Environmental Epidemiology of the National Research Council thoroughly reviewed all Love Canal research and reports and concluded that there was no definitive link between the health conditions of Love Canal residents and the chemical seepage from the canal, with the possible exception of decreased birth weights and heights. Legal settlements are starting to be resolved as well. In 1998, 2,300 Love Canal families received between payments ranging from $83 to $400,000 from Occidental Chemical Corporation.

Two quotes will serve to summarize public reaction to the site that eventually led to the Superfund program:

> *"Love Canal doesn't end with this generation's cancer or even with the next generation's birth defects. For many residents, the damage is permanent in their genes and their children's. The mutated genes will affect all of their descendents, one generation after another."*
> Lois Gibbs, (executive director of the Center for Health, Environment and Justice and former Love Canal resident) *Who's Poisoning America*, p. 270.

> "It is not enough for industry and government to act in good faith – their mistakes are counted in human lives."
> *Glamour*, November 1980

7.1.2 Times Beach, Missouri

All that remains of Times Beach, Missouri, a small community once located 17 miles west of St. Louis, is a legacy of an environmental disaster. In 1972 and 1973, the city of Times Beach hired Russell Bliss to manage air-borne dust from its unpaved roads. During that time, Northeastern Pharmaceutical and Chemical Corporation also hired Bliss to dispose of their wastes, including dioxin yielded from the production of a then popular skin cleanser called hexachlorophene. In an attempt to complete both tasks efficiently, Bliss mixed Northeastern Pharmaceutical and Chemical Corporation's wastes with oil and sprayed the mixture on Times Beach roads. Days later animals started dying, and months later children got sick. After Bliss sprayed Shenandoah Stables' roads, several horses died and the proprietor's daughter became very ill. In November 1982, the EPA found Bliss' oil mixture to be contaminated with dioxin, a known human carcinogen. Dioxin is an unintentional hazardous byproduct of many common industrial processes such as the bleaching of paper and wood pulp; production of herbicides and wood preservatives; and incomplete combustion of wood and industrial and municipal wastes. One month later, the nearby Meramee River flooded. As the water receded, experts predicted that it would redistribute dioxin throughout the city. Consequently, not only would Times Beach roads be contaminated, but the entire Times Beach community might also be laden with dioxin contamination.

During this time, several studies emerged supporting the highly carcinogenic nature and potential dangers associated with dioxin. Based on this research, in 1982, the Centers for Disease Control and other experts recommended completely evacuating Times Beach. On March 4, 1983, Times Beach was proposed for Superfund's NPL. The town was officially closed in April 1985 and six months later, on September 8, 1983, Times Beach was placed on the final NPL. By the end of 1986, the federal government had spent $33 million to permanently relocate all 2,240 Times Beach residents. The title to the town was conveyed to the State of Missouri, and any remaining parcels of land were purchased by the Federal Emergency Management Agency (FEMA). As part of the remediation of the site, almost all buildings in the city were demolished and the entire area was enclosed by a chain-link fence.

Doubtful of the severity of the adverse health impacts associated with dioxin (such as cancer and infertility), as well as the proposed pathways of human exposure, many scientists and experts characterized the Times Beach relocation as an over reaction. An article in the *Wall Street Journal* written the week of the evacuation supported this sentiment, "There are two dangers with toxic wastes. One is the very real threat to health posed by the chemicals themselves. The second is that a hysterical exaggeration of that threat will needlessly frighten people and drive them from their homes." Considering the best available research at that time, the Times Beach evacuation was indeed an over-reaction because it was based primarily on the analysis of soil samples, rather than the potential human health risks and exposure pathways of dioxin.

In 1991, several scientific experts, including Dr. Vernon Houk of the Centers for Disease Control, reversed their initial conclusions about the toxicity of dioxin and their recommendations to evacuate Times Beach. This reversal was based on new research, which wholly contradicted previous conclusions about dioxin. The new research found dioxin to be less harmful to human health than originally suspected, making the Times Beach evacuation seem that overly drastic and unwarranted. As Houk stated, "Times Beach was an over-reaction. It was based on the best available scientific information we had at the time. It turns out that we were in error…. The only thing I would have done differently, I would have said we may be wrong. If we're going to be wrong, we'll be in the wrong side of protecting human health. I don't think we ever said we may be wrong."

Upon learning of the new research, industry representatives complained vociferously about the over-regulation of dioxin and the exorbitant costs associated with its stringent regulation. Prompted by these complaints and under the direction of William Reilly, the EPA Administrator under President Bush, Sr., the EPA undertook an extensive series of highly technical experiments on the toxicity of dioxin. Three years later, to the surprise and dismay of industry representatives, these experiments reaffirmed the link between dioxin and cancer even at very low levels of exposure. These experiments also revealed that dioxin bioaccumulates in living tissue and can cause stunted fetal development, suppression of the immune system, interference with regulatory hormones, and increased likelihood of developing endometriosis and diabetes. However, like the second round of dioxin research, this research also revealed that the major pathway of dioxin exposure is not environmental but through the ingestion of dairy foods which contain small amounts of the compound.

Armed with this new knowledge, the EPA devised a plan for the remediation of Times Beach contamination that included the construction of an on-site thermal destruction plant. Incineration of the dioxin-contaminated soil began in March 1996. Community action groups, such as the Times Beach Action Group and Dioxin Incinerator Response Group, strongly opposed this incinerator fearing that burning the dioxin might spread contamination rather than reduce it. Research studies conducted on a Jacksonville, Arkansas incinerator -- similar to the one constructed at Times Beach -- confirmed these fears: blood levels of dioxin among residents living near the Arkansas incinerator were 22 times higher than before incineration began. The Arkansas studies further concluded that these elevated levels of dioxin caused increased incidences of diabetes among residents living near the incineration plant. In 1993, Missouri state officials confirmed that the Times Beach incinerator was also producing more dioxin than it was destroying, and the EPA disbanded the plant in 1997. Remediation of the site cost $200 million and was completed in 1997 with the closing of the incineration plant. The property, now a 40-acre state park was named Route 66.

Although more than two decades have passed since the Times Beach evacuation, many former residents still speculate about the true effects of dioxin on their families and friends. One Times Beach resident recalls several now-dead community members that suffered from cancer, immune deficiencies, miscarriages, and suicides. She laments, "I'm so tired of death. There's not a day [that] goes by that I don't wonder if all this is coincidence – or dioxin."

7.1.3 The Defective Dalkon Shield

In the 1960s, many women became concerned about the possible adverse health effects, such as cancer and strokes, associated with oral contraceptives and began seeking alternatives. In response, several pharmaceutical companies invested heavily in the development of intrauterine devices (IUDs) as a potentially substitute for birth control pills. A.H. Robins (Robins) decided to enter the IUD market in 1970 by acquiring Dalkon Corporation, a manufacturer of the Dalkon Shield. Robins had no experience in the development of contraceptive devices and was best known for its non-prescriptive remedies such as flea and tick collars and cough medicine. Because Robins had neither obstetricians nor gynecologists on its staff (nor an appropriate department at that time), it assigned the production and assembly of its IUD, the Dalkon Shield (Shield), to its Chap Stick division.

Other than one research study conducted by Dr. Hugh Davis, a co-inventor of the Shield, Robins had conducted no testing of the Shield in women or animals when it entered the market in 1971. Yet A.H. Robins positioned the Dalkon Shield as the "Cadillac of contraceptives" and "the truly superior modern contraceptive". Dr. Davis' research boasted, among other things, that the Shield was five times safer than other IUDs. After its release in January 1971, the popularity of the Shield blossomed as a total of 4.5 million Dalkon Shields were sold to women worldwide by 1975. However, as early as the summer of 1972, Robins began receiving reports of the Shield's ineffectiveness in preventing pregnancy as well an increased incidence of pelvic infection among its users. In 1974, Robins was ordered to stop producing the Dalkon Shield and required to recall the product. By the time most Dalkon Shields had been removed, reports documented a total of 15 premature Shield-related deaths and an estimated 90,000 Shield-related injuries including sterility, pelvic inflammatory disease (PID), septic abortions, hemorrhaging, perforated uteri, and birth defects in children.

Even though the shortcomings of the Dalkon Shield were well known to A.H. Robins, the company continued to produce and distribute its product. Evidence contrary to the purported comfort, effectiveness, and safety of the Shield was suppressed. For example, research conducted by Dr. Davis claimed the Shield's failure rate in preventing pregnancy was 1.1%. Davis did not reveal, however, that participants in his study used a backup method of birth control for three months after the Shield was inserted. An independent researcher later found the Shield's failure rate to be 3-5%, making it inferior to other IUDs and the pill in preventing pregnancy. Robins was also forewarned in several memos and conversations of the Shield's tendency to cause infection. R.W. Nickless, management coordinator for pharmaceutical products, wrote a memo to 39 officials at Robins on June 29, 1970, detailing the Shield's propensity for wicking and infection. A July 28, 1971 memo written by Wayne Crowder, a quality control supervisor in Robins' Chap Stick Department, reinforced these findings as well as the need to address the issue immediately. Crowder's memo was ignored and his position later eliminated. Evidence presented by Crowder was confirmed several months later by Irwin Lerner, the inventor of the Dalkon Shield, in an October 11, 1971, conversation with Kenneth Moore, Shield project coordinator. In 1972, Dr. Thad Earl, an investor in Dalkon Corporation prior to its acquisition by Robins, also sent Robins a memo in 1972 warning that women who became pregnant while using the Shield needed to have it removed immediately to prevent infection. However, Robins warned neither physicians nor Shield users of the dangers associated with the Shield for another three years, despite being alerted to the potentially dire consequences of its use.

The Centers for Disease Control (CDC) substantiated the results and warnings contained in previous memos, correspondence, and conversations. Its study conducted from 1976 to 1978 found that, depending on the length of use, the risk of developing PID among Shield users was five to ten times higher than for non-Shield IUD users. Two studies conducted in 1985 in Boston and Seattle yielded similar results.

Researchers found the defective component of the Shield to be the unique design of the string, or "tail", which facilitates the removal of IUDs. Previously, a single piece of nylon formed the tails of IUDs. But the tail of the Shield was comprised of many strands of nylon encased in a nylon sheath to prevent the spread of bacteria. But the nylon sheath was left open at both ends of the Shield, allowing bacteria to spread up, or "wick" into, the tail into the uterus.

Although Robins had been warned of this wicking tendency numerous times, it was reluctant to withdraw the Shield from the market because it generated profit margins of 40% in the United States and 70% internationally.

In 1974, Dr. Howard Tatum, an independent researcher, testified before Congress about the relationship between Dalkon Shields and PID. Based on this testimony, FDA officials pressured Robins into halting production of the product. Robins stopped distributing the Shield in the United States in June 1974, but continued to market the Shield abroad for another 10 months. Finally, in April 1975, Robins stopped international distribution of the Shield. By the time distribution of the Shield ceased, it had been used by 2.8 million American women and another 1.7 million women worldwide. Fearing legal repercussions, however, Robins refused to recall Shields already in use for several more years. In 1983, when FDA officials suspected that most Shields had already been removed, Robins publicly recalled the Shield and offered to pay for the removal of any still in use. Over 4,000 women accepted this offer within the first two months of the announcement.

By 1984, more than 10,000 claims for Shield-related injuries had been filed against Robins. According to U.S. District Court Judge Miles Lord, who presided over 21 Shield court cases, “The only conceivable reasons you [Robins] have not recalled this product are that it would hurt your balance sheet and alert women who have already been harmed that you may be liable for their injuries. You [E. Claiborne Robins Jr. (President and CEO), William Forest (General Counsel), and Dr. Carl Lunsford (Director of Research)] have taken the bottom line as your guiding beacon and the low road as your route.” Robins’ former general attorney, Roger Tuttle, echoed this sentiment, “Robins entered a therapeutic area with no prior experience, no trained personnel, and reliance on statistics from an admittedly biased source. Although the device was based on sound scientific principles, Robins over-promoted it without sufficient clinical testing in an effort to ride the crest of a marketing wave for financial gain.”

Largely as a result of litigation over the Dalkon Shield, A.H. Robins filed for Chapter 11 bankruptcy in 1985 and established a multi-million dollar trust for unresolved complaints three years later. Prior to the court trial regarding Robins’ negligence, 12 boxes of correspondence attributing PID in Dalkon Shield users to the wicking effects of the Shield’s tail disappeared, and Aetna Life Insurance canceled its contract with Robins.

In 1989, American Home Products purchased A.H. Robins. As of July 1992, 115,000 of the 137,000 claims that have been finalized have received a settlement of $1,000 or less from the trust. Since the problems with Dalkon Shield, product labeling and package inserts for all IUDs include extensive and comprehensive information regarding user profiles and potential side-effects.

7.1.4 The Discovery of Cold Fusion

Imagine a world of equitable nations where resource-poor countries no longer struggle to survive on dwindling natural resources; where industrialized countries are not tethered to the vast oil riches of the Middle East; where energy consumption does not necessarily mean environmental degradation. This is the world promised by cold fusion, the remarkable discovery of two highly respected University of Utah chemists.

Prior to this discovery, scientists, physicists, and chemists around the world had deemed cold fusion impossible because the fusion of two atoms required extreme heat temperatures and expensive heavy metals such as uranium. In March 1989, Stanley Pons and Martin Fleischmann held a press conference claiming to have had detected bursts of excess heat and the appearance of neutrons that exceeded background levels in their cold fusion experiments. This unprecedented discovery astounded the world and promised the world great amounts of energy generated simply and inexpensively. Cold fusion meant an abundance of energy and the end of all potential future energy crises.

The day of their announcement, Pons and Fleischmann intimated that their results could be easily replicated and scaled up for a nuclear reactor, despite the fact that their experiments substantiated neither claim. A worldwide flurry of media articles, accusations, press conferences, confirmations, and objections ensued as governmental agencies, scientists, and industrial representatives raced to replicate the results of Pons's and Fleischmann' experiments.

Many experts remained skeptical of cold fusion, because of the inability to replicate their results. The few experts who claimed to successfully repeat Pons's and Fleischmann's experiments later retracted their results. As was later determined, neuron detectors, used by Pons and Fleischmann, are very inaccurate and often detect "neutrons" that are actually small variances in temperature, humidity, or electric power surges. In the end, Pons's and

Fleischmann's results were rejected because they not only lied about the amount of energy produced in their experiments, but they also failed to conduct control experiments to establish accurate baseline data.

Despite the credibility of the scientists who announced cold fusion, the integrity of the institutions that supported them, and the scientific fervor that surrounded the incidence, cold fusion's skeptics prevailed, and Pons's and Fleischmann's experiments are now largely recognized as a scientific hoax. According to one CalTech researcher, "[Cold fusion] has been cast out by the scientific establishment. Between cold fusion and respectable science there is [now] virtually no communication at all."

7.1.5 The Failure of Biosphere 2

On September 26, 1991, eight "biospherians" entered the world's first self-contained, human-constructed, completely independent ecosystem. A massive media blitz highlighted the lofty goals of this experiment, to test the ability of humans to construct and survive independently in a self-contained environment that would provide everything necessary to sustain life. The construction of Biosphere 2 took six years and cost $200 million. It contained five distinct ecosystems (rain forest, ocean and coral reef, fog desert, marsh, and grasslands) and 3,800 different species of animals. Scientists and engineers designed the structure to replicate as closely as possible the metabolic and biologic functions of the first biosphere, earth. Once they entered, the biospherians would remain inside the three-acre Biosphere 2 for two years, growing and harvesting their own food, managing their own wastewater systems, monitoring ecological systems, etc. According to the project goals, any contact whatsoever with the outside world, be it importing food or allowing air to escape into the Earth's atmosphere, would completely destroy the experiment. Only in the event of a medical emergency would the biospherians be allowed to leave Biosphere 2.

Discover heralded Biosphere 2 as "the most exciting scientific project to be undertaken in the United States since President Kennedy launched us toward the moon." The *New York Times* and the *Boston Globe* followed *Discover*'s enthusiastic lead. As they reported, hummingbirds pollinated the flowers within; a colony of termites aided the decomposition of vegetation; and bugs such as ladybugs, lacewings, and spiders minimized insect damage to Biosphere 2 crops.

No outside energy entered the structure. Energy was, instead, provided by an internal solar power plant. Sensors placed throughout the structure provided 24-hour monitoring of the balance within Biosphere 2, including the mixture of gasses in the air, emotional and mental stress of the biospherians, and aerobic rate of microbes in the soil. Lastly, Biosphere 2 was completely sealed off to prevent any atmospheric exchange between the earth and Biosphere 2.

The purposes of the experiment, as portrayed by the media, varied from developing the new science of “biospherics” to “develop[ing] the technology necessary to colonize other planets with biosphere structures” (*New Republic*). The public later learned that indeed Space Biosphere Ventures (SBV), the owner of Biosphere 2, intended to develop and sell this type of technology to NASA and the European Space Agency. SBV also had other intentions, to develop an extensive 2,500-acre theme park adjacent to Biosphere 2. As the knowledge of these plans became more common, it strained the credibility of the program among the public as well as many scientists nationwide.

Within weeks of the biospherians’ entrance, problems arose inside Biosphere 2. One biospherian, Jane Poynter, cut off the tip of her finger while using the thresher. She left Biosphere 2 to seek medical attention and returned two days later with a duffel bag purportedly containing fresh food and new sealant to patch Biosphere 2's air leaks. SBV denied these rumors for three months until they admitted that Poynter had indeed returned with a duffel bag containing items such as plastic bags, film, and computer parts. Two months later, Marc Cooper of the *Village Voice* confirmed and reported that SBV had installed a carbon dioxide scrubber in Biosphere 2 just before its closure. Later that month, SBV secretly injected Biopshere 2 with 600,000 cubic feet of outside air to relieve its falling atmospheric pressure. Upon learning of this injection, Biospherians Linda Leigh and Roy Walford threatened to leave Biopshere 2 unless a public announcement of the injection was made.

These incidents led SBV to hire a panel of scientists to review how Biosphere 2 science was being conducted. During this time, the amount of oxygen inside the structure was dropping from a normal 21% to 14%, approximately the amount of oxygen found at an altitude of 17,500 feet. SBV had no choice but to breach the structure’s seal once again and inject oxygen-enriched air into the Biosphere 2. Despite the recommendations of the science review panel, business remained as usual at Biosphere 2 and by the end of April 1993, all of the science panel review members had resigned. As the chair of the science review panel, Thomas Lovejoy of the Smithsonian Institution indicated, “The Biospherians will soldier on, but their two-year experiment in self-sufficiency is starting to look less like science and more like a $150 million stunt.” Two years after their entrance, the biospherians emerged from Biosphere 2 as planned, but were greeted with much less public and media enthusiasm. Fifteen to thirty percent of Biosphere 2 species had gone “locally extinct” while other populations exploded. Fruit trees had produced little to no fruit, and all seven species of frogs disappeared. Despite these problems and repeatedly breaking Biosphere 2’s atmospheric seal, SBV proclaimed Biosphere 2 a success.

Biosphere 2’s reputation and credibility never recovered from the deliberate public deceptions of its management and the media ridicule that followed. After remaining dormant for two years, Columbia University’s Lamont-Doherty Earth Observatory took over Biosphere 2 and is currently using it as a hands-on research and educational center.

7.1.6 The Three Mile Island Accident

Although it led to no immediate deaths to plant workers or citizens of nearby communities, the accident at Three Mile Island on March 28, 1979, was the most serious nuclear power plant accident in the history of the United States. Unbeknownst to the 140,000 residents of Harrisburg, Pennsylvania ten miles away, a combination of human and system errors caused the nuclear core of the Three Mile Island nuclear power plant to dangerously overheat and melt.

At about 4:00 a.m., primary water pumps at the plant shut down allowing the cooling waters circulating through the core of the plant to escape. The emergency backup water coolers failed because their flow valves had not been reopened after routine testing two days prior. Pressure immediately began to build in the main nuclear portion of the plant. A safety pressure release valve opened to relieve the pressure, but later failed to close causing the pressure of the system to fall below normal. This combination of decreasing pressure and delayed water cooling produced erroneous readings in the control room. In response to these faulty readings, plant operators shut off the cooling waters, and the temperature within the reactor core climbed above 4,300 degrees Fahrenheit, 900 degrees below the complete meltdown threshold. This extreme heat caused fuel to melt through the concrete containment floor of the reactor, and as a result, radiation leaked into other areas inside the plant as well as into the outside environment. There was great uncertainty about how to properly contain and minimize the exposure to radiation. However, predicting the next reaction of the core under such stress became a much greater concern. One possibility was that pressure within the core would continue to increase, causing an explosion of radioactive gas and debris. According to Walter Cronkite on CBS Evening News, “The world has never known a day quite like today. It faced the considerable uncertainties and dangers of the worst nuclear power plant accident of the atomic age. And the horror tonight is that it could get much worse.”

With these impacts and uncertainties in mind, all non-essential staff were evacuated by 11:00 a.m. that day. Over the next two days, efforts to halt toxic releases to the environment failed. Two days later on March 30, Pennsylvania Governor Thornburgh called for the evacuation of all preschool children and pregnant women within a five-mile radius of the plant and ordered everyone within a ten-mile radius of the plant to remain indoors with their windows closed. Unlike the April 1986 accident at Chernobyl, the nuclear power plant at Three Mile Island was fortunately encased in a protective dome that prevented the leakage of large amounts of radiation. Estimates of immediate exposure to radiation ranged from one millirem of radiation to 100 millirems of radiation per person. (A standard x-ray exposes an individual to approximately six millirems.) Phone calls to the Governor’s Three Mile Island hot-line reported dramatic effects related to radiation exposure, including stillborn and deformed pets and livestock, unexplainable livestock deaths, radiation poisoning, and mutated vegetation. Two dentists eight miles northwest of Three Mile Island also found that all dental x-rays of their patients’ teeth taken within two days of the Three Mile Island accident were fogged or banded. After the Three Mile Island accident, residents also found dandelion and maple tree mutations comparable to what was later found in Germany after the Chernobyl accident.

The health affects of the Three Mile Island accident were greatly disputed. After the accident, several hundred people in the area reported hair loss, eye irritations, skin rashes, headaches, menstrual irregularities, blistered noses and lips, nausea, vomiting, and a number of livestock and pet deaths. However, initial studies of the area conducted by the U.S. Nuclear Regulatory Commission (NRC); U.S. EPA; U.S. Department of Health, Education and Welfare (now Health and Human Services); National Cancer Institute; Pennsylvania Department of Energy; and State of Pennsylvania revealed the presence of “very little off-site releases of radioactivity." These reports further stated that "comprehensive investigations and assessments by several well-respected organizations [conclude] that in spite of serious damage to the reactor, most of the radiation was contained and that the actual release had negligible effects on the physical health of individuals and the environment". In fact, according to one report, "residents within 20 miles downwind of the plant had fewer cancer deaths than expected during the five-year period." The report of the President's Commission on the accident at Three Mile Island found the only adverse health effect of the Three Mile Island accident to be psychological. A 1990 study conducted by the Division of Epidemiology at Columbia University confirmed that there were no significant adverse health impacts resulting from the Three Mile Island accident.

Finally, Dr. Steve Wing, associate professor of epidemiology at the University of North Carolina, School of Public Health, led a ten-year study (1975-1985) of residents within ten miles of Three Mile Island. His study found two to ten times more lung cancer and leukemia among residents downwind of the plant than among those upwind. Dr. Wing also reanalyzed data from the 1990 Columbia University study that concluded no significant increase in cancer due to the Three Mile Island accident. According to Dr. Wing's analysis of the data and adjustment for pre-accident cases of cancer, the 1990 Columbia University study *does* reveal "a striking increase in cancers downwind from Three Mile Island." Dr. Wing further stated, "The cancer findings, along with studies of animal, plant, and chromosomal damage in the Three Mile Island area residents, all point to much higher radiation levels than were previously reported. If you say that there was not high radiation, then you are left with higher cancer rates downwind of the plume than are otherwise unexplainable."

The cleanup of the nuclear power plant took nearly twelve years and cost approximately $973 million. As a result of the incident at Three Mile Island, the U.S. Nuclear Regulatory Commission significantly tightened its regulatory standards and oversight of nuclear power plants. Yet, the public still perceives that nuclear power poses a significant threat to public safety. This distrust of nuclear power and scientific estimates is not unwarranted. According to the Reactor Safety Study conducted in 1975 by Professor Norman Rasmussen of the Massachusetts Institute of Technology with the financial support of the NRC, the probability of any nuclear power plant accident happening was .000001 accidents per 1,000 reactor years.[5] However, five years after the Three Mile Island accident, another NRC-sponsored study increased this likelihood of a nuclear power plant accident to 1.7 to 4.5 accidents per 1,000 reactor years.

No new nuclear reactors have been built since the accident at Three Mile Island. Recently, however, as of 2004, two groups of companies have formed with the intentions of applying for licenses to build new nuclear power plants. Though neither group actually has plans yet to build the power plant, they intend to work with the U.S. Department of Energy to obtain a license for an advanced nuclear power reactor.

7.1.7 Union Carbide Accident in Bhopal, India

At approximately 1:00 a.m. on December 3, 1984, hundreds of residents of Bhopal, India, sought medical attention for persistent coughing, extreme difficulty breathing, fever, eye tearing, vomiting, difficulty keeping their eyes open, and brief spells of blindness. Because of the number of complaints and the symptoms described, doctors at Hamidia Hospital immediately suspected the release of toxic chemicals from the nearby pesticide-producing Union Carbide plant. When questioned, the Chief Medical Officer for Union Carbide, Dr. L.D. Loya, admitted to an accidental gas emission of methyl isocyanate (MIC) the night before. Dr. Loya, however, denied that MIC was toxic and poisonous even though Union Carbide's plant manual clearly stated that "MIC is a poison to human beings by inhalation, swallowing, and skin contact." Dr. Loya explained that any temporary side effects experienced, such as agitated eyes and strained breathing, would soon subside. Over the course of the next weeks and months, Union Carbide maintained this position and claimed that MIC was "nothing more than a potent tear gas." They refused to divulge any information regarding the composition or toxicity of the gas. Likewise, Medical research conducted by the Indian Government regarding the Union Carbide-MIC accident was also immediately classified as confidential by the government under the Official Secrets Act. The effects of this "non-poisonous" gas, however, included approximately 3,800

[5] Reactor years are the cumulative number of years in which ALL nuclear power plants have been operational. For example, two nuclear power plants operating a total of two years each yields four reactor years.

immediate deaths and the hospitalization of 200,000 more people. One thousand animals were also killed by the accident and another 6,000 harmed.

Studies conducted by the Indian Council of Medical Research (ICMR) revealed that 40,000 new cases of asthma were reported three months after the accident. Five years after the accident victims continued to display chronic deterioration of the lungs, gastrointestinal disorders, partial and complete blindness, impaired immune systems, neurological disorders, menstrual irregularities, reproductive disorders (including stillbirths and deformities), and post traumatic stress symptoms. Additional ICMR studies also found: three times more people suffered from MIC-related respiratory disorders in 1991 than in 1987; a three-fold increase in pulmonary tuberculosis and cataracts among those exposed to MIC (as compared to an unexposed control group of Bhopal residents); a 300% increase over the national average for spontaneous abortions; delayed motor and language skills among children conceived or born after the accident; and the likelihood of permanent damage given the 10-year persistence of symptoms. The International Medical Commission of Bhopal, comprised of 14 medical specialists from 11 different countries, confirmed these findings in January 1994, and additionally reported lung impairment, loss of limb control, neurotoxic injuries, reduced memory, and 10-15 related deaths per month among those exposed to MIC.

Union Carbide's accidental 40-ton release of MIC is attributable to human and design errors as well as to a history of unsafe operations. Inadequate systems and unsafe operations are not unique to the Union Carbide plant in Bhopal. In 1981, Union Carbide was fined $50,000 for spilling 25,000 gallons of a cancer-causing chemical into the Kanawha River in West Virginia. That year, 402 Union Carbide Eveready workers in Indonesia developed kidney disease from exposure to mercury. Between 1980 and 1984, the EPA detected 61 MIC leaks in the West Virginia Union Carbide plant. According to the International Confederation of Free Trade Union, "[B]roken gauges made it hard for the MIC operators to understand what was happening. In particular, the pressure indicator/control, the temperature indicator, and the pressure level indicator for the MIC storage tanks had been malfunctioning for more than a year." Bhopal operators considered this to be the status quo, "[having broken gauges] was not unusual at the factory" (*New York Times*, January 30, 1985). The consequences of this negligence culminated on December 2, 1984. That night 1,000 to 2,000 gallons of water leaked into an MIC storage tank causing a highly exothermic reaction and the formation of a high-pressure MIC gas bubble. This increase in pressure went undetected by plant operators. Apparently, the MIC pressure value gauge was giving abnormally low-pressure readings (i.e. 2 psi instead of 20 psi) prior to the accident. Two hours before the accident, the gauge indicated an increase in pressure from 3 psi to 10 psi, but plant operators decided that, like many others in the plant, the gauge was faulty.

Thirty minutes after the MIC reaction began, operators suspected a gaseous leak not because of the plant's monitoring systems, but because their eyes began to tear. Unable to see or breath, operators immediately abandoned their control panels. The refrigeration capacity of the MIC storage tank had been turned off to conserve electricity, and all of the plant's backup safety systems failed or were delayed allowing a massive amount of the gas to escape the plant. Although a safety alarm sounded an hour after the spill, most of the damage had already been done. Before residents could escape, MIC gas contaminated a 20 square kilometer area. People within two and a half kilometers of the plant sustained lethal injuries, and people within a four kilometer radius sustained severe injuries.

Union Carbide officials never notified local authorities of the toxicity of the chemicals they produced. Consequently, no evacuation or emergency medical procedures were in place, and no public knowledge of how to deal with the toxic gas cloud existed. Health officials estimate that hundreds of lives could have been saved had the public been instructed to breathe through a damp cloth. The catastrophe might also have been avoided if Union Carbide had: 1) heeded the safety warnings issued after the death of one plant worker in December 1981, the injury of 28 workers in January 1982, or the October 1982 spill of MIC, hydrochloric acid, and chloroform and/or 2) repaired the "61 hazards, 30 of them major and 11 in the dangerous phosgene/MIC units" as reported in a May 1982 safety audit. This outright negligence on the behalf of Union Carbide affected almost a third of all people living in Bhopal at the time. To date, approximately 20,000 people have died from MIC exposure.

Victims of the Union Carbide accident filed a $3 billion lawsuit against the corporation, but Union Carbide adamantly denied liability blaming a fictitious disgruntled worker for the accident. The Central Bureau of Investigation (CBI), with the help of plant workers, developed a strong case supporting a connection between the MIC incident and negligent management. On December 7, 1984, Union Carbide's Bhopal CEO, Warren Anderson, and 11 other corporate officials were arrested for culpable homicide, grievous hurt, and death and poisoning of animals. Warren Anderson bailed himself out of jail for $2,000 (US) and has never returned to India.

In private, out-of-court deliberations and fearing the loss of other transnational corporations, the Indian government settled on a payment of $470 million for the survivors of the accident (an average payment of $940) as well as a full liability release for Union Carbide. In an attempt to create goodwill, Union Carbide agreed to set up the Bhopal Hospital Trust, a hospital to treat the victims of the 1984 accident. Today, Union Carbide's plant in Bhopal no longer operates, but the site remains, never cleaned up and still potentially releases dangerous chemicals into the environment. The Indian government has not been able to extradite Warren Anderson, and in 2002 the Indian government was prevented by Indian courts from reducing the charges against Union Carbide officials in an attempt to speed extradition from the United States.

7.2 Contradictory Information in the News

As the examples presented above show, news about human and environmental health is omnipresent, yet much of this information is contradictory. Nearly everyday, newspapers, magazines, and television shows report new information that tends to further obscure issues rather than clarify them. A cursory survey of two major national newspapers conducted between September 1, 1999, and November 1, 1999, yielded several articles that contested previously reported claims or presented evidence of scientific or expert misjudgment and error. These articles reported the following:

- "Studies Bolster Link between Diet Drugs, Heart-Valve Leaks." Contrary to the previous claims of the manufacturer, the diet drugs Redux and fen-phen can cause permanent heart damage (*Wall Street Journal*, September 10, 1999).
- "Questions for Drug Maker on Honesty of Test Results: FBI Asks About Diet Product's Approval." A drug manufacturer did not report to the Federal Drug Administration all relevant test results prior to petitioning for approval of a drug (*New York Times*, September 10, 1999).
- "Tobacco Industry Accused of Fraud Lawsuit by U.S." For more than forty years, the tobacco industry suppressed evidence that tobacco use causes cancer (*New York Times*, September 23, 1999).

- "Japanese Fuel Plant Spews Radiation after Accident." Trained operators of a nuclear power plant in Japan poured more than six times the required amount of uranium into a tank, resulting in a nuclear chain reaction (*New York Times*, October 1, 1999).
- "Two Teams, Two Measures Equaled One Lost Spacecraft." The Mars Orbiter burned in space because the spacecraft's creator used imperial measurements when the spacecraft's navigational team used metric measurements (*New York Times,* October 1, 1999).
- "Drug May Be Cause of Veterans' Illness: Pentagon Survey Links Gulf War Syndrome to Nerve-Gas Antidote." Persian Gulf War soldiers who were given a drug to protect them from nerve gas attacks suffer from damage to areas of the brain that control reflexes, movement, memory, and emotion (*New York Times*, October 19, 1999).
- "Testing in Nevada Desert is Tied to Cancers." Soldiers who participated in nuclear tests for the military in the 1950s have higher than normal death rates and an increased likelihood of developing leukemia and prostrate and nasal cancer (*New York Times*, October 26, 1999).

Due to this steady flow of events and news stories that present contradictory, inaccurate, or incomplete expert evidence, the public is unlikely to accept expert evidence as absolutely accurate all the time. The frequency of events, as well as the ambiguity and uncertainty of experts, government officials, and the media, as demonstrated by these short case studies, leads to doubt and skepticism on behalf of the public. The implication is that residents living near Superfund sites are forced to construct their own risk beliefs based on perceptual cues and media coverage. McClelland et al. (1990) surveyed residents near OII about their risk beliefs and found a bimodal response with more than half believing that living near the site was as dangerous as smoking more than one pack of cigarettes per day, with an incremental annual risk of death of approximately 1/100. Most of the remaining residents viewed the risk as trivial. Assuming typical values for statistical life and assuming three people per home, the discounted present value of the risk for the residents that assessed the risk as similar to smoking exceeds the price paid by these residents for their homes! Residents who responded this way did report that they were desperate to sell and sought immediate cleanup.

7.3 Events, Perceptual Cues, Risk Perception, and Stigma

Given the doubts that people will inevitably have with respect to the credibility of expert risk assessment, perceived risks will be based on personal and community judgments derived from other sources of information. Events that are associated with a Superfund site will lead to perceptual cues and media attention, that will most likely elevate perceived risk and stigmatize the site for reasons documented below. Some of the most important determinants of risk beliefs are perceptual cues. Perceptual cues are physical aspects of a site that are perceived by local residents, and are suggestive of risk. Examples of perceptual cues include odors emanating from landfills, unusual odors or flavors in well water, unusual soil or water coloration at the site, and a heavy volume of truck traffic going in and out of the site. Ironically, the actions taken by authorities to minimize public health and safety risks tend to exacerbate risk beliefs by providing clear cues that some risk is present. Erecting chain link fences, posting 24-hour guards, placing warning signs, conducting on-site tests (especially by workers wearing protective clothing) are all cues to residents that risk levels may be higher than they thought. Such actions, which may be necessary, almost never lower risk beliefs. Proximity to a site increases the frequency and duration of contact with, or observation of, perceptual cues, which contributes directly to the intensity of risk beliefs.

The effects of strong perceptual cues are well illustrated by the OII Landfill. Initially, concern about high volumes of truck traffic and odors (produced by decomposition in the landfill) prompted local residents to organize and confront problems associated with the site. McClelland et al. (1990) found a significant correlation between recognition of these perceptual cues and the high risk beliefs of many residents living near the site. Several of the perceptual cues were removed or reduced by (a) installing wells to extract the methane gas for commercial use and (b) closing the site, which eliminated most of the truck traffic. Even though these actions did not address risks that hazardous substances would migrate into local neighborhoods, the risk estimates of many residents dropped dramatically after the principal perceptual cues were removed. McClelland et al. also demonstrated that there were significant property value losses associated with these risk beliefs.

Attention given to a site in the media, apart from the actual content of news stories, is itself a perceptual cue that risks may be high. Many studies have shown that frequent exposure to media reports about a site increases the likelihood that residents will believe the site is very risky. The specific risk at a site and perhaps the site itself will usually be unfamiliar to residents. That in itself increases risk beliefs (Wilkins and Patterson, 1987). But more importantly, it means that residents are almost totally dependent on the news media for information about the risk. Reflecting the concerns of their consumers, the news media often focus on aspects that accentuate dread, such as the uncontrollability of the risk and the frightful worst outcome (e.g., dying of cancer), rather than on information about the low probabilities of the risk and how those probabilities compare to other risks that residents accept.

The signals that the media sends to the public regarding risks from hazardous waste sites are important, but the way in which the public interprets this information is equally important. A key feature of how news coverage is interpreted by residents is whether there is an easily identifiable "villain" responsible for the hazardous waste problems at the site. For example, if the responsible party is a corporation whose primary business activity is outside the community, then it is more easily portrayed as a villain than a local business which has strong affiliations to the community. Russell et al. (1991) found that the more important a site's PRPs were to the local economy, the more skeptical residents living near the site were that it needed to be cleaned up. Personal familiarity with a site also influences how news reports are interpreted. The greater the prior familiarity, the less risk beliefs are likely to be elevated by news stories.

The largest PRP for the OII Landfill was an outside corporation that had not provided significant employment or other economic benefits for the residents who lived nearby. Most of the waste, especially hazardous waste, was generated and brought to OII from outside the community. OII was primarily a commercial landfill serving many interests outside of the community. In short, conditions were ripe for news stories to elevate risk concerns significantly.

How a risk affects the community, society, and the economy will depend on individual and group perceptions of the risk (Slovic et al., 1991; Kunreuther and Slovic, 2001). There can be a compounding or "rippling" effect as more and more individuals respond to the risk (Kasperson et al., 1988). Or, as Dr. Paul Slovic describes it, interactions among individuals can produce a "social amplification of the original risk concern." The greater the population living near a site, the greater the potential for compounding or social amplification.

When residents or potential buyers are extraordinarily fearful of a site, they respond by shunning the site. This behavioral response has been labeled stigmatization and has been explored in a number of experiments that suggest that if risks are perceived as being excessive, people replace calculations of risk versus benefit with a simple heuristic of shunning, the avoidance of the stigmatized object.

Stigma has been shown to have a number of key properties. Laboratory experiments testing these properties have involved dipping a medically sterilized cockroach into glasses of juice and gauging subjects' willingness to drink the juice after the cockroach has been removed (Rozin, 2001). First, stigma shares many of the psychological characteristics of contagion, where contagion is associated with touch or physical contact. For example, while subjects refused to drink the juice if the sterilized cockroach was dipped into the glass, they would drink the juice if the cockroach was just placed near it. Second, stigma appears to be permanent. Subjects refused to drink the juice even if it had been in the freezer for one year. Third, stigma appeared to be insensitive to dose. Reductions in the duration of contact between juice and cockroach had little effect. Any contact was sufficient for subjects to shun the juice. Fourth, the source of contagion is usually unknown. Thus, while shunning may have evolved from an adaptive response to avoid contaminated food, it can be triggered in inappropriate circumstances. For example, subjects who saw sugar water placed in a clean empty jar and then saw a cyanide label placed on the jar still tended to refuse to drink the sugar water. Finally, subjects tend to medicalize the risk, arguing that the stigmatization was the result of a fear of health effects.

The possibility that Superfund sites might be stigmatized could have a major impact on the prospects for successful cleanup of contaminated sites. If such sites are permanently shunned because, like the "cockroached" juice, they are viewed as permanently stigmatized, property values may not recover immediately once cleanup is in progress (since future improvements should be capitalized into home values) or even when cleanup is completed.

Chapter 8

Property Value, Approach, and Data

8.1 Introduction

In this chapter, we undertake a comparison of hedonic property value models across four different Superfund sites: The Montclair, NJ, area radium sites, the OII landfill in the County of Los Angeles, CA, the Wells G&H and Industri-Plex sites in Woburn, MA, and the Eagle Mine site near Vail, CO. Our goal is to clarify whether the effects on property values of distance from a Superfund site vary over time in a manner that is related to the progress of remediation at that site. Distance is treated as a proxy for perceived risk. We control for area-wide variations in housing prices and we also use GIS techniques to measure distances to other local amenities or disamenities, which can confound the effects of proximity to the Superfund site. Some provocative results stem from our extensive efforts to control for variations in the socio-demographic characteristics of the surrounding neighborhood as measured by trends inferred from tract-level data from multiple decennial Censuses. Neighborhood change occurs and may be brought about in large part by the episode of "taint" precipitated by the identification and remediation of the Superfund site. These shifting socio-demographics can easily confound evidence about the rebound of property values that one would expect to observe following the cleanup of a Superfund site.

There is considerable public concern about how hazardous waste sites impact property values in their neighborhoods, both in the short run and in the long run. For a careful review of empirical studies that assess the negative effects on property values of locally undesirable land uses (LULUs) such as waste sites, hazardous manufacturing facilities, and electric utility plants, see Farber (1998). The typical implicit or explicit goal in this literature is to establish a monetary measure of the loss of welfare experienced by people who live near these sites. This monetary loss can be interpreted as the amount of money that would be required to compensate these individuals for this loss, or alternatively as a partial measure of the social benefits that would ensue from affecting a cleanup.

We examine distance and time patterns in property values in the vicinity of four different sites on the NPL for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or "Superfund") sites in four different states. These include sites in

- Woburn, MA (the Wells G & H site that was the subject of the book and motion picture, *A Civil Action*, and the nearby Industri-Plex site);
- Montclair, NJ (three large areas with radium contamination of the soil);
- Monterey Park, CA (the Operating Industries, Inc (OII) landfill site), also featuring some of the most dramatic demographic changes in Los Angeles County over the time period in question; and
- Vail, CO (the Eagle Mine site, upstream on the Eagle River from a sizeable fraction of housing along Interstate 70 west of Vail). Vail is notable as a winter resort area.

The key insights drawn from this work stem from our measurement of trends in both socio-demographic characteristics and housing stock characteristics at the neighborhood level. Taking advantage of the large data increment provided by the 2000 U.S. Census, we construct approximate time-series for the set of conformable Census-tract-level variables in order to span a 31 year time period, based on the 1970, 1980, 1990 and 2000 Censuses. We consider neighborhood change, both in terms of socio-demographics (ethnicity, age, and household composition) and the housing stock (owner- versus renter-occupancy and vacancy rates, as well as shifts over time and with distance from the Superfund site in the characteristics of homes in our large sample of transactions).

Our findings, borne out across several sites, suggest that endogenous neighborhood change can be precipitated by the identification and remediation of a Superfund site. While the objective or subjective risk associated with the site may initially account for decrements in housing prices around the site, these lower prices also make the neighborhoods more accessible to lower income groups, younger families, minorities, and non-traditional households. The increased presence of these groups can replace Superfund site risks as an explanation for systematically lower property values near the site over time, even after the site has been cleaned up.

A number of threads in the literature on hedonic property values must be acknowledged explicitly, since each has some bearing on the approach we take here.

8.1.1 Objective versus Subjective Risk

One body of work in this literature emphasizes the effects of objectively measured risk on property values. In a series of related papers concerning assorted hazardous waste sites and housing prices in Greater Grand Rapids, Michigan, Gayer (2000), Gayer and Viscusi (2002), and Gayer, et al. (2002) use detailed calculations of objective risk based partly on distance but also on assumed transport of pollutants.

An alternative approach typically involves the use of distance from the site as a proxy for either objective or subjective risk. This research falls into this second category. Even scientists have difficulty assessing the true levels of risk from a hazardous waste site with any degree of accuracy. Furthermore, home buyers tend to be less than perfectly well-informed about environmental risks (see Hite, 1998), and it is the perceptions of home buyers and sellers, rather than the facts, that will determine the prices observed for housing transactions. However, McClelland, et al. (1990) explore the distinction between subjective and objective risks to homeowners and their differential effects in hedonic property value models for the OII landfill. They find that distance to the site and odor levels are not statistically significant when included in a model in addition to a neighborhood average of homeowner risk levels.

8.1.2 Distance Effects over Time

In this research, we address some interesting empirical results concerning distance effects over time in the hedonic property value literature concerning hazardous waste sites. Farber (1998) reports that the literature suggests that the post-announcement impact of proximity to a site is roughly \$3500 per mile (in 1993 dollars). There is evidence in some cases that property values that have been temporarily depressed by the announcement of Superfund status rebound fully after cleanup (see Kohlhase, 1991).

A number of researchers have looked for this rebound effect. In particular, we will refer to a style of hedonic inquiry represented in work by Kiel (1995) and Kiel and Zabel (2001), in two papers by Kiel and McClain (1995), one paper by Dale, et al. (1999) and one by Carroll, et al. (1996). In these works, the authors estimate separate hedonic property value functions for discrete intervals of time separated by mileposts in the process of identifying and remediating a hazardous site.

Two of the Kiel papers (Kiel, 1995; and Kiel and Zabel, 2001) concentrate on a pair of Superfund sites in Woburn, MA, Wells G &H (the subject of the book and motion picture entitled *A Civil Action*) and the nearby Industri-Plex site. They identify six time periods: 1975-76, 1977-81, 1982-84, 1985-88, 1989-91 and 1992. (These sites are also one of the cases examined in our research, albeit for the time period 1978-97, and our data source is different. Kiel provides a very thorough background for the Woburn sites.) The earlier paper controls for a variety of structural characteristics of the house itself, and for the logarithm of minimum distance from the Superfund sites, finding strong evidence of a positive price gradient away from these sites in the second, fourth and fifth periods. The later paper also controls for two Census tract variables: the proportion of unemployed workers and median household income in nominal dollars. The paper does not appear to indicate whether more than one decennial Census was used to create values for these variables. The variables are billed as being necessary to control for omitted variables bias, and there is little further discussion of their contribution, since their coefficients are not statistically significant.

Kiel and McClain (1995) consider the timeline for the siting of an incinerator in North Andover, MA. These papers seek to discern different distance effects on housing prices in four different time intervals, 1989-90, 1981-84, 1985-88 and 1989-92.

Dale and his coauthors focus on the RSR lead smelter site in Dallas, Texas, identifying five time periods: 1979-80, 1981-84, 1985-86, 1987-90, and 1991-95. They use a sample of over 200,000 house sales distributed across these time periods, at an average distance of 11.8 miles from the smelter. The geographic scope of the sample subsumes 14 school districts. These authors interpolate between 1980 and 1990 tract-level Census data, and extrapolate based on the growth rates in variables for 1979 and the years beyond 1990. They control only for the percent of the Census tract below the poverty line, the percent Hispanic, and the percent black. These Census variables are the only ones that vary over time, beyond the yearly dummy variables included in the model. A simple distance variable is the key explanatory variable in these models, and the authors find that house prices increase with distance during the first three time periods, but fall with distance in the last two.

8.1.3 Endogenous Socio-demographics

Each of these substantial studies that focuses on the time pattern of distance effects on property values around a locally undesirable land use controls for two or three Census tract level characteristics, if not in earlier papers from the project, then in later ones. But these earlier studies were hampered by the absence of the 2000 Census data needed to construct plausible trends over time in neighborhood characteristics beyond 1990. These researchers have been limited to extrapolations based on the 1980 and 1990 Census data sets. The present work was also delayed considerably in its completing while the authors awaited the release of the year 2000 Census results.

None of the earlier papers addressing the time pattern of distance effects reports any exploration of whether population characteristics near the hazardous waste site also vary systematically with distance as well as with time. Concerns about omitted variables bias are acknowledged as justifications for including a few socio-demographic variables, but there are no reports of scrutiny of the correlations of these Census variables with distances over time.

Why might we expect socio-demographics, potentially, to be correlated with distance in ways that change over time? Housing prices are expected to be lower, the closer a property lies to a newly identified Superfund site. These lower prices may result in dwellings being sold to new owners who differ systematically from the existing population. If neighborhoods with greater proportions of residents with the characteristics of these new arrivals are typically associated with lower housing prices, this transition in the neighborhood may result in property values in this area failing to completely recover their original trajectories over time.

The existing studies which control for time-varying neighborhood demographics when measuring the effect on property prices of distance from a hazardous waste site may conclude, from the estimated coefficient on distance that property values have rebounded from an episode of Superfund designation and cleanup. However, demographics may be endogenously determined by this process. The evolution of the neighborhood over this time period may leave it with a different socio-demographic mix than prior to the episode. If these socio-demographic shifts have a negative effect on housing prices, these prices may not fully recover. Most models attempt to make welfare inferences concerning the losses in capitalized housing values to pre-existing owners based on the dynamics of the distance coefficient. What matters, however, is the actual effect on housing prices.

8.1.4 Endogenous Housing Stock Attributes

In addition to localized demographic changes that differ from trends in the broader community, the housing stock in the area near the hazardous waste site may also be affected differentially. There may be a shift in tenure from owner occupancy to more rental occupancy, and there may be changes in vacancy rates. If homeowners are less inclined to remodel houses nearest the site during the Superfund identification and remediation process, and developers are less inclined to replace older houses or construct new dwellings for sale in this area, or if new dwellings here are systematically different from new dwellings in areas beyond the influence of the hazardous waste site, then these changes in the housing stock in neighborhoods nearer the site can also contribute to sustained lower housing prices.

It is appropriate to control for demographic and housing stock changes, but all these hedonic studies implicitly assume that these changes are exogenous, and therefore do not bother to scrutinize them. We provide evidence that these variables are endogenously determined, and changes in their levels are correlated with distance from the site and dynamically related to the identification and remediation process. The full effect on housing prices of “proximity to a hazardous waste site” over time is captured not just by the simple distance coefficient, but also in part by the full complement of socio-demographic and housing stock variables whose values are also affected by the identification and remediation process.

McCluskey and Rausser (2001) utilize a dynamic, discrete-time model to analyze the evolution of perceived risk around a hazardous waste site and its effect on property values. Perceived risk enters the model as a state equation that involves a media coverage variable, and is an unobserved variable whose values are imputed from the model. (Gayer and Viscusi, 2002; also explore media coverage (newspaper stories) and their effect on property value changes in the vicinity of Superfund sites.) McCluskey and Rausser’s results suggest that media coverage and high prior risk perception increase current perceived risk, which in turn lowers property values. However, the pattern of evolution of these imputed perceived risks over time is derived from a specification that controls for distance from the site, but not for any changes in demographics, which could also account for systematic shifts in housing prices. Perceived risk is inferred to remain high if housing prices remain low. But if housing prices remain depressed near the site because of changes in neighborhood socio-demographics precipitated by the Superfund identification and remediation, such a model could falsely conclude that perceived risk remains high.

8.1.5 Environmental Justice/Equity

This research also contributes to the environmental justice literature by explicitly examining the effects on the socio-demographic mix of neighborhoods over space and time in response to the identification and cleanup of three different Superfund sites. (The Vail, CO, case has a settlement pattern that is too localized to allow for enough Census tracts for reliable analysis.)

The neighborhoods containing hazardous waste sites tend to be lower-income and possibly more non-white in their racial makeup. Bowen (2002) offers a critical review of the existing environmental justice literature and concludes, on the basis of studies that he identifies to be of relatively high quality, that

> "…it appears to be that hazardous sites are located in white working-class neighborhoods with residents heavily concentrated in industrial occupations, living in somewhat less expensive than average homes."

He acknowledges the possible presence of other patterns at the subnational level, but that these vary in their character from region to region.

When a spatial pattern of concentration of hazardous facilities in low-income or minority communities can be established, the question arises of which came first. Do industries or governments seeking to locate hazardous facilities disproportionately choose low income or minority neighborhoods, or does the tendency of these facilities to reduce the prices of nearby properties attract lower income home-buyers over time, and is ethnicity sufficiently correlated with income to produce this observed spatial pattern. Single cross-sections of data do not afford an opportunity to discern which came first, the low-income or minority neighborhood, or the hazardous waste site. It is necessary to determine how neighborhoods change over time, both close to the hazardous facility and elsewhere. A discussion of the issues is presented in Liu (1997), and in Been (1994) and Been and Gupta (1997).

Graham, et al. (1999) explore the siting of coke plants and oil refineries. They identify the year of the siting decision and retrieve historical Census data for the decennial Census preceding that year (or the earliest adequate Census data, if the siting decision preceded the advent of sufficiently detailed Census information). They conclude that market and non-market mechanisms, such as redlining, block-busting and other legal and illegal activities, may dominate the original coke plant and oil refinery siting decisions as explanations for the 1990 proportion of non-white residents near these facilities.

Graham, et al. (1999) cite “market dynamics theory” as predicting, over time, that hazardous or unattractive residential areas will lose high-income residents and attract low-income residents (due to the relatively depressed property values in these areas.)

8.2 The Sample

An ideal sample of data would consist of transactions data and housing structural characteristics, neighborhood characteristics, distances to all relevant amenities and disamenities, all collected contemporaneously with the time of sale. This ideal data would also include analogous information (except for selling price) about houses that did not sell in these periods, either because they were not for sale, or they did not find a buyer. This would allow the researcher to control for non-random selection into the pool of dwellings actually observed to be transacted.

When a researcher has data like these data over a number of years, it is possible to control for many unobserved housing and neighborhood characteristics that do not vary across time by using the so-called “repeat sales” method. When a house has sold more than once in the observed time period, the difference in the selling price can be explained in terms of differences in any explanatory variables that have also changed over time. This method for eliminating all the time-invariant characteristics from the analysis was first proposed by Bailey, et al. (1963), and has recently be used to good effect to analyze the influence of news stories about Superfund sites on housing prices (Gayer and Viscusi, 2002). One disadvantage of this method is that the sample of repeat-sales dwellings over-represents houses with greater turnover and excludes dwellings that have been sold only once during the window of time for which data are available. There is also a problem that any remodeling or updating of the property that is not captured by the quantity variables typically recorded in multiple listing service data will go unacknowledged in the process of dropping all structural characteristics by differencing over time.

We use a source of data that over-samples houses that have been sold only once over the time period in question. Our data roughly reflect the current status of dwellings. The data are provided, for the most part, by Experian, a company which provides information to direct mail marketers and others. These data are updated at fairly regular intervals, although not simultaneously. Anyone buying these records gets the most recent information available. For each street address in the sample, most records include information on the date when the house was purchased and the price that was paid at that time. For different localities, there are different quantities of structural information in the data set. From the same data supplier, all fields will be available for all localities, but for any given locality, blocks of fields will be blank. Blank fields differ across localities, possibly reflecting different public recording requirements.

In some cases, notably the Eagle County files sought for the Eagle Mine site near Vail, Colorado, the missing data problem was so severe that, despite the appearance of over 5,000 house transactions in the data, there were less than 50 with sufficient data for estimation of a basic hedonic property value model. It seems that a large share of dwellings are not owner-occupied. In that case, we sought and received data from the Eagle County Assessors office. There were roughly 1400 observations for owner-occupied units, lying between 2.6 and 19.3 kilometers of the nearest part of the Eagle Mine site. About 57% were owner-occupied but were not single-family dwellings. While the site description for the Eagle Mine site indicates that one of the main deposits of tailings was within 1500 feet of a middle school, there are apparently no current owner-occupied units in the vicinity. It would have been vastly preferable to have acquired the same assessor’s office information for each year during the time span of interest (in this case, from 1976 to 1999). However, data that are “obsolete” from the point of view of the assessor's office are apparently not retained merely for the convenience of researchers who wish to understand time patterns in property values.

The feature that has the greatest potential to compromise these data, then, is the fact that, in all of our data sets, we only observe selling prices for the most recent sale of a house. If a house is in an area where turnover is high, there will be more recent sales and fewer earlier sales. For analytical purposes, it would be preferable to have data on all sales in all years and selling price in those years, but such data do not exist. Data could be purchased from Experian every year, if a future study could be anticipated, but retrospectively, the data are not available. The data are collected primarily for current marketing purposes and records are updated without saving their previous values. Historical modeling is not a use anticipated by the providers of the data.

Consequently, there may be some systematic sampling. We observe earlier transactions prices only for houses which are still occupied by the owners who purchased them at that earlier date. We do not observe many early transactions prices for houses in neighborhoods where there has been a lot of turnover. It must be a maintained hypothesis that rates of turnover are uncorrelated with identification and cleanup of Superfund sites. This may be a strenuous assumption, but there are few alternatives. So it will be necessary to speculate upon the types of biases this non-random selection is likely to produce in the effects of distance from a Superfund site on housing transactions prices.

From these difficulties, we can glean an important item for the future research agenda.

8.2.1 Descriptive Statistics, Exclusions

For all of our sites, we exclude dwellings which are not owner-occupied, or if the selling price or lot size or other key variables are missing. We also omit houses which could not be successfully geolocated based on address information. For each site, we also limit the sample to the range of years for which data are sufficiently plentiful. We exclude dwellings with very unusual characteristics, such as very large values for number of floors, total numbers of rooms, numbers of bedrooms, numbers of bathrooms, square footage, and lot size, or extraordinarily high or low selling prices. We are attempting to model housing prices for a generous range of "typical" dwellings in the geographic areas in question. Very unusual dwellings are therefore excluded. Each of these exclusions accounts for a very small relative number of dwellings, and these unusual values may, in many places, be simply errors in data entry.

Selection on housing sale prices was conducted as judiciously as possible. Year by year distributions of house prices, in levels and in log form, were scrutinized for obvious outliers. Typically there were at most one or two deleted outliers in each year (aggregating across all Census tracts). Prices are in nominal terms, so it is important not to exclude outliers based on their identification from a marginal distribution.

Details are presented in the appendix for each site, along with complete descriptive statistics for each of the classes of variables used in our models.

8.2.2 Extent of the Market

It is at the discretion of the researcher to decide upon the extent of the market that may be influenced by proximity to a Superfund site. In some cases, if the disamenity is out of the line of sight, it will have negligible effects. In other cases, where it may contribute to unhealthful air quality or other obvious externalities, the geographic scope of its effects can be much more far-reaching. Furthermore, perception of the disamenity can be directional. For example, it can be influenced by prevailing winds (as in the case of the "Woburn odor"), or by the direction of water flow in a river (some houses in the Eagle Mine sample are downstream of the mine, others are not).

We selected a relatively large footprint for our initial models for each sample. For Montclair, the 11,982 houses in the sample range from zero to about 6.7 kilometers away from the site and a number of houses are actually located on top of areas of contaminated soil. The broader neighborhood for the OII landfill site includes 9,279 dwellings between 60 meters and about 8.5 kilometers from the boundary of the site. In Woburn, we characterize distances in terms of the distance from the nearer of the two sites, since they are in such close proximity. The sites are located in a non-residential area, so the range of distances represented among the 12,444 houses in the sample is from about 375 meters to about 8.4 kilometers.

The Eagle Mine site is anomalous. This is the mountainous territory around Vail, and most settlement is clustered along either the Eagle River or Gore Creek, which runs west through the town of Vail and into the Eagle River at a point downstream of the Eagle Mine site. Our sample of assessor's data should be relatively complete, but there is a very high proportion of non-owner-occupied properties in the region. There are only a handful of houses within six kilometers of the Superfund site, and we delete these because of their potential to have an inordinate effect on the price gradient in different years. The 1,087 owner occupied properties in the Eagle Mine sample lie between 6.09 and about 13 kilometers from the downstream portion of the site. No houses in the sample are upstream of the site. Furthermore, the numbers of transactions in each of 1976 through 1999 are sufficiently small that we needed to constrain the site distance effects to be equal across three-year intervals in order to discern any reliable effects.

The size of the sampling area in a study such as this should be sufficiently large that the distance premium in housing prices should arguably be zero near the boundary. We expect that statistically discernible distance premia should emerge only for houses considerably closer to each site.

8.3 Hedonic Property Value Models

Hedonic property values models have been used widely in literature, so we do not undertake in this research to explain their theoretical justification or limitations for their use. Many papers contain clear expositions of the underlying intuition. One recent example is Gayer and Viscusi (2002).

Most housing attributes are dummy variables or small integer values, with the exception of square footage and lot size. We retain square footage and lot size in linear form. However, all key continuous variables, including selling price SPRICE, the value of improvements, IMPVAL, and all distances, are logged. This allows sufficient flexibility for us to see diminishing marginal increases in housing prices with distance from a Superfund site, culminating in an essentially flat distance profiles beyond the radius at which further increases in distance have a negligible effect on property values.

Our basic model seeks to explain variations over space (i) and time (t) in nominal selling prices of dwellings, $SPRICE_{it}$. For some variables, the only available data correspond to the status of the structure in the last year of the sample, which we will denote as t=T. Our generic model takes the form:

(8.1) $$SPRICE_{it} = P_t \cdot DIST_{it}^{(\beta_{10t}+\beta_{11t}v_i)} e^{\beta_2 A_{iT}} e^{(\beta_{30}+\beta_{31}v_i)S_{it}} e^{(\beta_{40}+\beta_{41}v_i)D_{iT}} e^{\varepsilon_{it}}$$

Here, P_t is an area-wide price index for owner-occupied housing in year t, $DIST_{it}$ is the distance of each dwelling from the Superfund site in question, defined in a manner appropriate to the case. The coefficient associated with this variable will be allowed to differ across years by interacting the constant distance measure with yearly dummy variables. The variable v_i signifies lot size. This variable also appears as an element of the vector A_{iT} of property attributes. S_{it} is a vector of (interpolated) time-varying characteristics of the Census tract in which the dwelling is located, and D_{iT} is a vector of the logarithms of the distances from the dwelling to a potentially relevant set of other spatially differentiated local amenities or disamenities, calculated at time T, the end of the sample period, rather than contemporaneously.

Taking logarithms of both sides of the equation yields a version of this model that is appropriate for estimation:

(8.2) $$\begin{aligned} &LSPRICE_{it} = \\ &\quad \ln(P_t) + (\beta_{10t} + \beta_{11t}v_i)LDIST_{it} + \beta_2 A_{iT} + (\beta_{30} + \beta_{31}v_i)S_{it} + (\beta_{40} + \beta_{41}v_i)D_{iT} + \varepsilon_{it} \end{aligned}$$

where $LSPRICE_{it}$ denotes the logarithm of the observed selling price, $\ln(P_t)$ will be captured as an intercept for the first year in the sample and a set of intercept shifters activated by year dummy variables. The variables of key interest are the $LDIST_{it}$, which consist of a vector of logged distances from the dwelling to the Superfund site interacted with yearly dummies in order to permit year-varying elasticities of housing prices with respect to distance to the site. The control variables include the property attributes A_{iT}, the S_{it} vector of proportions of the number of persons, households, or dwellings in the Census tract falling into specific categories, and the D_{iT} set of logged distances to other local features, the identities of which vary according to the case in question. The effects of these other logged distances are constrained to be constant over the sample period.

The version of the estimating specification in Equation 8.2 highlights the special role of lot size, v_i , in the modeling. Each locational amenity or disamenity should be permitted to affect not just the price of the property overall, but its price per unit area. In our specifications, lot size can affect property values outright, but it can also shift the marginal effects of amenities and disamenities upon house prices. Our primary specifications restrict β_{11t} , β_{31}, and β_{41} to be zero, but in the Appendices, we explore the consequences of allowing these parameters to be non-zero.

8.4 Control Variables

The main objective in this study is to determine whether there are statistically detectable effects on the selling prices of houses due to proximity to a Superfund site, and whether these effects, if any, vary over time as the site is identified and remediated. Before the incremental effects of such proximity can be isolated, it is necessary to control for other factors which might influence these prices. If any of these factors is correlated with distance from the site, or varies over time, or especially both, then the apparent timewise variations in prices due to proximity to the site could be distorted by omitted variables bias.

In this study, we use four main classes of covariates to control for systematic variations in housing prices due to heterogeneity *other than* the effects of proximity to the Superfund site over time.

8.4.1 Annual Dummy Variables

The average price of housing in a region will rise and fall over time in response to regional business cycles that affect area-wide housing demand and other exogenous macroeconomic factors, such as interest rates. To the extent that housing prices vary over time independently of the dwelling's distance from the local Superfund site, we control for all these implicit time-varying factors with a set of yearly dummy variables in each of our models. Our dependent variable in all cases is the log of the most recent selling price of the dwelling. The annual dummy variables associated with all but the earliest period (the omitted category) therefore bear coefficients that can be interpreted as the area-wide percentage difference in housing prices, relative to the first year of data, in each year of the sample.

Appendices A through D contain descriptive statistics on the frequencies of observations in each year of the period spanned by each sample. Given the systematic selection on house sale data for houses still occupied by the same owner since the time of the sale, there are fewer observations with earlier sale dates and proportionately more observations with recent sale dates.

8.4.2 Distance to the Superfund Site

Montclair: For Montclair, the radium sites spanned three large footprints, and housing had been built on top of much of the affected areas. Distance is captured by a dummy variable for whether the house in question was on top of one of these sites (INSIDE) interacted with yearly dummies. It is also captured by distance from the boundary of the closest site, for houses which are not on top of a site. Both of these variables—the dummy for being inside or outside a boundary, and distance from the nearest boundary, if outside—are also interacted with lot size in a set of auxiliary models. This allows for overall distance effects on selling price to be influenced by lot size.

OII: In the OII case, there is one well-defined site with all housing external to that site. Distance from the boundary of that site interacted with yearly dummies. It is also interacted with lot size in auxiliary models.

Woburn: In the Woburn case, there are two fairly distinct sites, so the distances are calculated to each of them separately. But there are relatively few housing transactions right near these sites, since they are not located in residential areas. We went to considerable lengths to attempt to capture the independent effects on housing prices of proximity to each of these sites: Wells G & H, and Industri-Plex. However, the two sites are in too-close proximity relative to the distribution of housing locations, so we were forced, in the end, to consider the distance from each house to the nearest of the two sites.

The Industri-Plex site is known to have had a distinct olfactory externality downwind that we have attempted to accommodate. We have included variables measuring the absolute latitude and absolute longitude position of each dwelling. These variables allow for an underlying spatial profile in the form of a plane that rises most steeply in any arbitrary direction, whatever the data dictate. On top of this spatial profile can be stacked an additional spatial profile of housing prices that could rise with distance from the Superfund sites. If the distance premium is not symmetrical around the site, the combination of these two patterns will allow the level curves of housing prices relative to the site location to be elliptical and asymmetric around the site, as opposed to circular and centered on the site.

Preview: If anything, the strategy of using latitude and longitude (separately for each year of the sample) produced a suggestion that housing prices in many years seem definitely to rise towards the south and rise towards the east (although possibly at a decreasing rate the further north one goes). These absolute position effects are strengthened when distance from the nearest Superfund site is also included in the model.

Eagle Mine: There are four major parts to the Eagle Mine site, each of which we mapped with our GIS software and included as polygon features. In determining the distance from each house in the sample to the Eagle Mine site, we used the distance to the boundary of the nearest feature. In almost all cases, this is the feature that is furthest downstream towards the populated areas along the Eagle River and Gore Creek, north of their point of confluence.

8.4.3 Housing Characteristics

The dependent variable in all of our models is the logarithm of the selling price of the house.

All hedonic property value studies include at least some characteristics of the dwelling itself and the property upon which it is situated. For each of our samples, the available structural characteristics are as follows:

Montclair: In the Montclair case, the number of non-missing structural characteristics in the data is unfortunately rather small. We therefore experiment with using the information in the property tax assessment distinction between land value and the value of improvements. In the assessment data, the total (most recent) assessed value of most properties is divided into land value and the value of improvements. In principle, the land value should reflect the value of the location of the dwelling and the value of the improvements should reflect the quality of the structure itself. The impact of proximity to a Superfund site should show up the assessed value of the land, and should vary over time as the perceived negative impact of proximity changes. But the assessor's 1997 value of the improvements should reflect the size and quality of the structure itself. This assessed value of the improvements will reflect any remodeling or additions that have taken place since the last sale of the dwelling, so this is an imperfect control for the structural quality of the dwelling when it was last sold. However, it is worth exploring the assessed value of the structure as a rough proxy for missing structural information.

In some of the models we report, we have opted to employ the estimate of the value of the improvements to the property as a regressor in the class of housing characteristics. We continue to use all available and complete measures of the physical characteristics of the house. These are typically quantity measures, rather than quality measures (e.g. number of bathrooms, rather than how expensive the fixtures, flooring, and countertops might have been), so we use the improvements value as a proxy for the "fit and finish" and the quality of the materials embodied in the structure. Higher quality architectural features in a dwelling would be more likely to be captured by the improvements value than by strict counts of bedrooms or floor space.

The quality of the most recent assessed value of improvements as a proxy for housing quality at the time of the last sale will deteriorate with the elapsed time between that sale and the most recent assessment.

Table 8.1 Montclair Housing Characteristics

Variable	**Definition (n=11940)**
impval	assessed value of improvements, 1997
knowflr	=1 if number of floors is known, =0 otherwise
floors	= number of floors, if known
ageknown	=1 if age of structure is known, =0 otherwise
age20	=1 if age>=10 and age <20, =0 otherwise (omitted category= age<10)
age30	=1 if age>=20 and age <30, =0 otherwise
age40	=1 if age>=30 and age <40, =0 otherwise
age50	=1 if age>=40 and age <50, =0 otherwise
age60	=1 if age>=40 and age <60, =0 otherwise
age70	=1 if age>=40 and age <70, =0 otherwise

age70plus	=1 if age>=70, =0 otherwise
lot size	Size of lot, in ratio to sample average lot size = **9232 sq. ft.**

OII: The OII data are drawn from the same Experian source as the Montclair data, but many more data fields are non-empty in these data. Thus, a wider range of explanatory variables capturing structural characteristics can be entertained.

Table 8.2 OII Housing Characteristics

Variable	**Definition (n=9211)**
notold	=1 if structure was built after 1900, =0 otherwise
age	Age of structure if built after 1900
age2	Age of structure, squared
sqft	Square feet of floor space, in ‘000s
sqft2	Square feet of floor space, squared
bedrms	Number of bedrooms
bthrms	Number of bathrooms
sqftbed	Interaction term: sqft * bedrms
sqftbth	Interaction term: sqft * bthrms
fplace	=1 if at least one fireplace, =0 otherwise
knowflr	=1 if number of floors is report, =0 otherwise
floors	Number of floors, if data not missing
lot size	Size of lot, in ratio to sample average lot size = **6199 sq. ft.**

Woburn: The explanatory variables available for the Woburn model are the same as those available for the OII site, although lot size will be normalized on the mean for this different sample.

Table 8.3 Woburn Housing Characteristics

Variable	**Definition (n=12444)**
notold	=1 if structure was built after 1900, =0 otherwise
age	Age of structure if built after 1900
age2	Age of structure, squared
sqft	Square feet of floor space, in ‘000s
sqft2	Square feet of floor space, squared

bedrms	Number of bedrooms
bthrms	Number of bathrooms
sqftbed	Interaction term: sqft * bedrms
sqftbth	Interaction term: sqft * bthrms
fplace	=1 if at least one fireplace, =0 otherwise
knowflr	=1 if number of floors is report, =0 otherwise
floors	Number of floors, if data not missing
lot size	Size of lot, in ratio to sample average lot size = **15129 sq. ft.**

Eagle Mine: Given that the Eagle Mine data are drawn from the Eagle County assessor's office, rather than from the Experian data, the available variables are somewhat different.

Table 8.4 Eagle Mine Housing Characteristics

Variable	**Definition (n=1087)**
sfd	=1 if single-family dwelling, =0 if condominium
age	Age of dwelling
age2	Age of dwelling, squared
bedrms	Number of bedrooms
bthrms	Number of bathrooms
notwdframe	=1 if not wood-frame construction, =0 otherwise
heatelec	=1 if electric heating, 0 otherwise
constgood	=1 if construction quality rated as "good" or better, =0 otherwise
constfair	=1 if construction quality rated as "fair" or worse, =0 otherwise
downstream	=1 if nearest to Eagle River, =0 if nearest to Gore Creek
lot size	Size of lot, in ratio to sample average lot size = **5154 sq. ft.**

8.4.4 Neighborhood Characteristics

We define the neighborhood in which a house is located as synonymous with its Census tract. Been and Gupta (1997) give a very thorough rationale for the desirability and tractability of using Census tracts when there is a need to quantify socio-demographic and other very local characteristics over time. Since neighborhoods change over time, and might be expected to change as a result of the discovery and remediation of a Superfund site, it is important to distinguish between changes over time in the effect on housing prices of mere proximity to the site, versus the influence of changing local demographics on property values. Hedonic property value studies which ignore changing demographics are essentially estimating reduced form model, which confounds the proximity effects with the changing demographics. It is possible that the pure effects of proximity to a site are completely resolved with remediation, but the effects of changing demographics as a result of the experience are more permanent.

We have been careful to collect Census data from all relevant decennial Censuses and interpolated all of the conformable socio-demographic characteristics. For some sites, we needed the 1970, 1980, 1990 and 2000 Census counts in order to interpolate a series between, for example, 1978 and 1997. Obviously, the decennial interval is problematic and these characteristics will inevitably be measured with some error. Errors-in-variables attenuation may lead to underestimates of the effect of neighborhood characteristics on housing prices.

The 2000 Census will offer greater resolution for a number of these variables, but the complete 2000 Census data at the Census tract level are not yet available at the time of this writing. We strived to achieve comparability across the different Censuses in these data, subject to the constraints imposed by the available data in each year. Counts were collected for each Census tract in each of four Census years, and categories were aggregated until they conformed and the data could be pooled and used in an algorithm to interpolate approximate values for each variable in each year between Census years. This procedure resulted in a Census dataset that could be merged with housing transactions by Census tract and year, so that the approximate current neighborhood mix could be used to explain housing prices in each year.

The Census variables we constructed that conformed across all four Census years and could be computed for each Census tract for each of our four sample areas are described in the following table. A smoothing algorithm was used to “connect the dots” in each Census year and to impute approximate values for each inter-Census year. These approximated time series will not accurately represent inter-Census variations in each variable, but this procedure seems to dominate the use of just one single year of Census year or the use of all three or four spanning Census years for each of our samples.

Table 8.5 Neighborhood Characteristic Variables

Variable	**Description**
tract	Each tract number represented in the sample

year	Actual data for each Census year; interpolated data for between-Census years
population	Total population of the tract in each year
households	Number of households in each tract in each year
housing units	Number of housing units in each tract in each year
males	Number of males
females	Number of females
white	Number identifying race as "white" (omitted category)
black	Number identifying race as "black"
other	Number identifying as "other race"
age_under5	Number of persons aged under 5
age_5_29	Number of persons aged between 5 and 29
age_30_64	Number of persons aged between 30 and 64 (omitted category)
age_65_up	Number of persons aged 65 or older
marhh_chd	Number of households consisting of married heads of household with children
mhh_child	Number of households consisting of male head of household with children
fhh_child	Number of households consisting of female head of household with children
vacant	Number of housing units vacant
owner_occ	Number of housing units owner-occupied (omitted category)
renter_occ	Number of housing units renter-occupied

These Census variables were converted to analogous percentage variables, prefixed with the letter "p", based upon the appropriate denominator (either population, households, or housing units). Where percentages sum approximately to 100%, the majority or (typically omitted) category is dropped. For example, we will arbitrarily drop pmale, pwhite, page_30_64, pmarhh_chd, and powner_occ. This leaves a typical vector of socio-demographic variables in the same Census tract as each observation that includes:
[pfemale, pblack, pother, page_under5, page_5_29, page_65_up, pmhh_child, pfhh_child, pvacant, and prenter_occ].

We anticipate that these Census tract characteristics may be very important to the problem of sorting out the variations over time in the effect of proximity to a Superfund site on housing values. Over the time horizons involved in our different cases (which range from 11 years to almost 30 years), there is a substantial scope for demographic shifts. Initial decreases in housing prices due to the recognition of an environmental disamenity can make the neighborhood accessible to lower-income households, who may be prepared to accept the disamenity in exchange for more housing at the same price, or cheaper housing, than they can obtain elsewhere. Neighborhood characteristics are not independent of the “taint” due to a Superfund site. It is important to ascertain whether the observation that housing price gradients often tend to rise as one moves away from a Superfund site, even after remediation, may be due to filtering-down of this housing stock that occurs during the period when taint is maximum.

It is entirely possible that, controlling for neighborhood changes that ensue from an episode of major environmental taint, the eventual effect of proximity to the site is actually positive (the price gradient moving away from the site is negative following remediation). Homeowners may value proximity to a cleaned up site more than they value proximity to other less-certifiably safe features.

The fact that Census data are available only at ten-year intervals has been an impediment to addressing this research issue. It was necessary to wait for the availability of the year 2000 Census data to be able to interpolate between the 1990 Census tract information and the 2000 Census information in order to construct usable data for the last seven to nine years of housing sales in our various data sets.

8.4.5 Other Local Amenities and Disamenities

Many earlier hedonic property value studies have included only one or two other distances in their models (such as distance to the nearest shopping center, or the central business district), or even no other distance variables at all. In the last few years, a number of environmental aspects of spatial data have been examined by researchers who are interested in determining their potential effects on property values. Acharya and Bennett (2001) use a sample of about 4000 houses in New Haven county in Connecticut between 1995 and 1997 to explore whether open space and land-use diversity affect housing prices. Diversity, richness, evenness and dominance measures are used to quantify the patterns of land use within a fixed radius of each dwelling. Among the spatial features they include as controls are distances to open space, lakes, streams, the ocean, parks, and highways. They also use Census block group data for the percentage of white households, the crime rate, average income, percentage college-bound students, to quantify neighborhood characteristics. However, they do not attempt to isolate variations over time in the effects of perceived environmental quality on housing prices. The marginal effects are assumed to be static.

In this research, based on our geo-location of each property using GIS software, we have measured for each house the distance to a wide variety of other topographic features, land uses, and institutions. Some of these are common to all four of our samples, such as distance to the nearest park and distance to the nearest school or shopping center. Others are unique to each site. Major freeways may be close enough to matter, or they may not, and airports or the flight paths implied by their runway configurations may be close enough to affect housing prices, or they may not. Based on a careful examination of the features in the region of each sample, we have identified and measured distances for a wide variety of things that could plausibly affect housing sale prices. The “other distance” variables relevant to each Superfund site are discussed in detail in the appendices devoted to each site, but will be summarized briefly below.

Concerning precedents in the literature for controlling for certain classes of variables, we can identify the following:

Summits: Benson, et al. (1998) assess the influence on housing prices of a variety of views, differentiated by both type and quality. They find that depending upon the particular view, willingness to pay for this type of amenity is quite high. While map proximity to a summit does not translate into the presence of a view, there may be some correlation.

Schools: “Close to schools” is considered by many home-buyers to be a positive feature of housing location, but Clauretie and Neill (2000) find that proximity to year-round schools, tends to decrease housing values.

Roads: Spatiotemporal fluctuations in location premiums associated with a major urban highway construction project in a study by Vadali and Sohn (2001). Boarnet and Chalermpong (2001) consider the effect of introducing new toll roads that increase accessibility.

Airports: Espey and Lopez (2000) find the airport in their study to be a disamenity. This stands in contrast to earlier work by Tomkins, et al. (1998), who found proximity to one particular airport to be a net positive amenity.

Railroads: Strand and Vagnes (2001) study the relationship between the price of residential properties and proximity to railroads in Oslo. Bowes and Ihlanfeldt (2001) consider the effect of commuter rail stations on the value of nearby properties.

Parks: Open spaces are not synonymous with parks, but work by Smith, et al. (2002) and by Geoghegan (2002) considers the impact of open spaces on housing prices, suggesting that urban parks may play this role to a certain extent in the more heavily settled examples in this research.

Water Bodies: Poor, et al. (2001), Spalatro and Provencher (2001), and Mahan, et al. (2000) all consider hedonic property models with water features incorporated.

One shortcoming of these data concerning other distances is that they are "snapshot" data based on the present geographic configuration of the local area. We have no way (at reasonable cost) to reconstruct the appearance, during our sample periods, of new airports or new parks, for example. We must rely upon the assumption that each of these features has remained fairly constant over time (the 11 to 30 years of our samples) so that its effects are independent of time. Of course, one could interact each of these distances with annual dummy variables to distinguish year-specific distance effects for each, but the number of regressors would rapidly become even more unmanageable than it is at present.

It must be acknowledged, however, that the emergence (part-way though our sample period) of one of the shopping malls present in our sample in 2000 could distort the apparent effect of distance from a Superfund site in that year. Suppose a shopping mall appears inside the sample area, close to the Superfund site, half-way through the sample period. Suppose further that the presence of the shopping mall causes housing values to increase with proximity to the mall. Prior to the introduction of this mall, the prevailing effect might be the negative effect of proximity to the Superfund site. Proximity to the yet non-existent mall would have no effect.

After the mall appears, however, proximity to the mall will increase prices, but proximity to the Superfund site will decrease it, and the effects essentially wash out. The coefficient on the distance from the mall location would be the average over the whole time period of the zero effects without the mall and the positive effects with the mall, which would be overall positive but smaller than their "true" effects. The coefficients on proximity to the Superfund site are allowed to vary by year, however.

In the hedonic property value literature, there is some discussion about whether local amenities and disamenities should make a fixed difference in the price of a property, regardless of the size of that property, or whether these factors should in fact affect the per-unit-area price of the property. We deem it unlikely that either one of these assumptions is entirely credible. Hence, whenever a local amenity or disamenity enters a model, we explore expanded models with both the amenity/disamenity distance and this distance interacted with the lot size of the property in question. The effect of the amenity on house price (the derivative of expected property price with respect to the amenity or disamenity) is therefore permitted to depend, in a linear fashion, on the size of the property in question. If no such dependence is present in the data, the coefficient on the property size interaction term will be indistinguishable from zero.

The "typical" magnitude of a non-constant marginal effect can sometimes be difficult to appreciate when pondering regression results. Thus we undertake a convenient normalization. Whatever our estimating sample, we first scale the raw data on lot size by the sample average of the lot size variable, so that the sample mean of the scaled variable is one. Then, at the mean lot size in the sample, the marginal effect of an amenity or disamenity that is interacted with lot size will be given simply by the sum of the coefficient on the level of that amenity and the coefficient on the interaction term. If these two coefficients are of opposite signs, the coefficient with the larger absolute value will determine the sign of the effect at the means of the data. This convention is observed for all of our local amenity and disamenity effects: neighborhood socio-demographic and housing stock characteristics, distances from other potentially relevant amenities and disamenities (parks, freeways, etc.), and the effects of distances from the Superfund site in each year.

Montclair We will mention the other distances in the order in which they appear in the estimating models. By using an additively separate specification in the logarithms of “distance to the nearest X,” we are of course imposing the strong assumption that the distance gradients relative to all amenities or disamenities of the same type are identical, and that the effect on house prices of proximity to one site is not affected by proximity to another. These are strong assumptions, but given the number of candidate variables, a considerably larger data set would probably be required to discern the magnitudes of these interactions.

For Montclair, we include distances to the nearest summit of land, to the nearest school and nearest retail center (shopping mall). We also use distance to the nearest hospital, church, and cemetery. With respect to surface transportation, we control for distance from a railroad, a major road, Interstate 280 and the Garden State Parkway. We include distance from parks and major bodies of water. Among institutions, we have distance to the nearest college or university and distance to the nearest golf or country club. In addition to controlling for distance from the nearest airport, we include a separate airport distance unique to Newark International Airport. The details for each of these amenities or disamenities are included in Appendix A.

OII: For our housing price model for the OII landfill area, we measure and control for distances from the nearest school, retail center (shopping mall), hospital, church and cemetery. We also control for distance from the nearest railroad and for distances from a number of specific Southern California freeways: Interstate 5, Interstate 605, Interstate 10 and State Route 60. The effects for these distances are in addition to those of the distance from the nearest major road, which may sometimes be one of these freeways, but will often be a large “surface street.” We control for distance to the nearest “river” (often seasonal in Southern California) and the nearest major body of water (typically a non-seasonal river constrained within concrete for flood control). The distance to the nearest park is measured, with additional controls for distance from the largest regional park, the Whittier Narrows recreation area. There is one college campus that may be relevant, the California State University at Los Angeles, and we also control for distances from the nearest country club or golf course.

Full details of the features captured by the “other distance” variables for the OII landfill site are included in Appendix B.

Woburn: For Woburn, we control for distance from the nearest summit of land, as well as distances from the nearest school, retail center (shopping mall), hospital, church and cemetery. Along with distance to the nearest railroad, we include a number of different measures of proximity to roads: the distance to Interstates 93 and 95, the distance to the nearest principal artery, the distance to the nearest other principal road, the distance to the nearest road including smaller roads.

Air transportation corridors could also have an effect on housing prices in this area. We control for distance from each of Boston's four airports: Logan airport, Beverly Municipal airport, "Tew-Mac" airport and Hanscom Air Force Base. In addition to the simple distance measures, we also plotted the potential flight paths over the sample area, based on the trajectories of runways at each airport. We then computed the distance from each house to the nearest flight path associated with each airport.

Finally, we include distances to the nearest park, major body of water, and country club. Details concerning each of these types of "other distances" we have computed for the dwellings in the Woburn area sample are contained in Appendix C.

Eagle Mine: The universe of available and potentially relevant "other distance" variables considered in the Eagle mine analysis is displayed below. While we measured distances for variables in the similar classes as those used for other Superfund sites, the distances to many features, for the Eagle Mine sample, were great enough that one would not expect them to have an influence on variations in housing prices within the sample.

Measured distances include distances to the nearest summit (and there are about 20 named summits in the sample area) and to the nearest river, either Eagle River or Gore Creek. Elevation might plausibly explain housing values, but horizontal distances to the nearest summit are likely to be a poor proxy for elevation in this terrain. We also collected information about distances to the nearest school and retail area, hospital, church and cemetery, as usual. Only schools, however, are contained in the sample area and some of the other distances are extremely large (up to 50 miles). The effects of distances from the nearest railroad or road will be confounded by proximity to the nearest river, since the highways and railroad follow either the

Eagle River, or Gore Creek, or both, due to the topography of the area. There are no “major bodies of water” in the area other than the rivers. “Recareas” include three golf clubs, and these may have independent distance effects. Other points of local interest are too heterogeneous to be combined (e.g. campgrounds, ranger stations). The one exception is distance to the Vail ski area.

We did measure distances from each site to the nearest town for seven distinct towns (Avon, Eagle, Eagle-Vail, Leadfille, Minturn, Redcliff, and Vail itself). However, the linear arrangement of houses and towns along Interstate 70, leaves very little independence in these distances. The main distance variable we retain in the model is the distance to the Vail ski area.

A full description of these “other distances” for the Eagle Mine sample is included in Appendix D.

Chapter 9

Property Value Results

9.1 Classes of Hedonic Property Value Models

Our most basic specification, called Model 1, explores for time-varying proximity effects in a generic specification of the following sort:

(9.1) $$LSPRICE_{it} = \ln(P_t) + (\beta_{10t})LDIST_{it} + \beta_2 A_{iT} + \varepsilon_{it}$$

This model is designed to mimic the most rudimentary type of specification that a researcher might first explore when looking for time-varying distance effects. Distance is interpreted as a proxy for perceived risk. When we estimate each of our models with time-varying distance effects, we test the hypothesis that the profile of the distance premium (i.e. the perceive risk premium) is the same in all years in the sample, since a simpler model yet would not even distinguish distance effects that may vary over time.

The key argument of this research is that time-varying socio-demographics, both near and further away from the Superfund site, can have a systematic effect on housing prices. To determine the effects of demographics when other distances are not controlled, the generic version of Model 2 is:

(9.2) $$LSPRICE_{it} = \ln(P_t) + (\beta_{10t})LDIST_{it} + \beta_2 A_{iT} + (\beta_{30})S_{it} + \varepsilon_{it}$$

However, the question of whether there are any general proximity effects, at all, cannot be reliably ascertained without controlling for proximity to other amenities and disamenities. The apparent magnitude of the proximity effects across years may be rendered generally higher or lower by controlling for time-constant effects of proximity to other features. Model 3 will take the general form:

(9.3) $$LSPRICE_{it} = \ln(P_t) + (\beta_{10t})LDIST_{it} + \beta_2 A_{iT} + (\beta_{40})D_{iT} + \varepsilon_{it}$$

This model is similar to the type of model estimated by many previous researchers, although most models of this form control for a rather limited selection of other distances.

Our most complete general model is Model 4, corresponding to Equation 8.2 above, which employs all five classes of regressors: the set of year dummies that reveals the area-wide price index, $\ln(P_t)$; the complete set of interactions between the logarithms of distance from the Superfund site and annual dummy variables, giving $(\beta_{10t})LDIST_{it}$; the structural characteristics, A_{iT}; the other distances, D_{iT}, and the time-varying demographics, S_{it}. In selected cases, we will include other or different variables, such as potential lot size shifters on the key coefficients, or, in the case of Woburn, latitude and longitude shifters for the entire price function, or downstream/non-downstream variables, as in the case of Eagle Mine.

Before we delve into the details of the estimated hedonic property value models, however, it is important to look at some auxiliary models. These models specifically examine the trends over time in the socio-demographic characteristics of the populations both near, and further away from, each Superfund site.

9.2 Auxiliary Models Time-Varying Demographic Patterns

There has been considerable interest in the environmental equity/justice literature about whether hazardous waste sites are selected because the population in the area is relatively lower income, has a larger proportion of minorities, or unlikely to organize to resist a siting decision. The Superfund sites in our sample are not new siting decisions. These sites were in place before much of the residential development around them began to occur. [See the approximate timelines listed above.] Much of the population around the site has accumulated during or since the time the site was in operation. The environmentally relevant “events” in our cases are not decisions to site a new facility, but the news surrounding each site’s designation as a Superfund site and the resulting deliberation about cleanup strategies and actual remediation. So in this context, it is not so much the siting decision that matters, but the consequences over time of the publicity about the site’s Superfund status, and therefore public awareness of the site and the hazards that it may represent. Perceived risk is assumed to vary over time, and should also vary over space in a way that is approximately correlated with possible exposure.

It is difficult to reconstruct reliable time-series of neighborhood socio-demographic characteristics. As Gayer (2000) points out, Census block groups allow a more refined measure of a dwelling's neighborhood than the Census tract. However, even Census tracts pose problems for splicing together data across different Censuses. Tracts tend to be split as density increases, and it is enough of a challenge to construct a time series at the tract level, since coding categories change across time. We constructed a set of characteristics that aggregated socio-demographic groups sufficiently to afford a match across decennial Censuses and aggregated Census tracts to a common denominator across years. This leads to a loss of some resolution both in detail and spatially, compared to what is available if one relies solely on the 1990 Census, for example.[6] However, we deem it important for us to use a comparable set of variables across the three samples where this strategy is feasible. We also need to approximate neighborhood characteristics for years that span the 1970's, 1980's and 1990's, which requires conformation across four different Censuses.

One of the most significant empirical enquiries into the effects of hazardous waste sites on local demographics is described in Been and Gupta (1997). These researchers identify 608 commercial hazardous waste treatment, storage, and disposal facilities opened between 1970 and 1990. They collect Census data for the Census prior to the opening, and for 1990 for each of these tracts. As controls, they draw a random 5% sample of all tracts in the U.S. They analyze "before" demographics and "after" demographics, but of primary interest in the context of the present work is their study of the difference-in-differences between the host tracts and all other tracts, between the Census prior to the facility opening and 1990. As multivariate analyses, these researchers pooled the host and non-host Census tracts and regressed the 1990 values for each demographic characteristic (in percentage terms) against the value of this variable in the Census prior to the siting, along with a dummy variable for whether the tract hosted a site.

Using these empirical techniques, Been and Gupta (1997) conclude that their study "does not support the argument that market dynamics following a siting of a TSDF change the racial, ethnic, or socioeconomic characteristics of host neighborhoods. The analysis suggests that the areas surrounding TSDFs sited in the 1970s and 1980s are growth areas: in host areas, the

[6] Only "short-form" 2000 Census statistics are available at the Census tract level as of this writing.

number of vacant housing units was lower than in sample areas, and the percentage of housing built in the prior decade was higher. Such growth suggests that the market for land in the host areas is active and should respond to any nuisance created by the TSDFs. It also may suggest that the burdens of the TSDF are being off-set by the benefits, such as increased employment opportunities."

As Liu (1997) prescribes, any assessment of market dynamics as a potential explanation for neighborhood change around a locally undesirable land use requires controlling both for the characteristics of the neighborhood before a siting decision and for changes in other neighborhoods. The Been and Gupta (1997) approach uses randomly selected Census tracts elsewhere in the country as a control for what is happening in "other neighborhoods." Here, we control for patterns in other neighborhoods by enlisting the broader area around the host tract as control tracts. Rather than looking for discrete differences in socio-demographic characteristics between a host tract and tracts that are greatly displaced in terms of distance, we look for patterns in demographics over time that differ continuously with distance from our Superfund sites. If the socio-demographic patterns near the site are indistinguishable from those farther away the distance gradient relative to the site will be flat. Depending upon conditions at the beginning of our sample periods, there may be other reasons why we might observe a positive or negative distance gradient in socio-demographic characteristics. What matters, however, is how this gradient changes over time. If white residents tend to move out, and non-white residents to move in, in the wake of publicity about Superfund designation and remediation, then the distance gradient for whites should be observed to become relatively more positively sloped (or less negatively sloped) with time. Likewise, the distance gradient for non-whites would be expected to become less positively sloped (or more negatively sloped) over time.

In the auxiliary models described in this section, we explore the simple trends in demographics near our four Superfund sites over time. Each observation is a house sale, and for each observation we know the log of the distance from the site in question. As dependent variables, we use the Census tract proportions of inhabitants in each class, pX, where X is a Census category. These are the neighborhood characteristics associated with each house in our main sample. In future work, we plan to aggregate the analysis to consider each Census tract as a unit of observation, but for now we preserve houses as observations since this will most clearly highlight the multicollinearities present in our main hedonic property value models. For the purposes of these main models, we interpolate the information for each Census tract across time to provide approximate time series for each variable.

We assess the propensity for lower-income families, non-whites, and non-traditional families to "come to the nuisance," possibly attracted by lower housing prices brought about by taint from the Superfund site. The models we examine regress proportions for each socio-demographic and housing tenure characteristic, across Census tracts and over time, against a measure of distance, a time trend, and an interaction between distance and time. We use the log of distance, since this transformation is important in our main hedonic property value models. The log transformation allows any effect of proximity to the Superfund site to dissipate with distance until, in the limit, further increases in distance have very little effect on socio-demographic proportions. This is a reasonable maintained hypothesis, since the "reach" of influence of any particular Superfund site must be finite.

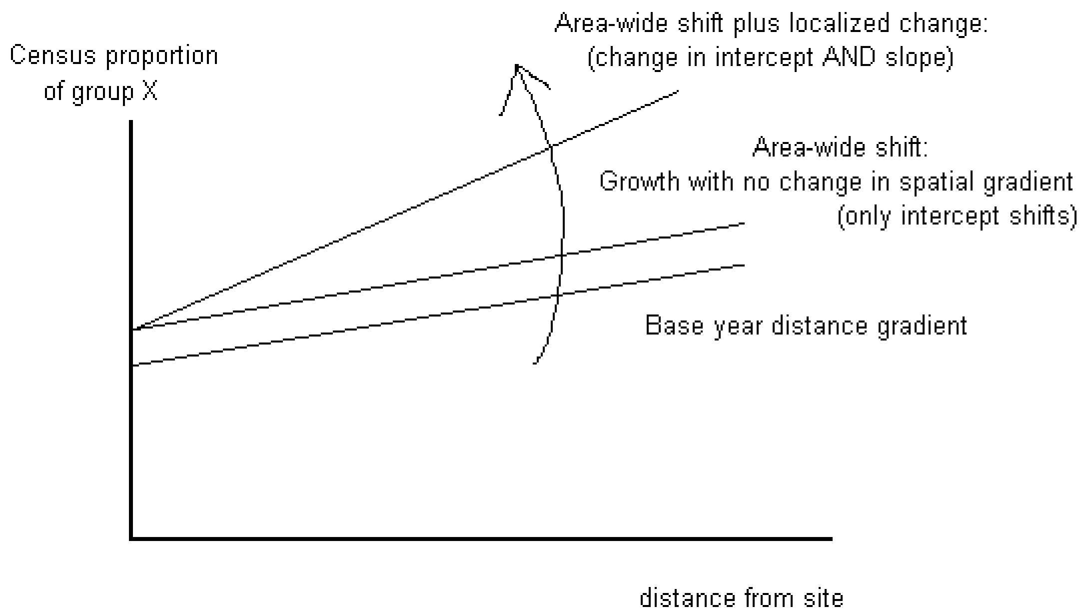
Our specifications take the following simple form:

(9.4) $$pX_{it} = \alpha_0 + \alpha_1 LDIST_{it} + \alpha_2 t + \alpha_3 t \cdot LDIST_{it} + \nu_{it}$$

Using the log of distance from the site permits the marginal effect of distance on proportions to decline with distance, since as distance increases, the same percent change in distance corresponds to a greater and greater increment of distance. This functional form assumes that the effect of a percent change in distance is constant.

The effect of the log of distance from the Superfund site on the neighborhood proportion of a given group is given by $\alpha_1 + \alpha_3 t$. The effect of the passage of time on the neighborhood proportion of a given group is given by $\alpha_2 + \alpha_3 LDIST_{it}$. If the distance profile for the proportion of residents of a particular type is merely shifting upwards or downward everywhere in the region, we would expect to see α_2 nonzero, but $\alpha_3 = 0$. In contrast, if the distance profile is changing systematically over time, we will see $\alpha_3 < 0$ if this group is becoming relatively more numerous near the Superfund site, and $\alpha_3 > 0$ if this group is becoming relatively less numerous near the Superfund site (Figure 9.1).

Figure 9.1 Changes in Socio-demographics near Superfund site over time



In the Montclair case, there is not only a distance variable measured from the perimeter of the nearest site for houses outside the sites, there is also a dummy variable indicating whether the dwelling in question is inside the site boundaries. In this case, Equation 9.4 will be adapted to:

(9.5)
$$pX_{it} = \alpha_0 + \alpha_1 LDIST_{it} + \alpha_2 t + \alpha_3 t \cdot LDIST_{it} + \alpha_4 INSIDE_{it} + \alpha_5 t \cdot INSIDE_{it} + \nu_{it}$$

In reporting these results, we concentrate on the estimated value of α_3 (and α_5 in the Montclair case) for each type of Census group, X, for each of the Superfund sites for which we are able to employ Census tract characteristics (i.e. all sites except Eagle Mine). In the case of groups becoming relatively more numerous throughout our sample areas, independent of distance from the Superfund site, any effects of these changes on housing prices will be picked up by the estimated area-wide price index, P_t, that is captured by the set of year dummies in the model for $LSPRICE_{it}$.

In perusing the estimated values of α_3 in the tables that follow, keep in mind that the dependent variable is constant for all houses in a particular Census tract in a particular year. To the extent that this variable does not perfectly reflect the "neighborhood" that is relevant to the house sale in question, there will be a degree of error in this dependent variable. The explanatory variables, distance and year, are observation-specific.[7]

It must also be acknowledged that these specifications constrain the time trends to be monotonic. If they are non-monotonic, perhaps first increasing then decreasing, for example, or vice versa, this would tend to obscure any trends.

(9.6) $$pX_{it} = \alpha_0 + \alpha_1 LDIST_{it} + \alpha_2 t + \alpha_3 t \cdot LDIST_{it} + \alpha_4 t^2 + \alpha_5 t^2 \cdot LDIST_{it} + \nu_{it}$$

This specification yields a distance gradient for Census tract characteristic X in the form of

(9.7) $$\frac{\partial pX_{it}}{\partial LDIST_{it}} = \alpha_1 + \alpha_3 t + \alpha_5 t^2, \quad \text{or}$$
$$\frac{\partial pX_{it}}{\partial DIST_{it}} = \frac{\alpha_1 + \alpha_3 t + \alpha_5 t^2}{DIST_{it}}$$

This implies that the effect will decrease with distance, and is quadratic in time, if the α_5 coefficient is significantly different from zero. The fitted turning point occurs at $t^* = -\alpha_3 / (2\alpha_5)$. If t^* lies within the range of the data, the fitted time trend in the Superfund

[7] There is an alternative strategy, which we are currently exploring. We find the effective center of gravity for the all the houses in each Census tract across all years by computing the mean latitude and mean longitude of these houses. We then locate these centers of gravity in our GIS software and use ArcMap to measure the distance from each tract centroid to the boundary (or center) of the Superfund site. The number of observations can then be limited to just actual Census years and individual or merged tracts that can be conformed across all Census years. In these more limited data, we lose the resolution on distance for each house, but avoid the spurious estimation precision that accompanies the use of the same Census tract information for all houses in a tract and smoothes the time profile by interpolating. These results are not yet finalized.

distance profile of Census characteristic X changes sign. If t^* lies beyond the range of the data, the trend is approximately monotonic.

We have explored the data for evidence of significance in quadratic terms and found some evidence. But one must bear in mind that the underlying real data consist of only four decennial snapshots of neighborhood characteristics. The interpolated data are only approximate. Given the quality of the data, we do not deem it judicious to push too hard on this generalization.

In this research, we report only the key coefficient estimates, and their standard errors, for the α_3 coefficient in Equation 9.4. The rest of the results for each model for each Census tract attribute are presented in Appendices A through D. The appendices also illustrate the progression of fitted distance profiles over time, with the heavier line in each graph depicting the first-year in the sample and the progression being captured by representative intervening years between then and the end of the sample period.

9.2.1 Montclair

There are significant numbers of observations from each of over 60 different Census tracts represented in the Montclair sample, so there is considerable variation in tract characteristics across the sample in any one year, and also in the interpolated time series within each tract.

The Montclair model for each Census tract characteristic differentiates between distance effects, implied by α_3, and the effect of being on top of one of the radium sites, α_5. Only these two coefficients for each model are presented in the following table. The rest of the results for each model are presented in Appendix A.

Table 9.1 Montclair Census Tract Proportion Coefficient

Census tract proportion	**α_3 Coefficient (robust t-test statistic)**	**α_5 Coefficient (robust t-test statistic)**
pfemale	.0000813 1.33	.00078 2.94***
pwhite	.0028637 3.00***	-.0171576 -3.84***
pblack	-.0033634 -3.39***	.0184994 4.13***
pother	.0003952 1.85*	-.0013925 -1.03

page_under5	-.000146 -3.98***	-.0000739 -0.38
page_5_29	-.0005365 -3.00***	.0012068 1.68*
page_30_64	-.000451 -3.33***	-.0007805 -1.16
page_65_up	.001029 6.10***	-.000403 -0.57
pmarhh_chd	-.0005364 -1.79*	.0002539 0.18
pmhh_child	-2.45e-06 -0.06	.0002933 1.68*
pfhh_child	-.0003317 -1.90*	.002167 2.54***
powner_occ	-.0002585 -0.26	-.0023418 -0.45
pvacant	-.0000826 -1.11	-.0002405 -0.50
prenter_occ	.0003412 0.36	.0025831 0.53

Over the 1987-1997 time period for which we have data for the Montclair area, we will first consider changes in the distance profile of relative concentration for different groups. The α_3 coefficient if negative, conveys that the group in question has been becoming *more* concentrated closer to the Superfund site. Groups that have become statistically significantly more prevalent nearer the site include: blacks, children under 5, young people aged 5-29 and people aged 30-64, as well as (possibly) married heads of household with children and female-headed households with children. Positive α_3 coefficients indicate that a group has become relatively less numerous closer to the site. These groups include whites and seniors, and possibly other non-white ethnic groups.

For houses inside the contaminated areas, a positive α_5 coefficient implies an increase in the proportion of that group over time. The relative share of female residents has become statistically significantly higher over time here, as has the proportion of blacks, female-headed households with children, and possibly young persons between the ages of 5 and 29 and male heads of household with children. In contrast, whites have tended to move away from the contaminated areas.

One notable feature of these results is that there seem to have been no systematic effects on housing tenure or vacancy rates, either on top of the Montclair sites, or close to them.

9.2.2 OII

There are over 50 different Census tracts around the OII landfill. This creates a diversity of different values for neighborhood effects within any one year, and more variation across years in the interpolated Census tract data.

In the 1960's and 1970's, Asian emigrants began to populate what had been a mostly white bedroom community. By the 1980s, racial tension between longtime residents and new immigrants became significant, leading to a controversial law requiring English on business signs, Chinese books in the public library and attempts to make English the city's official language. Racial problems have now mostly subsided and Monterey Park has become the only city in the San Gabriel Valley with an Asian majority.

The pattern in this Southern California community is somewhat different from that in the Montclair and Woburn cases. Our conformable Census measures do not include a distinct category for Asian ethnic groups, so these populations are captured by the "pother" category. Again, only the key α_3 coefficient for each model is presented in the following table. The remainder of the results for each model appear in Appendix B.

Table 9.2 OII Census Tract Proportion Coefficients

Census tract proportion	α_3 Coefficient (with robust t-test statistic)
pfemale	-.0000198 -1.27
pwhite	-.0018906 -10.81***
pblack	.000019 2.57***
pother	.0020202 11.42***
page_under5	.0000226 0.92
page_5_29	.0002393 4.20***
page_30_64	.0003549 6.10***
page_65_up	-.0004772 -10.35***
pmarhh_chd	.0009305 9.33***
pmhh_child	-.0002995 -8.45***
pfhh_child	.0000927 2.21***
powner_occ	.0009346 4.05***
pvacant	.000279 15.02***
prenter_occ	-.0012124 -5.54***

Over the 1970-1999 time period for which we have data for the vicinity of the OII landfill site, groups that have become relatively *more* numerous nearer the site include: whites, seniors, and male heads of household with children (although this last group is very small everywhere). The relative increase in whites near the site could be the flip side of a relative increase in Asian groups at locations further way from the Superfund site. In an area experiencing a wave of immigration, if immigrants avoid tainted neighborhoods and settle away from them, the older racial mix of inhabitants will persist nearer the site. Renter-occupied housing has also become more common near the site.

The groups that have become significantly relatively *less* numerous nearer the site include blacks, and especially other non-whites (including Asians), as well young people aged 5-29, middle aged persons aged 30-64, married heads of household with children and female heads of household with children. Owner occupied housing has become less prevalent near the site, but so have vacant properties. There has been little discernible change in the relative abundance near the site of women or children under 5.

Graphical depictions of the implications of these models are presented along with complete regression results in Appendix B.

9.2.3 Woburn

Our estimating sample contains significant amounts of data from 22 different Census tracts in the Woburn area. Again, only the estimates for α_3 for each model are presented in the following table. The estimates of these key coefficients control for the baseline trend in concentrations with distance, and for trends in the area-wide concentration of each group. See Appendix C for more details on the remaining coefficients in each model.

Table 9.3 Woburn Census Tract Proportion Coefficients

Census tract proportion	**α_3 Coefficient (with robust t-test statistic)**
pfemale	.0000174 0.42
pwhite	.0019515 14.34***
pblack	-.0003281 -14.38***
pother	-.0024137 -14.64***

page_under5	.0002072 5.33***
page_5_29	-.0003548 -1.93*
page_30_64	.0001168 0.93
page_65_up	-.0000607 -0.41
pmarhh_chd	.0016572 6.66***
pmhh_child	-.000145 -11.20***
pfhh_child	-.0006561 -10.69***
powner_occ	-2.66911 -1.54
pvacant	-.0003236 -9.13***
prenter_occ	-.0033483 -7.69***

Over the 1978-1997 time period for which we have data for the Woburn area, groups that have become *relatively* more numerous *nearer* the site include: blacks, other non-white groups, the age 5-29 group, male heads of household with children, female headed households with children, vacant properties, and rental properties. Groups that have become relatively less numerous near the site include: whites, children under 5, and households with children headed by married couples. Groups for which there has been little discernible change in the relative abundance near the site are: females, persons between the ages of 30 and 64, seniors, owner occupants.

Woburn was incorporated in 1652 and leather, tanning, and boot and shoe production was the main industry from the mid-1800's to 1915. Suburban growth began in the mid-1900's and has continued. The site has been described extensively by other authors, including Kiel (1995) and Kiel and Zabel (2001).

9.2.4 Eagle Mine

There are insufficient numbers of Census tracts represented around the Eagle Mine site to allow an analysis of trends in Census tract attributes associated with house sales over time.

9.2.5 Synthesis

It seems eminently clear that there is a strong tendency for fundamental neighborhood change in the wake of a Superfund identification and remediation process. The property prices we use from our analysis stem from house sales, and every time there is a house sale, the occupants of that dwelling typically change. Who moves out and where they choose to go, and who moves in, determines the change in the composition of the community in the vicinity of a site. If the negative price shock accompanying a Superfund designation and the cleanup process make housing in the vicinity of the site more affordable to lower income households, unconventional households, ethnic minorities, or absentee landlords, a sufficient number of sales can detectibly alter the makeup of the community.

There is a considerable literature in urban economics concerning the mechanisms of neighborhood change (invasion-succession, tipping). The precipitating agent for the process, in our cases, seems likely to have been the identification of the Superfund site.

Empirical models may fail to control for neighborhood change over time as a Superfund identification and remediation process takes place. This can lead to omitted variables bias that creates the impression that the Superfund process “taints” a neighborhood long after the site itself has been cleaned up. In reality, what accounts for the persistent negative price differential closer to the site could be the gradient in socio-demographic and income classes approaching the site.

With site-induced neighborhood change, this “income-socio-demographic” gradient will masquerade as a persistent “Superfund site proximity” gradient. When the site is clean, it may be that nobody in the neighborhood or beyond is the least worried about any residual hazard. In fact, having been certifiably cleaned, the site may even appear safer and more environmentally attractive than competing uncertified areas elsewhere in the region. The true post-cleanup “environmental gradient” might even display higher property prices near the cleaned site. However, if one fails to control for the changed “income-socio-demographic gradient,” it is possible to misidentify the phenomenon as a persistent taint or perceived risk due to the site.

9.3 Auxiliary Models: Time-Varying Housing Attributes

The housing stock in a region can change more slowly than the characteristics of the population. Many houses are remodeled and updated, sometimes to include additional bathrooms or perhaps bedrooms, lots are subdivided in order to permit increases in density. In this section, we examine the trends over time in the average characteristics of houses sold, as a function of their distance from each Superfund site. To the extent that the housing stock around a Superfund site is not upgraded or renovated at the same rate as dwellings in the more distant surrounding area, this decline in the relative quality of the housing stock can account for persistent negative price differentials in the region nearest the site. In the text of this research, we report only the most significant effects. For complete models, see the Appendices A-D associate with each site.

The same basic estimating models used for Census tract proportions of different groups in the neighborhood around the site are used in this section (either Equation 9.4, or 9.5 for Montclair). Now, however, the dependent variables are not all proportions of the population of persons, households, or structures. Instead, the dependent variables are discrete or continuous measures of structural attributes of each house itself.

9.3.1 Montclair

For the Montclair site, the data provide very few housing attributes to use in the property value model. We exploit the age variable as completely as possible and substitute the most recent tax assessor's "value of improvements" as a proxy for the current quality of the housing stock. Interpretation of "impval" as a dependent variable is therefore somewhat problematic. We do not observe its value contemporaneously with the sale of the house, but only currently.

Table 9.4 Montclair Housing Attribute Coefficient

Housing Attribute	α_3 **Coefficient (robust t-test statistic)**	α_5 **Coefficient (robust t-test statistic)**
knowflr	-.0032718 -2.30***	-.0065508 -0.73
floors*	.0029175 1.45	.0123721 1.00
ageknown	-.0045979 -2.71***	-.000424 -0.04
age10*	-.0002659 -0.41	.0126552 1.52
age20*	-.0009382 -1.80*	-.0023625 -0.76
age30*	-.0005861 -0.51	-.0050581 -0.59
age40*	-.0111006 -5.79***	-.0137029 -1.13
age50*	.0055656 2.93***	-.0093004 -0.87
age60*	.0016836 0.94	-.002016 -0.33
age70*	.0053225 2.12**	.0208763 1.55
age70plus*	.0003191 0.10	-.0010915 -0.06
age*	.2577415 1.61	.1463102 0.13

lot size	.0002315 0.08	.015799 1.41
* in first column: if data observed;		

The statistically insignificant α_5 coefficients indicate that none of the information about age, floors, or lot size for the Montclair properties displays any tendency to change systematically over time for houses located on top of any of the radium contaminated sites.

The age dummy variables, capturing decade intervals of age for each house at the time it was sold for the observed price, show a few notable patterns. The relative proportion of houses that are less than 40 years old at the time of sale (age40=1) seems to have been increasing nearer the site. The relative proportion of houses more than 40 years old at the time of sale has been falling nearer the sites.

9.3.2 OII

Table 9.5 OII Housing Attribute Coefficient

Housing Attribute	**α_3 Coefficient (with robust t-test statistic)**
age	-.0009755 -0.06
sqft	.0007751 1.03
bedrms	.0020337 1.55
bthrms	.0006031 0.53
fplace	.0022162 3.20***
knowflr	.002548 4.76***
floors*	.0038295 4.12***
lot size	.0026144 3.98***
* calculated only for observations where data are observed	

In the OII sample, the houses sold which are nearest the landfill site are not becoming relatively older than are those at locations further away. More distant houses are also becoming more likely to have fireplaces, to have more than one floor, and to be situated on larger lots.

Lot sizes are getting relatively smaller nearest the site. This suggests more subdivision or R-2 zoning in this area than in more distant areas, where lot sizes are being preserved. R-2 zoning increases density and makes a neighborhood less attractive to many potential homeowners. Lot sizes do not appear to be shrinking farther away from the site.

9.3.3 Woburn

Table 9.6 Woburn Housing Attribute Coefficients

Housing Attribute	α_3 Coefficient (with robust t-test statistic)
notold	6.06e-06 0.01
age*	-.3173891 -3.99***
sqft	.0026118 1.00
bedrms	.0042233 1.33
bthrms	.0109726 3.75***
fplace	-.0060986 -3.52***
knowflr	-.0152776 -8.89***
floors*	-.0051249 -1.59
lot size	-.0026604 -1.04
* calculated only for observations where data are observed	

Over time, houses which are sold nearer the site are becoming differentially older than those sold elsewhere in the sample area. Number of baths per house are increasing over time at points more distant from the site, but not nearby the site. Fireplaces are becoming a more commonplace feature in houses sold at points farther from the site. All this points towards a conclusion that the housing stock nearest the site is not undergoing the amount of renewal and there is not as much new construction near the site as there is elsewhere. If the housing stock near the Superfund site is in decline compared to the stock elsewhere, then it is not surprising if observed housing prices persist in being lower near the site than elsewhere in the sample.

9.3.4 Eagle Mine

The Eagle Mine data come from a different source than the data for the other sites, so the available structural variables are somewhat different.

9.3.5 Synthesis

In none of our examples does it appear that the housing stock nearest the Superfund site is being renewed and upgraded at the same rate as housing at locations further removed from the site. It may be the case that after a sufficient period of time has passed following a cleanup project, and the site is designated as "safe" that homeowners in the area will again undertake to accelerate maintenance of the housing stock to bring it back into line with the typical housing stock in the surrounding area. However, if lower-income homeowners have moved into the area, and if rental rates have increased, this may not set the stage for such accelerated renewal of the stock. Despite cleanup, housing price may remain lower than the surrounding area due to deferred maintenance and slower remodeling schedules or teardowns and replacements.

As in the case of the "income-socio-demographic" gradient created by earlier price differentials due to the Superfund identification and cleanup process, we may see a "deferred maintenance" gradient come into being relative to the location of the Superfund site. To the extent that degradation of the housing stock accompanies a Superfund experience and the attendant income and socio-demographic changes, and persists beyond the end of the cleanup process, this factor may also masquerade as a persistent environmental taint.

9.4 Hedonic Property Value Models with Time-Varying Proximity Effects

Due to the very large number of control variables, and hence estimated coefficients, in each of the models we estimate, we limit our discussion in the text of this research to the properties of the key set of year-specific coefficients that describe the elasticity of selling prices with respect to distance from the Superfund site, by year.

Our key results will be displayed in tables that merely note the presence or absence of the other types of regressors in the specification. An extensive appendix for each site contains the full specifications and other supporting statistical results. In the text of this research, we limit our attention to specifications that constrain the lot size effects to be zero. In some cases, these lot size effects are individually statistically significant, but including this generalization in the model does not alter the general weight of the findings in any case, so we do not emphasize those results.

9.4.1 Montclair

The format of the estimating model for the Montclair sample is somewhat different from the generic specification. Suppressing the β_{11t}, β_{31}, and β_{41} parameters on the lot size interaction terms, the Montclair estimating model is:

(9.8)
$$LSPRICE_{it} = \ln(P_t) + (\beta_{00t})INSIDE_{it} + (\beta_{10t})LDIST_{it} + \beta_2 A_{iT} + (\beta_{30})S_{it} + (\beta_{40})D_{iT} + \varepsilon_{it}$$

Recall that since there are houses being sold that lie inside the boundaries of the radium sites in the Montclair area, we include year-specific dummy variables, $INSIDE_{it}$, for these houses. The coefficients on these variables may also be permitted to vary systematically with lot size, but this interaction is suppressed in this equation. For houses outside the radium sites, we compute the distance from the boundary of the site to each house.

If the radium contamination negatively affects housing prices, we expect the coefficients β_{00t}, in some or all years, will be negative. If proximity to the radium contamination depresses housing prices in some or all years, we expect the coefficients β_{10t} to be positive in those years, reflecting the increase in average selling prices at locations further away from the boundaries of these sites.

The change in neighborhood characteristics over time, in the vicinity of a Superfund site, can contribute to the changes in observed property values that have nothing to do with levels of perceived risk over time.

Table 9.7 presents the portion of the results for the Montclair sample concerning the price differentials for being on top of the site, as well as the distance coefficients intended to capture perceived risks. Complete results are presented in Appendix A.

Table 9.7 Montclair

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
inside87	-.0657	(-.41)	-.06151	(-.38)	-.0907	(-.56)	-.06221	(-.38)
inside88	-.1609	(-.92)	-.1263	(-.7)	-.2015	(-1.15)	-.1822	(-1.01)
inside89	-.0995	(-2.23)**	-.07226	(-1.36)	-.1029	(-2.08)**	-.06194	(-1.1)
inside90	-.02656	(-.56)	.04012	(.76)	-.03043	(-.67)	.01035	(.19)
inside91	-.5115	(-2.28)**	-.4604	(-2.1)**	-.5175	(-2.29)**	-.4786	(-2.13)**
inside92	-.08959	(-1.06)	-.02405	(-.29)	-.1016	(-1.11)	-.05251	(-.58)
inside93	-.2383	(-2)**	-.1378	(-1.13)	-.2408	(-2.02)**	-.1809	(-1.48)
inside94	-.06177	(-1.58)	-.0458	(-1.27)	-.03933	(-.87)	-.041	(-.97)
inside95	-.05908	(-1.33)	-.04211	(-.95)	-.06601	(-1.35)	-.05923	(-1.14)
inside96	-.1324	(-1.94)*	-.1386	(-2.09)**	-.131	(-1.96)**	-.1389	(-2)**
inside97	-.1899	(-.98)	-.205	(-1.1)	-.246	(-1.21)	-.243	(-1.23)
ldis87	-.02189	(-.84)	-.06202	(-2.35)***	-.03166	(-1.24)	-.06222	(-2.39)***
ldis88	.03968	(1.83)*	.01417	(.7)	.0374	(1.76)*	.02204	(1.09)
ldis89	.008715	(.87)	-.02332	(-2.34)***	-.003609	(-.33)	-.02613	(-2.31)**
ldis90	.03492	(2.62)***	-.0007486	(-.06)	.02711	(1.96)**	-.00106	(-.08)
ldis91	.04532	(3.8)***	.02125	(1.83)*	.03412	(2.78)***	.01903	(1.57)
ldis92	.0368	(3.04)***	.008775	(.8)	.02854	(2.32)**	.01049	(.89)
ldis93	.03403	(3.74)***	.01032	(1.19)	.02741	(2.88)***	.01467	(1.59)
ldis94	.05929	(4.19)***	.03949	(2.73)***	.04881	(3.31)***	.04154	(2.74)***
ldis95	.0551	(5.34)***	.03157	(3.16)***	.04518	(4.1)***	.03649	(3.37)***
ldis96	.04956	(4.46)***	.03363	(3.13)***	.04136	(3.57)***	.03739	(3.27)***
ldis97	.09538	(5.62)***	.08996	(5.26)***	.08389	(4.96)***	.09065	(5.37)***
structure	yes		yes		yes		yes	
other distances	no		no		yes		yes	
neighborhood characteristics	no		yes		no		yes	
years	yes		yes		yes		yes	

9.4.1.1 Model 1: No Census Variables or Other Distances

At the Montclair site, the problem was identified prior to the beginning of our data. The first Record of Decision was issued in 1989, whereupon remediation could begin. Remediation was essentially completed by 1997, at the end of our sample period. We are looking for statistically significant price differentials associated with a house being on top of one of the radium contaminated areas, and/or positive coefficients on the log distance variables, suggesting a premium for houses at locations which are exposed to lower risks. We find negative coefficients on the INSIDE dummies in all years, and statistically significant coefficients in 1989, the year of the first ROD, in 1991, in 1993, and again in 1996. The distance premia in this model are all positive after 1987 and statistically significantly different from zero in all years after 1989. These results would suggest significant perceived risks closer to the site.

9.4.1.2 Model 2: Including Census Variables

When we control for variations over time in the socio-demographic makeup of the population near the site, compared to changes elsewhere in the study area, we find that the point estimates for all of the decrements in house value on top of the site shrink in size up until 1996, and only the decrements for 1991 and 1996 remain individually significant. The distance effects actually change sign in the early years, becoming statistically significantly negative in 1987 and 1989, and they lose their statistical significance in 1990 through 1993. If distance captures perceived risk, this perceived risk is only evident in housing prices during 1994-1997, and its magnitude is diminished from what was suggested in Model 1.

In the rest of the results for Model 2, reported in Appendix A, it is notable that the proportion of blacks in the neighborhood makes a very strongly significant positive difference in housing prices in this context. Appendix A also shows changes in the degree of racial integration across the different Census tracts over time. There are several predominantly black communities and several predominantly white communities. Some of these remain strongly segregated throughout the sample period, but a wide range of other communities in the area has become considerably more integrated. Blacks, in particular, have moved nearer to the Superfund site in considerable numbers. It also seems somewhat counter-intuitive that housing prices are highest where there is a higher proportion of vacant dwellings and a higher proportion of renter-occupied units.

9.4.1.3 Model 3: Including Other Distances

When we include only other distances in Model 3, and leave out the Census variables, the patterns in terms of the Superfund proximity variables exhibited in Model 1 are mostly restored, although the point estimates of the distance (perceived risk) effects shrink very slightly. The other distance effects, reported in Appendix A, seem to imply that high points of land (for New Jersey), retail centers, hospitals, roads, Interstate 280, and especially the Garden State Parkway, major water bodies (again, this is New Jersey), and Newark International Airport are considered to be disamenities. Desirable features include: cemeteries, parks, colleges, and airports other than Newark International. All of these seem to qualify as examples of open space, to some extent.

9.4.1.4 Model 4: Both Census Data and Other Distances

This final model wherein the coefficients on neighborhood characteristics and other distances do not depend upon lot sizes more or less preserves the same results obtained for the Superfund site proximity variables attained separately in Models 2 and 3.

9.4.1.5 Models with Lot size Interaction Terms

In Table 9.8, we present just the coefficients on the Superfund proximity variables, but in these four models, we now interact all of the proximity variables, the neighborhood characteristics variables, and other distances variables with lot size to determine whether the premium or discount associate with different attributes is independent of lot size or changes with the size of the parcel in question. Recall that lot sizes are scaled to equal one at the means of the data, to aid in the interpretation of the estimates. At the means of the data, the effective slope coefficient will be the sum of the base coefficient and the coefficient on the lot size interaction term. These models can reveal whether the losses in property values near a Superfund site are borne disproportionately by homeowners selling smaller properties, or whether they are borne disproportionately by homeowners selling larger properties.

Table 9.8 Montclair (with lot size interactions)

	Model 1		Model 2		Model 3		Model 4	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
inside87	1.204	(1.57)	1.328	(1.74)*	1.312	(1.76)*	1.32	(1.72)*
inside88	-.2893	(-1.16)	-.314	(-1.23)	-.2724	(-1.09)	-.2131	(-.81)
inside89	-.156	(-2.17)**	-.09118	(-1.09)	-.1442	(-1.79)*	-.05622	(-.54)
inside90	.03244	(.51)	.07578	(1.04)	.08889	(1.11)	.115	(1.41)
inside91	-.8026	(-2.52)***	-.7539	(-2.39)***	-.8318	(-2.6)***	-.7885	(-2.45)***
inside92	.1341	(1.11)	.1988	(1.65)*	.1736	(1.39)	.2425	(1.9)*
inside93	-.4908	(-1.95)*	-.4436	(-1.83)*	-.4005	(-1.64)	-.3638	(-1.5)
inside94	.08437	(1.05)	.1083	(1.37)	.1253	(1.38)	.1475	(1.56)
inside95	-.01186	(-.08)	-.01322	(-.09)	.03542	(.2)	.001388	(.01)
inside96	.02536	(.28)	.04732	(.54)	.0682	(.75)	.03598	(.36)
inside97	.1995	(.62)	.1772	(.54)	.235	(.72)	.1947	(.57)
ldis87	-2.032	(-1.5)	-2.211	(-1.63)	-2.242	(-1.7)*	-2.195	(-1.61)
ldis88	.2354	(.71)	.3521	(1.02)	.1583	(.48)	.1111	(.31)
ldis89	.08432	(1.63)	.005509	(.08)	.06731	(.85)	.002244	(.02)
ldis90	-.08558	(-1.2)	-.07026	(-.67)	-.1523	(-1.92)*	-.1619	(-1.69)*
ldis91	.4007	(2.08)**	.409	(2.1)**	.4514	(2.3)**	.4508	(2.24)**
ldis92	-.2878	(-1.33)	-.3188	(-1.47)	-.3377	(-1.52)	-.3933	(-1.73)*
ldis93	.2283	(1.65)*	.2368	(1.7)*	.1408	(1.07)	.1374	(1)
ldis94	-.2021	(-2.08)**	-.2102	(-2.07)**	-.2235	(-1.92)*	-.2371	(-1.84)*
ldis95	-.07835	(-.31)	-.0282	(-.11)	-.14	(-.43)	-.05203	(-.19)
ldis96	-.1843	(-1.85)*	-.2274	(-2.16)**	-.2392	(-2.16)**	-.1943	(-1.52)
ldis97	-.5096	(-.86)	-.491	(-.81)	-.598	(-1)	-.5287	(-.84)
vinside87	-.04527	(-1.34)	-.06673	(-1.98)**	-.06854	(-2.06)**	-.08702	(-2.61)***
vinside88	.02927	(1.04)	.001667	(.06)	.01633	(.59)	-.007	(-.26)
vinside89	.04006	(2.54)***	.01334	(.8)	.01808	(1.13)	-.009747	(-.53)
vinside90	.0554	(2.81)***	.02067	(1.15)	.01132	(.57)	-.02621	(-1.33)
vinside91	.06625	(3.6)***	.05084	(2.85)***	.03852	(2.16)**	.02363	(1.23)
vinside92	.05323	(2.85)***	.02485	(1.44)	.02719	(1.47)	.00332	(.18)
vinside93	.07795	(4.94)***	.05211	(3.38)***	.04443	(2.76)***	.03258	(1.97)**
vinside94	.05488	(2.63)***	.04984	(2.36)***	.02964	(1.36)	.02317	(1.02)
vinside95	.0653	(3.54)***	.04575	(2.19)**	.02722	(1.37)	.01563	(.74)
vinside96	.07897	(4.55)***	.07134	(4.05)***	.04789	(2.66)***	.04409	(2.26)**
vinside97	.06813	(2.3)**	.08531	(2.76)***	.05896	(2.05)**	.0669	(2.22)**
vldis87	.02719	(.94)	.002705	(.09)	.03459	(1.15)	.02197	(.75)
vldis88	.01052	(.53)	.0135	(.68)	.02157	(1.04)	.03402	(1.66)*

vldis89	-.0331	(-2.56)***	-.03629	(-2.35)***	-.02188	(-1.66)*	-.01317	(-.76)
vldis90	-.02587	(-1.45)	-.02958	(-1.75)*	.01631	(.9)	.02515	(1.29)
vldis91	-.02399	(-1.46)	-.03508	(-2.14)**	-.006006	(-.38)	-.004871	(-.25)
vldis92	-.01942	(-1.14)	-.02103	(-1.25)	-.0006561	(-.04)	.00637	(.33)
vldis93	-.04774	(-3.15)***	-.04496	(-2.89)***	-.01848	(-1.15)	-.01703	(-.99)
vldis94	.004041	(.26)	-.01731	(-1.09)	.01786	(1.05)	.01603	(.86)
vldis95	-.0126	(-.5)	-.0219	(-.71)	.01796	(.65)	.01531	(.51)
vldis96	-.03439	(-2.23)**	-.0479	(-2.81)***	-.01098	(-.67)	-.01636	(-.81)
vldis97	.02978	(1.1)	.0002769	(.01)	.02711	(1.01)	.01808	(.63)
structure	yes		yes		yes		yes	
distance from nearest site interacted with lot size	yes		yes		yes		yes	
other distances	no		no		yes		yes	
other distances interacted	no		no		yes		yes	
neighborhood characteristics	no		yes		no		yes	
neighborhood characteristics interacted with lot size	no		yes		no		yes	
years	yes		yes		yes		yes	

In the version of Model 1 with lot size interaction terms, the coefficient on the interaction terms for being on top of the site is statistically significant and positive in all time periods after 1988, suggesting that the impact of house prices of being on top of the site gets more positive (less negative) as lot sizes get bigger, and these results control for lot size itself. Where significant, the distance premium for a decrease in perceived risk, which can also be interpreted as a proximity discount for increased perceived risk, gets smaller as lot sizes get larger. This means that houses on smaller lots at any given distance from the Superfund site experience a larger relative decrease in value than do houses on large lots.

In the more complete specification in Model 4, however, with both neighborhood and other distances in the model, lot size effects on the distance premium are much less apparent. Appendix A also displays the lot size effects on all of the other variables. Over half of the Census tract variables, and over half of the other distance variables retain statistically significant lot size effects. In general, the lot size interaction terms have coefficients bearing the opposite sign to the main effects, indicating that the housing price premiums or discounts associated with location decrease in absolute magnitude as lot size grows.

9.4.2 OII

For the OII site, the generic estimating formula suffices. There are no special features to these data. The estimates for the distance effects are contained in Table 9.9.

9.4.2.1 Model 1: No Census Variables or Other Distances

In this model, with no controls for socio-demographic change or distances to other amenities or disamenities, the fitted model creates the impression that the locale of the landfill was systematically more desirable than the surrounding area until about 1983. In 1984, the landfill was closed and the site was proposed for the NPL. Following this, there is evidence of a proximity premium in 1987, 1992, and again in 1999, although a proximity discount is evident at the 10% level in 1989, 1991 and 1997. A Consent Decree was signed in 1989, and construction of some of the remediation measures began in 1991. 1996 was the year of the final Record of Decision and landfill cover work began in 1997, so activity at the site would have been apparent then.

Table 9.9 OII Landfill

	Model 1		Model 2		Model 3		Model 4	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
ldis70	-.09106	(-1.34)	-.07008	(-.99)	-.1274	(-1.71)*	-.08746	(-1.17)
ldis71	-.1911	(-2.86)***	-.153	(-2.28)**	-.2088	(-2.98)***	-.1682	(-2.39)***
ldis72	-.1452	(-3.34)***	-.129	(-2.96)***	-.1767	(-3.81)***	-.1442	(-3.03)***
ldis73	-.1446	(-4.15)***	-.1135	(-3.18)***	-.1642	(-4.17)***	-.1307	(-3.27)***
ldis74	-.1544	(-3.18)***	-.1353	(-2.78)***	-.1842	(-3.5)***	-.1533	(-2.88)***
ldis75	-.1339	(-5.8)***	-.1044	(-4.47)***	-.1461	(-5.55)***	-.1234	(-4.38)***
ldis76	-.08965	(-5.91)***	-.0682	(-4.31)***	-.1182	(-6.14)***	-.09191	(-4.42)***
ldis77	-.09486	(-4.65)***	-.07244	(-3.67)***	-.1215	(-5.12)***	-.09261	(-3.69)***
ldis78	-.07947	(-4.49)***	-.05892	(-3.35)***	-.09687	(-4.36)***	-.07437	(-3.09)***
ldis79	-.02105	(-.53)	.0009394	(.02)	-.04875	(-1.13)	-.01745	(-.4)
ldis80	-.1574	(-3.79)***	-.147	(-3.56)***	-.1827	(-4.29)***	-.1584	(-3.65)***
ldis81	-.1389	(-1.05)	-.1049	(-.8)	-.1629	(-1.22)	-.12	(-.89)
ldis82	.1391	(1.69)*	.1327	(1.56)	.104	(1.16)	.1175	(1.32)
ldis83	-.1294	(-3.28)***	-.1166	(-2.98)***	-.1617	(-3.81)***	-.1318	(-3.1)***
ldis84	-.02547	(-.53)	-.009132	(-.19)	-.05933	(-1.17)	-.03113	(-.61)
ldis85	-.05666	(-1.26)	-.03818	(-.85)	-.08788	(-1.85)*	-.05643	(-1.18)
ldis86	.001428	(.04)	.01342	(.43)	-.03696	(-1.05)	-.005591	(-.16)
ldis87	-.05865	(-2.15)**	-.04202	(-1.56)	-.08905	(-2.8)***	-.05456	(-1.67)*
ldis88	-.0136	(-.25)	.0005704	(.01)	-.04601	(-.81)	-.01318	(-.23)
ldis89	.08966	(1.7)*	.1019	(1.98)**	.05101	(1.03)	.08643	(1.74)*
ldis90	-.03567	(-.96)	-.0164	(-.45)	-.07362	(-1.91)*	-.03331	(-.86)
ldis91	.1127	(1.8)*	.1236	(1.95)*	.07644	(1.11)	.111	(1.61)
ldis92	-.0556	(-2.59)***	-.03762	(-1.8)*	-.08487	(-3.25)***	-.04724	(-1.74)*
ldis93	-.02067	(-.94)	-.005524	(-.25)	-.05289	(-1.94)*	-.01805	(-.64)
ldis94	-.01194	(-.61)	.01012	(.54)	-.04331	(-1.74)*	-.003816	(-.15)
ldis95	.001991	(.05)	.01688	(.42)	-.0317	(-.72)	.003596	(.08)
ldis96	.04686	(1.25)	.06034	(1.67)*	.01493	(.37)	.0459	(1.13)
ldis97	.0606	(1.75)*	.08704	(2.56)***	.03561	(.96)	.0734	(1.98)**
ldis98	-.004532	(-.34)	.009177	(.72)	-.03436	(-1.76)*	-.004028	(-.2)
ldis99	.02549	(2.15)**	.02755	(2.22)**	-.01498	(-.75)	.01017	(.48)
structure	yes		yes		yes		yes	

other distances	no	no	yes	yes
neighborhood characteristics	no	yes	no	yes
years	yes	yes	yes	yes

9.4.2.2 Model 2: Including Census Variables

When we include Census variables, there are no statistically significant proximity premia after the site closure in 1984, with the possible exception of 1992, where the distance effect is negative and significant, but only at the 10% level. The apparent proximity premia suggested by Model 1 for two other years after the landfill closure all disappear. Proximity discounts become more strongly significant in 1989, 1991, 1997, 1999, and possibly in 1996, which was the year of the final ROD.

The coefficients on the Census tract variables are presented with the full results in Appendix B. Housing prices are enhanced in tracts with a higher proportion of females, but are lowered when there are higher proportions of children under 5, married heads of household with children, and male heads of household with children. These Census data are very highly correlated, so one cannot be certain that the independent effects of each variable are being accurately captured. See the auxiliary R-squared values for each one of the Census variables, presented in Appendix B.

9.4.2.3 Model 3: Including Other Distances

If we introduce into Model 1 only a set of other distance variables, not the set of Census tract variables, the apparent proximity premia in the vicinity of the landfill site, evident in Model 1, reappear. These effects are strongly significant in many years prior to 1984, and considerably less so afterwards. Again, there is little evidence in this model of any increase in perceived risk nearer the site.

The distance variables suggest that in this area, churches, Interstate 10, and golf and country clubs are amenities, while cemeteries, Interstates 5 and 605, railroads, rivers (this is Southern California, where many riverbanks are concrete to protect against flash floods), roads, and California State University at Los Angeles are all considered disamenities, as may be the Whittier Narrows Recreation Area.

Table 9.10 OII Landfill (with lot size interactions)

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
ldis70	-.27	(-1.83)*	-.2827	(-1.8)*	-.2855	(-1.83)*	-.2893	(-1.76)*
ldis71	-.1485	(-1.2)	-.175	(-1.27)	-.1823	(-1.31)	-.1592	(-1.04)
ldis72	-.0259	(-.28)	-.09312	(-.93)	-.09609	(-.94)	-.09796	(-.85)
ldis73	-.07654	(-.91)	-.1058	(-1.21)	-.08494	(-.99)	-.08642	(-.87)
ldis74	-.1172	(-1.31)	-.1764	(-1.86)*	-.194	(-1.92)*	-.2076	(-1.92)*
ldis75	-.005313	(-.09)	-.04556	(-.73)	-.04565	(-.61)	-.07106	(-.89)
ldis76	-.1384	(-3.02)***	-.1926	(-4.28)***	-.1906	(-3.08)***	-.2316	(-3.67)***
ldis77	-.09239	(-2.24)**	-.1263	(-2.97)***	-.1348	(-2.2)**	-.1678	(-2.52)***
ldis78	.01811	(.41)	-.06694	(-1.51)	-.03481	(-.56)	-.1049	(-1.64)
ldis79	-.02743	(-.34)	-.0795	(-.95)	-.06993	(-.75)	-.1102	(-1.16)
ldis80	-.1004	(-1.29)	-.1876	(-2.28)**	-.1599	(-1.78)*	-.2106	(-2.22)**
ldis81	.3079	(1.1)	.2662	(.95)	.2934	(1.01)	.2646	(.91)
ldis82	.2359	(1.9)*	.1086	(.86)	.1516	(1.07)	.06886	(.48)
ldis83	-.07051	(-.74)	-.0834	(-.92)	-.08315	(-.86)	-.09621	(-.98)
ldis84	.1435	(1.6)	.08438	(.97)	.05283	(.53)	-.005956	(-.06)
ldis85	.06277	(.89)	.01631	(.23)	-.00965	(-.11)	-.02657	(-.3)
ldis86	.1827	(1.79)*	.154	(1.44)	.113	(1)	.1158	(1.01)
ldis87	-.09714	(-1.95)*	-.131	(-2.58)***	-.1757	(-2.47)***	-.1703	(-2.25)**
ldis88	-.05173	(-.65)	-.05799	(-.73)	-.1172	(-1.28)	-.1056	(-1.09)
ldis89	.1526	(2.01)**	.1368	(1.9)*	.08203	(1.02)	.09581	(1.15)
ldis90	.107	(1.07)	.1163	(1.17)	.0691	(.67)	.09904	(.95)
ldis91	.3504	(3.37)***	.3204	(3.04)***	.2788	(2.33)***	.2747	(2.28)**
ldis92	-.009454	(-.2)	-.01275	(-.26)	-.08638	(-1.34)	-.05117	(-.72)
ldis93	.009659	(.24)	.0063	(.16)	-.07089	(-1.18)	-.03885	(-.58)
ldis94	-.02342	(-.48)	-.004869	(-.1)	-.08747	(-1.28)	-.03493	(-.47)
ldis95	.1405	(2.49)***	.1549	(2.67)***	.08279	(1.12)	.1349	(1.67)*
ldis96	.1152	(1.63)	.1441	(2.05)**	.03524	(.42)	.1013	(1.12)
ldis97	.09979	(1.97)**	.1283	(2.56)***	.04271	(.65)	.111	(1.53)
ldis98	.03436	(1.07)	.05402	(1.59)	-.03338	(-.62)	.0321	(.51)
ldis99	.03965	(1.6)	.05542	(1.92)*	-.03476	(-.68)	.03708	(.61)
vldis70	.1847	(1.37)	.2119	(1.48)	.1554	(1.1)	.2052	(1.37)
vldis71	-.03955	(-.47)	.01896	(.2)	-.02667	(-.26)	-.007716	(-.07)
vldis72	-.1149	(-1.42)	-.03491	(-.4)	-.08224	(-.94)	-.04611	(-.45)

vldis73	-.06112 (-.76)	-.008749 (-.11)	-.08803 (-1.14)	-.04798 (-.55)
vldis74	-.0304 (-.44)	.03737 (.49)	.01076 (.13)	.05655 (.64)
vldis75	-.1062 (-2.25)**	-.04743 (-1)	-.09497 (-1.64)	-.04278 (-.67)
vldis76	.04763 (1.08)	.1328 (2.99)***	.07517 (1.23)	.1502 (2.36)***
vldis77	-.004628 (-.15)	.05602 (1.72)*	.008887 (.17)	.07814 (1.29)
vldis78	-.089 (-2.05)**	.009527 (.21)	-.06312 (-1.08)	.03014 (.48)
vldis79	.005398 (.08)	.07723 (1.13)	.01691 (.21)	.08485 (1.05)
vldis80	-.05687 (-.81)	.04746 (.65)	-.03085 (-.39)	.05572 (.65)
vldis81	-.4912 (-1.56)	-.4108 (-1.29)	-.5125 (-1.57)	-.423 (-1.29)
vldis82	-.07137 (-1.17)	.02564 (.39)	-.04998 (-.65)	.03959 (.47)
vldis83	-.05983 (-.63)	-.02607 (-.29)	-.08017 (-.87)	-.0243 (-.25)
vldis84	-.1691 (-2.12)**	-.09 (-1.22)	-.119 (-1.36)	-.02818 (-.31)
vldis85	-.1112 (-2.57)***	-.04642 (-1.1)	-.07743 (-1.25)	-.0189 (-.3)
vldis86	-.1753 (-1.73)*	-.1323 (-1.25)	-.1492 (-1.33)	-.1136 (-1.01)
vldis87	.03552 (.87)	.088 (2.07)**	.08476 (1.36)	.1174 (1.73)*
vldis88	.03658 (.58)	.05722 (.9)	.05822 (.77)	.08596 (1.06)
vldis89	-.06469 (-1.12)	-.03303 (-.61)	-.0361 (-.52)	-.00754 (-.1)
vldis90	-.1528 (-1.37)	-.1389 (-1.26)	-.1618 (-1.45)	-.1448 (-1.28)
vldis91	-.2477 (-2.63)***	-.2025 (-2.16)**	-.2142 (-2.08)**	-.1698 (-1.65)*
vldis92	-.04449 (-1.18)	-.02181 (-.53)	-.001723 (-.03)	.003867 (.06)
vldis93	-.03445 (-.97)	-.01395 (-.43)	.01704 (.32)	.02118 (.34)
vldis94	.01093 (.27)	.01633 (.36)	.03404 (.57)	.02696 (.4)
vldis95	-.1418 (-2.64)***	-.1395 (-2.55)***	-.1218 (-1.81)*	-.1381 (-1.82)*
vldis96	-.071 (-1.6)	-.08543 (-1.86)*	-.02421 (-.39)	-.05795 (-.84)
vldis97	-.04198 (-1.26)	-.04459 (-1.28)	-.01321 (-.25)	-.04349 (-.7)
vldis98	-.03999 (-1.38)	-.0434 (-1.37)	-.007049 (-.14)	-.0393 (-.68)
vldis99	-.01624 (-.69)	-.02705 (-1.04)	.01472 (.32)	-.03046 (-.54)
structure	yes	yes	yes	yes
distance from nearest site interacted with lot size	yes	yes	yes	yes
other distances	no	no	yes	yes
other distances interacted	no	no	yes	yes

neighborhood characteristics	no	yes	no	yes
neighborhood characteristics interacted with lot size	no	yes	no	yes
years	yes	yes	yes	yes

9.4.2.4 Model 4: Both Census Data and Other Distances

When both Census variables and other distances are included in the model, there are no strongly significant proximity premia after 1983. There is some evidence (at the 10% level) of proximity premia in 1987 and 1992, and some evidence of a proximity discount in 1989 and 1997, the year a Consent Decree was signed and the year landfill cover work began respectively.

The only strongly significant demographic effects in this model remain the positive effects of higher percentages of females and the negative effects of children under 5. There may be a modest decrease in housing values accompanying greater renter-occupancy.

The only remaining apparent disamenities are the I-605 freeway, rivers, roads, and the Cal State campus. The only remaining significant amenity is the I-10 freeway.

9.4.2.5 Models with Lot Size Interaction Terms

Distance effects for models with lot size interaction terms are displayed in Table 9.10. As was the case for the Montclair models, the inclusion of lot size interaction terms tends to lead to lot size diminishing the absolute magnitude of the effect. The interaction terms typically have the opposite sign from the baseline effect of any variable.

9.4.3 Woburn

Very conveniently, Kiel (1995) and Kiel and Zabel (2001) have labeled their six different phases of the process at the Woburn sites: pre-discovery (1975-76), discovery (1977-81), EPA announcement of Superfund listing (1982-84), cleanup discussion (1985-88), cleanup announcement (1989-91), and cleanup (1992). Our results are detailed in Table 9.11.

9.4.3.1 Model 1: No Census Variables or Other Distances

The most interesting feature of our Woburn results is that our simplest models tend to confirm the findings of Kiel and Zabel (2001), who find that housing prices increase with distance from the Woburn sites. In Model 1, we see that the distance elasticities in housing prices are insignificantly different from zero up through the end of the cleanup discussion. Beginning in 1990, however, there is evidence of a positive distance elasticity. The effect appears to dip in 1994, and again in 1997 (probably because of our smaller sample size covering only part of 1997). Otherwise, the distance elasticity ranges between 0.05 and 0.10.

Table 9.11 Woburn

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
ldisw78	-.02852	(-.74)	-.07515	(-2.01)**	-.0816	(-1.93)*	-.1184	(-2.67)***
ldisw79	-.1323	(-1.78)*	-.1633	(-2.24)**	-.1858	(-2.47)***	-.2127	(-2.75)***
ldisw80	-.0005082	(-.01)	-.02039	(-.34)	-.05354	(-.84)	-.07207	(-1.11)
ldisw81	-.05335	(-.63)	-.1036	(-1.24)	-.1366	(-1.58)	-.1565	(-1.79)*
ldisw82	.007758	(.14)	-.04167	(-.77)	-.09406	(-1.66)*	-.1157	(-1.97)**
ldisw83	-.09781	(-1.8)*	-.1412	(-2.74)***	-.1711	(-3.06)***	-.1991	(-3.56)***
ldisw84	.04437	(1.17)	-.1057	(-2.68)***	-.1122	(-2.64)***	-.1772	(-3.91)***
ldisw85	.1042	(2.37)***	-.02891	(-.69)	-.01804	(-.39)	-.0843	(-1.79)*
ldisw86	-.008799	(-.2)	-.101	(-2.39)***	-.1165	(-2.47)***	-.1607	(-3.35)***
ldisw87	-.01143	(-.34)	-.1306	(-3.84)***	-.1179	(-3.11)***	-.1775	(-4.39)***
ldisw88	.04308	(1.54)	-.07725	(-2.64)***	-.08086	(-2.39)***	-.1327	(-3.64)***
ldisw89	.03717	(1.36)	-.08354	(-2.89)***	-.08138	(-2.46)***	-.1365	(-3.84)***
ldisw90	.05218	(1.93)*	-.07328	(-2.62)***	-.0873	(-2.66)***	-.1376	(-3.79)***
ldisw91	.05028	(1.76)*	-.06244	(-2.2)**	-.08535	(-2.52)***	-.1279	(-3.47)***
ldisw92	.07371	(2.63)***	-.03901	(-1.32)	-.05477	(-1.54)	-.0982	(-2.55)***
ldisw93	.07933	(3.6)***	-.02932	(-1.26)	-.03415	(-1.19)	-.08197	(-2.63)***
ldisw94	.04168	(1.67)*	-.08882	(-3.48)***	-.1062	(-3.54)***	-.1525	(-4.79)***
ldisw95	.1095	(4.41)***	-.01088	(-.43)	-.03558	(-1.19)	-.08104	(-2.48)***
ldisw96	.1032	(5.65)***	-.01269	(-.65)	-.04663	(-1.83)*	-.0921	(-3.22)***
ldisw97	.04631	(1.28)	-.0573	(-1.59)	-.1077	(-2.79)***	-.1448	(-3.54)***
structure	yes		yes		yes		yes	
other distances	no		no		yes		yes	

neighborhood characteristics	no	yes	no	yes
years	yes	yes	yes	yes

9.4.3.2 Model 2: Including Census Variables

Model 2, however shows what happens when we introduce our time-varying Census tract information. What once were insignificant or positive distance elasticities now turn negative and significant in many cases. The effect is dramatic. This model does not control for distances to other amenities and disamenities, so we will not yet attempt to interpret individual Census tract characteristics coefficients. However, only the proportion of black and the proportion of male heads-of-household fail to make a statistically significant contribution. This is due to the tiny absolute numbers of these groups in the tracts represented in our sample. In contrast, the only neighborhood variables that Kiel and Zabel (2001) control for are the proportion of unemployed in the Census tract and median household income in the Census tract. They find that the unemployment rate influences housing prices only in the 1982-84 period, and median income influences housing prices only in the 1989-91 period.

Why does the inclusion of time-varying Census tract information have such a profound influence on the distance elasticity of housing prices? The answer seems to lie in the different trends over time in the characteristics of Census tract nearest the site versus farther away. Appendix C presents a full set of regression models and fitted time-and-distance profiles for the neighborhood characteristics associated with each house in our sample. Since our main hedonic price models employ the logarithms of distance, we use the log of distance in these specifications as well. The most substantial socio-demographic effects we discover include:

- The proportion of whites near the site fell more than it did further away.
- The proportion of blacks, while remaining small, grew much more near the site than elsewhere in the sample area.
- The proportion of other ethnic groups grew faster near the site than elsewhere.
- About a 30% growth elsewhere in the sample in the proportion of children under 5 whereas the population of young children nearest the site increases hardly at all.
- The proportion of 5-29 year olds shrank more slowly near the site than elsewhere.

- The population of prime-aged 30-64 year olds grew more slowly near the site than elsewhere, as did the population of seniors.
- There was no discernible difference in the rate of decrease over time in the proportion of married heads of household with children by distance from site.
- The proportion of male heads of household with children, while very small, grew more quickly near the site than further away.
- Female headed households with children grew, close to the site, but declined as a proportion of the population further away.
- Owner-occupancy fell near the site, but remained more or less constant further away.
- Renter-occupancy grew over time near the site, but remained relatively constant farther away.
- There was no discernible difference in the growth in vacancy rates across the sample area.

It must be noted that the suite of Census variables at our disposal are very highly correlated with one another. The appendix reports the R-squared values for auxiliary regressions conducted among the Census variables used in our Models, and these R-squared values are all over 60% and range as high as almost 96%. As a consequence, it will be difficult to attribute variations in housing prices to the independent effects of each of these variables. Collectively, however, they make a considerable difference (for micro-data) to the R-squared value between Model 1 and Model 2, boosting it from 0.49 to 0.53.

9.4.3.3 Model 3: Including Other Distances

Instead of controlling for different and shifting Census tract characteristics, we include distances to other amenities in Model 3. These distances do not vary over time, but their presence in the model also causes the previously significant site distance elasticities to change sign and even become significantly negative. Among the set of other distances, auxiliary R-squared values reveal that the distances to the nearest d_retail, d_hospital, d_church, and distances to the four airports (all of which lie outside the sample area) are highly correlated with the rest of the variables in the model. The coefficients on these particular distance variables are prone to multicollinearity problems.

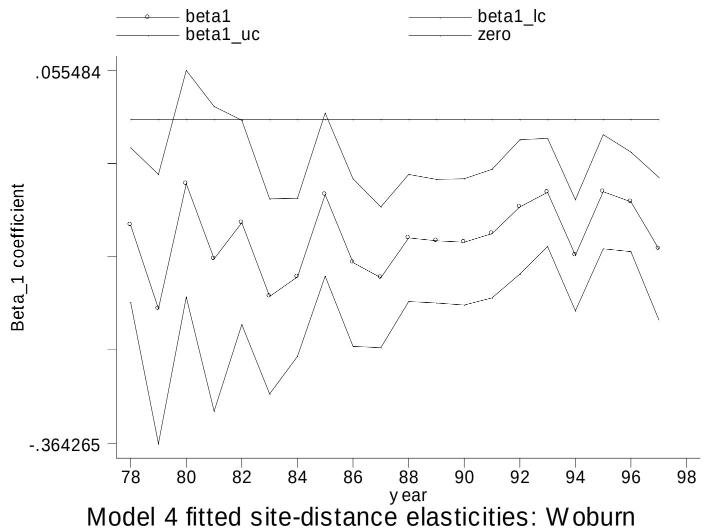
When we do not control for socio-demographic characteristics, it appears that the housing prices increase with distance from: hospitals, churches, railroads, “other” primary roads, smaller roads, Interstate 93, and all four airports. Housing prices appear to decrease with distance from: schools, retail centers, cemeteries, principal arteries, the flight-path of Tew-Mac airport, parks, major water bodies, and golf and country clubs. Each of these effects could be argued to be plausible.

9.4.3.4 Model 4: Both Census Data and Other Distances

In Model 4, where we include both time-varying Census tract characteristics and other distance variables, we find that housing prices seem to vary significantly with a number of individual Census characteristics, although the resolution on these variables is doubtful because of the high multicollinearity. Most plausible are the findings that housing prices tend to vary negatively with the proportion of young people aged 5-29 in the population, and positively with the proportion of married heads of household with children. Many of the “other distance” coefficients lose their individual significance, leaving only the results that prices no longer significantly increase with distance from: churches, and one of the four airports. Prices no longer significantly decrease with distance from: cemeteries, the flight-path of Tew-Mac airport, or golf and country clubs, but they now decrease with distances from summits. This seems plausible, since proximity to a summit is likely to increase the chance of the dwelling having a view.

The striking effect of including these Census tract attributes and other distances in Model 4 is that the site-distance elasticity of housing prices is now negative and significant at the 10% level for all but one year in the 1978-1997 interval. It is significant at the 5% level in all but four years. Next, we need to consider the time profile of these distance elasticities. How do they change over time?

Figure 9.2 Woburn Model 4



9.4.3.5 Synthesis

In a naïve specification, there do seem to be measurable impacts of proximity to the nearest of two Woburn Superfund sites. However, when we control for other distances, it is plausible that the apparent negative effect of proximity to the Superfund sites is just a manifestation of greater distance from other desirable amenities or greater proximity to other undesirable disamenities, including physical features as well as neighborhood socio-demographic effects.

What then of the apparent variations in the effects of proximity to the nearest of the two Woburn Superfund sites over time? There appears to be a substantial likelihood that the negative effect of proximity to these sites towards the end of the sample period in a naïve model like Model 1 may be due to neighborhood transition. Lower housing prices in the vicinity of the Superfund sites can be explained in part by demographic trends in that areas that differ from those in the broader sample area.

There is evidence that Superfund site identification and remediation may at first lower housing prices, but this impact in turn initiates a pattern of in-migration by socio-demographic groups that previously would have been unable to afford housing in this area. Traditional higher-income groups will be inclined to buy elsewhere and lower-income groups will have an opportunity to move in. However, their growing presence may then become the dominant factor keeping downward pressure on housing prices, even though the Superfund remediation takes place.

9.4.3.6 Models with Latitude and Longitude Variables

The Woburn models can differ from the generic model if we allow the absolute location of each house to systematically affect the sales price. This permits a tilted planar spatial pattern in housing prices to overlay the systematic effects due to distance from each house to the nearest of the two Woburn sites; Wells G&H, or the Industri-Plex facility. The rationale for allowing this generalization is that it may pick up the asymmetric spatial effects due to the "characteristic Woburn odor" that was apparently carried generally eastward from the area of the sites by the prevailing winds. The most general model for the Woburn site, short of including lot size effects, is:

(9.9)
$$LSPRICE_{it} = \ln(P_t) + (\beta_{00t})LL_{it} + (\beta_{10t})LDIST_{it} + \beta_2 A_{iT} + (\beta_{30})S_{it} + (\beta_{40})D_{iT} + \varepsilon_{it}$$

Here, LL_{it} denotes vectors of interaction terms between year dummies and the latitude and the longitude of the house location (in decimal degrees, to six decimal places). We also consider models wherein these latitude and longitude dummies in each year are interacted with the distance variable. The models reported in the text of this research do not include this generalization. These results are reported in Appendix C along with other more general models.

Appendix C details models that include latitude and longitude variables by year, and latitude and longitude by year also interacted with log(distance from site), in addition to Census variables and other distance variables. Housing prices appear to be significantly increasing to the east and increasing to the south, overall (or, roughly increasing in the direction of Boston). This is not surprising, and undoubtedly captures an accessibility effect as well as any directional gradient in distance effect for the Woburn sites. Adding these variables to Model 4, discussed above, does not alter its findings concerning the separate effects of the year-specific site-distance variables.

However, there is a glimmer of something interesting when we also interact the site-distance variables with the latitude and longitude variables. The coefficient on site distance then becomes a linear function of the absolute location of the house. For these models, the years 1985 and 1988 develop positive and significant main distance effects, negative and marginally significant latitude*distance effects and longitude*distance effects. The implied formulas for the elasticity of housing price with respect to distance are as follows in these two years:

1985: 0.25 – 5.4 * latitude -3.2 * longitude
1988: 0.35 - 4.3 * latitude – 2.6 * longitude

Latitude increases to the north and longitude increases to the east. However, mean latitude in the sample is 42.50474 degrees and mean longitude is -71.13818. Thus, at the means of the data, the overall effect of distance on house prices is still negative, rather than positive.

9.4.4 Eagle Mine

The Eagle Mine housing sample from the Eagle County Assessor's office does not span enough distinct Census tracts for the differences in socio-demographic characteristics across these tracts to be useful in explaining the variation in housing prices. Only Census tracts 9534, 9535, 9536 and 9537 are represented in the estimating sample, and the total populations for each of these tracts were only 6162, 2480, 166 and 1134 persons at the time of the 1990 Census. If we attenuate the footprint of the data to attempt to get a better picture of the more-nearby housing price effects, we drop to just two Census tracts, which makes of the Census data perfectly collinear. In the spirit of the models used for the other sites, the richest Eagle mine estimating model would thus be just:

(9.10) $$LSPRICE_{it} = \ln(P_t) + (\beta_{10t})LDIST_{it} + \beta_2 A_{iT} + (\beta_{40})D_{iT} + \varepsilon_{it}$$

However, there is more information that can be brought into play in this case. Eagle River flows NNW through the mine site. Several kilometers downstream from the mine site, it is joined by Gore Creek, which flows in from the direction of Vail. The houses in our sample are split between those lying on the Eagle River, downstream of the Eagle Mine site, and on Gore Creek, which is not affected by the mine site. Thus, we differentiate between houses in these two groups, using a set of time-specific dummy variables for houses located downstream of the mine site on Eagle River, rather than Gore Creek, $DOWNSTR_{it}$. We will also interact these timewise dummy variables with the distances from the Eagle Mine site, $LDIST_{it}$ to yield a richest model of the form:

$$LSPRICE_{it} = \ln(P_t) + (\beta_{10t})LDIST_{it} + \gamma_{1t}DOWNSTR_{it} + \gamma_{2t}DOWNSTR_{it} \cdot LDIST_{it} + \beta_2 A_{2T} + \beta_{40}D_{iT} + \varepsilon_{it} \quad (9.11)$$

This functional form allows the effect of proximity to the mine to depend on distance in the following way:

$$\frac{\partial LSPRICE_{it}}{\partial LDIST_{it}} = \beta_{10t} + \gamma_{2t}DOWNSTR_{it} \quad (9.12)$$

The elasticity of selling prices with respect to distance from the Eagle Mine site will be just β_{10t} in year t for houses on Gore Creek. For houses on the Eagle River, downstream of the mine site, the elasticity of selling prices will be $\beta_{10t} + \gamma_{2t}$. If the estimated parameter γ_{2t} in year t is insignificantly different from zero, being downstream of the mine does not affect the elasticity of selling price with respect to distance. If β_{10t} is zero and γ_{2t} is positive, then there is no premium from being further from the mine site if the house is not downstream from the mine on Eagle River, but there is a distance effect if the house is downstream.

In the housing data for this site, there are insufficient numbers of observations to permit entirely separate distance coefficients to be estimated for each individual year. We retain the yearly dummy variables to control for area-wide increases in housing prices in each year, but we constrain the distance and downstream effects to be constant across roughly three-year intervals. To conform with some of the main benchmark years in the site's history, and to create sufficient observations while aggregating as little as possible, we hold the downstream and distance effects constant across the following sets of years: 1976-1979, 1980-1982, 1983-1985, 1986-1988, 1989-1991, 1992-1994, 1995-1997, and 1998-1999.

The site was listed on the NPL in 1986 and a remediation plan was approved in 1988, so there would have been much publicity in the area in the 1986-1988 period. 1996 saw an agreement between the agencies involved and the responsible party to evaluate and possiblely construct a groundwater extraction system, although the capping of the main tailings pile was completed in 1997. This discussion might also have created awareness of the problem in the 1995-1997 period. In 1999, state and federal authorities formally sought to change the cleanup agreement to include pumping of groundwater to keep it from filling the mine and complicating treatment of contaminated water from the mine. The lead-up to this re-opening of the agreement might be expected to influence housing prices in the 1998-99 period.

Empirical results for the distance coefficients are presented in Table 9.12, with complete results relegated to Appendix D.

9.4.4.1 Model 1: No Control for Other Distances

As usual, Model 1 considers distance effects over time, controlling for structural attributes of the dwelling and general appreciation in housing prices, but not for any other distances. This model suggests that distance from the mine site mattered little to housing prices along Gore Creek, but did affect housing prices downstream from the mine along the Eagle River in some years. House prices increased with distance from the mine along the Eagle River in the 1976-1979 period, and in the 1986-1988 period. In 1992-1994, it seems that there were distance effects along Gore Creek, but not along the Eagle River. This is difficult to explain. Thus we consider a richer model, which also controls for other distances that may affect housing prices.

9.4.4.2 Model 2: Controlling for Other Distances

We include in Model 2 the logarithms of distance to the Vail ski area, distance to the nearest recreational area (golf course or country club), distance to the nearest railroad, and distance to the nearest river. The coefficients on the distances to each of these features bears the expected sign and all are statistically significant. The Vail ski area is an amenity, with housing prices decreasing as one moves away from it. Likewise, golf courses and country clubs are amenities, as are rivers. In contrast, proximity to a railway is a disamenity. Housing prices rise as one moves away from the railroad.

Table 9.12 Eagle Mine

	Model 1		**Model 3**	
	Coefficient	t-statistic	Coefficient	t-statistic
ldis79	-.181	(-.57)	-.3849	(-.96)
ldis82	-.3655	(-1.35)	-.4108	(-1.47)
ldis85	-.007467	(-.02)	.1481	(.37)
ldis88	-.1457	(-.7)	-.216	(-.93)
ldis91	.1182	(.7)	.002615	(.01)
ldis94	.4586	(2.66)***	.3133	(1.5)
ldis97	.05625	(.62)	-.1811	(-1.06)
ldis99	.1029	(1.2)	-.0487	(-.27)
downldist79	6.481	(5.56)***	5.702	(4.57)***
downldist82	.9653	(1.22)	1.172	(1.47)
downldist85	-1.42	(-1.73)*	-1.084	(-1.21)
downldist88	1.716	(2.11)**	2.599	(3.01)***
downldist91	-.5503	(-.89)	.4107	(.5)
structure	yes		yes	
other distances	no		yes	
years	yes		yes	

In this model, there are no individually statistically significant distance effects for houses along Gore Creek, which are not likely to be exposed to any contamination from the Eagle River. Downstream, however, there are significant positive distance effects in each of four different time intervals. The largest effect appears to be in the 1976-1979 period, before the site was listed on the NPL. If we knew more about accessibility of residential areas downstream area in this period, it might be possible to say more about this observation. This area, further away from Vail, may have been less accessible in that time period. Significant distance effects appear next in the 1986-1988 interval, during which the site was proposed for the NPL and the remediation plan was approved. This would have been a period of high publicity. The next discernible effect came between 1995-1997. This is when the groundwater flooding problem became apparent and the government agencies involved began to consider groundwater extraction in order to reduce the amount of contaminated water that had to be treated. A further effect is apparent in 1998-1999 housing prices. In this period, the EPA formally proposed a change to the prior agreement concerning remediation plans. It is not surprising that houses downstream of the site might reflect this concern in their selling prices.

9.4.4.3 Models with Lot size Interaction Terms

Appendix D also details a set of models where the context of the dwelling, as opposed to its attributes, affects not the unit price of the house, but the price per square foot of the land that it occupies. We include both the usual lot size independent distance effects, and an interaction term with lot size that allows us to see whether lot size affects the size of the premium for distance from the site. Our models show that there are no strongly significant effects of lot size on the "other distances." If anything, the premium for being closer to the Vail ski area or the local recreation areas (golf and country clubs) is enhanced when lot sizes are larger. (Lot sizes in this model are normalized to one to permit evaluation of compound coefficients at mean lot size.) However, the premium for being further downstream of the Eagle Mine site, now observed for the 1976-1979, 1986-1988 periods and the 1989-1991 periods, is positive. For the first period it increases with lot size, but for the two later periods the premium diminishes with lot size.

The positive effects of greater distance observed for the last two periods in Model 2 above disappear when we move to this more complex model. In this model, however, two downstream simple dummy variables disappear due to multicollinearity and their effects are absorbed by some of the interaction terms.

9.5 Synthesis and Conclusions

This research contributes four additional case studies to the literature on the time-varying effects of localized environmental risks on housing prices. Over the relatively long time horizons involved in Superfund identification and remediation processes, we find that the apparent time patterns in proximity effects on housing prices seem to be confounded by systematic changes in neighborhood composition in the vicinity of these sites. There is some evidence that housing tenure patterns and the housing stock near the site are also altered by the process.

A "reduced form" type specification where individual house selling prices are modeled as depending only upon structural variables, an area-wide price index for housing, and proximity to a Superfund site interacted with time dummies will indeed document observed patterns in housing prices during a Superfund identification and remediation process. However, such a reduced form cannot distinguish between the effect of perceived risk at each distance and the effects of changing socio-demographic or housing stock variables at each distance. To isolate the effects of perceived risk, one must control for these other effects, but at the same time, recognize that these other changes are not exogenous.

The implicit experiment imbedded in an estimated distance effect is a change in the risk associated with increased distance from the site. At a great enough distance, the risk is presumed to go to zero, and so should the property value differential. When, over a long time horizon, property value distance profiles do not return to a zero slope when the risk is reduced essentially to zero, neighborhood change is a potential explanation for persistent price differentials with distance. It is not at all possible to conclude that perceived risk does not respond to cleanup.

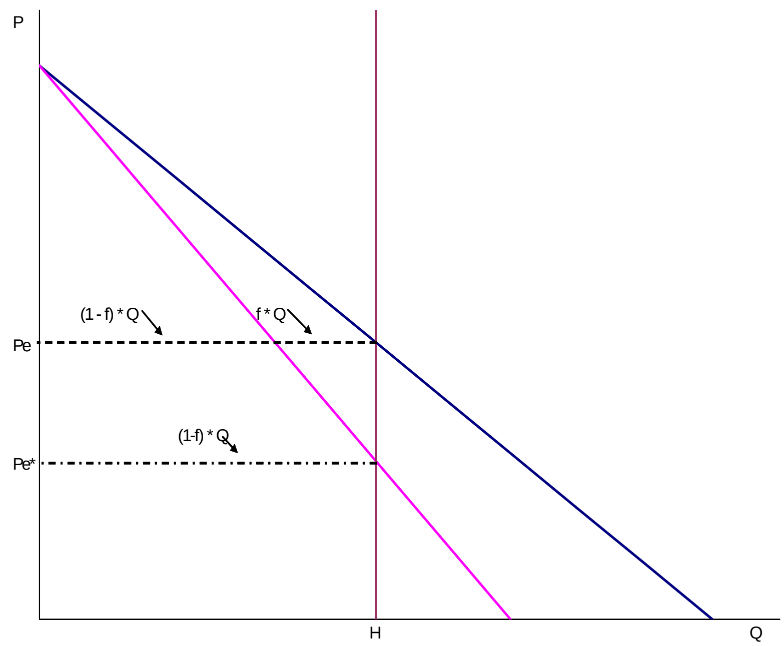
In some cases, especially the Woburn case, we find that controlling for timewise variation in neighborhood characteristics such as gender, ethnicity, the age distribution, family structures and housing tenure reveals very little in the way of a remaining distance profile, so that any inferences about persistent risk perceptions are difficult to make.

Chapter 10

Conclusion: Stigma and Property Values

The possibility that stigma may cause large losses in property values has been noted by other researchers (e.g., Dale et al., 1999; Adams and Cantor, 2001) and the EPA (Harris, 2004). In contrast to the hedonic approach (Rosen, 1974; and for application to hazardous sites see Bartik, 1998; Harris, 2004; Harrison and Stock, 1984; Ketkar, 1992; Kolhase, 1991; Mendelsohn, et al., 1992; Michaels and Smith, 1990; etc.) where risk is treated as one of many attributes that contribute to a determination of sale price, stigma is likely to effect property values in a rather different and more direct manner. Upon learning of the contamination potentially affecting their community, some current home owners may simply be unwilling to continue to live in their home, and likewise, potential buyers will be unwilling to consider buying a home in that community. If some owners and buyers have lexicographic preferences, the standard hedonic model fails since it relies on a tradeoff between risk and home prices. Rather, shunning by both current owners and potential home buyers will reduce the total demand for housing for a neighborhood near a site as shown in Figure 10.1. Imagine that the total demand for homes in a particular fully built-out neighborhood with H existing homes is Q(P) where Q is the number of desired homes, P is the sale price, and quantity demanded falls with price, $Q' < 0$. If, for example, homes were sold in a competitive uniform price auction, the equilibrium price, P_e, is obtained by solving $H=Q(P)$, so $P_e=Q^{-1}(H)$. Now consider the case where a fraction f of home buyers and owners shun a neighborhood because of a nearby Superfund site. The usual hedonic model cannot handle this phenomenon because the hedonic price adjustment for these individuals, either through very high subjective risk beliefs (assuming conventional values of statistical life) or shunning would give homes a risk deficit greater than or equal to the value of the home. In other words, in either case the perceived costs of staying in the home are greater than the entire value of the home and the observed behavior would be identical. This implies that fraction f of current owners will sell and that the number of potential buyers will be reduced by fraction f as well. As shown in Figure 10.1, since we have defined total demand for the neighborhood to include current owners, the equilibrium price will now be determined by the solving $H=(1-f)Q(P)$, so $P_e^*=Q^{-1}(H/(1-f))$ and $P_e^* < P_e$ for $f > 0$. If f falls with distance from the site, as is likely since perceptual cues decline with distance, then property values will rise with distance, *ceteris paribus*. Of course, relative demand for housing that is more distant from the site will increase, but presumably this increase in demand will fall on a much larger group of homes, resulting in a negligible increase in prices of homes farther from the site.

Figure 10.1 The Effect of Stigma on Equilibrium Housing Prices

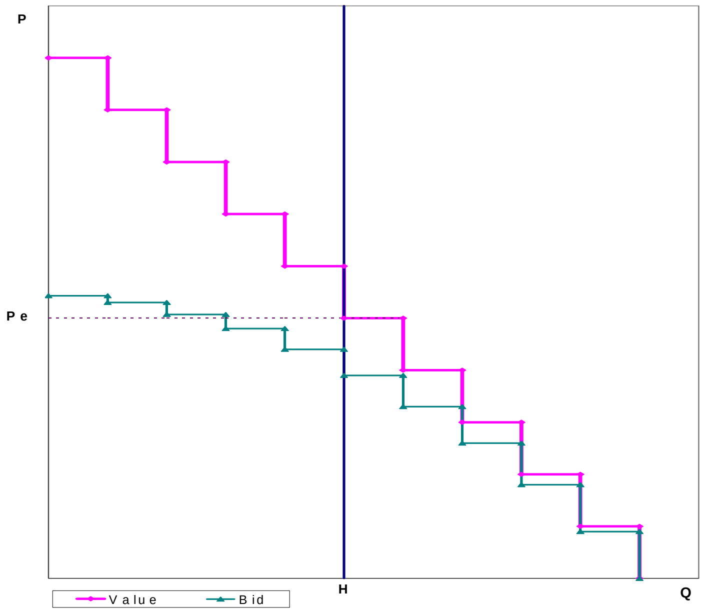


The next question is, since a hedonic analysis is used to incorporate normal attributes for predicting property prices, how can downward sloping demand be incorporated into the analysis? The answer proposed here is that hedonic models predict an average price based on home and community attributes, but do not take into account individual buyer characteristics, including bidding errors, which will affect the willingness to pay for homes in a particular area. So, for example, relative to a predicted hedonic price, P_h, one particular individual will be willing to pay more because grandmother happens to live in the neighborhood and another particular individual will be willing to pay less because of a random error in bidding strategy. Clearly no hedonic market can exist for such attributes since they are buyer specific, and these sale price deviations will appear as part of the error term in the estimated hedonic equation. Thus, for homes with a particular set of hedonic attributes in a homogenous neighborhood with a mean sale price of P_h, there exists an array of values for homes among potential buyers, V, with a cumulative distribution function of Q(V). Presumably, the H buyers with the highest individual values will own homes in the area.

To further understand the property value market, we model the market itself as a discriminative auction to account for the fact that identical homes in the same neighborhood can, in fact, sell for different prices depending on unobserved individual buyer errors and other attributes (see Cox et al, 1984, for a discussion of the relevant theory and an experimental test of this auction). Approximating the property value market with an appropriate auction where multiple buyers compete for available homes solves the potential problem associated with modeling real estate sales as bilateral negotiations where some sellers potentially have no value. Rather, in a discriminative auction other potential buyers provide competition that maintains the price at a higher level than that which would be predicted by bilateral negotiation. The properties of a discriminative auction are well understood, and this auction provides a reasonable approximation of the real estate market under the special circumstances where homes near a site are stigmatized.

As previously discussed, sellers in our model may have little or no value for the homes they are selling since they shun the site. Thus, any price they can get for the home is acceptable. This corresponds to an auction situation where buyers bid on H homes put up for sale, and the H bidders with highest bids obtain the homes for the prices bid. Figure 10.2 shows this market in the context of total demand where all homes in a neighborhood are potentially up for sale. Note that the bids in a discriminative auction (shown as the lower step function) fall below the true values (upper step function). Note also, that compared to the price that would be obtained in a uniform price auction giving a price, P_e, in a discriminative auction there is a distribution of bids and sale prices around the equilibrium price, since buyers pay accepted bid prices. In a discriminative auction, it is well known that if buyers are risk neutral, the average of the accepted bids will equal the uniform price, so revenue neutrality exists in theory between uniform price and discriminative auctions. Note also that risk aversion will increase bids in a discriminative auction and bring them closer to true values because buyers trade off the gain in consumer surplus of a lower accepted bid against the reduced probability of having their lower bid accepted. The lower bid curve shown in Figure 10.2 assumes risk neutrality and plausibly provides a lower bound for bids in a real estate market.

Figure 10.2 Discriminative Auction Market



With these concepts in mind, we can then turn to the hedonic model used to estimate property values at each of our study sites described in Chapters 8 and 9. The hedonic model estimated to explain property values uses a logarithmic specification and takes the form:

(10.1)
$$SPRICE_{it} = P_t DIST_{it}^{b_{1t}} e^{b_2 A_{iT}} e^{b_e S_{it}} e^{b_4 D_{iT}} e^{\varepsilon_{it}}$$

Here, P_t is an area-wide price index for owner-occupied housing in year t, $DIST_{it}$ is the distance of each dwelling from the Superfund site in question. The coefficient associated with this variable will be allowed to differ across years by interacting the constant distance measure with yearly dummy variables. The vector A_{iT} is property attributes and S_{it} is a vector of (interpolated) time-varying characteristics of the Census tract in which the dwelling is located, and D_{iT} is a vector of the logarithms of the distances from the dwelling to a potentially relevant set of other spatially differentiated local amenities or disamenities, calculated at time T, the end of the sample period, rather than contemporaneously.

Taking the logarithms of both sides of the equation yields a version of this model that is appropriate for estimation:

(10.2) $$LSPRICE_{it} = \ln P_t + b_{1t} LDIST_{it} + b_{2t} A_{iT} + b_{3t} S_{it} + b_{4t} D_{iT} + \varepsilon_{it}$$

where $LSPRICE_{it}$ denotes the logarithm of the observed selling price, $\ln P_t$ will be captured as an intercept for the first year in the sample and a set of intercept shifters activated by year dummy variables. The variables of key interest are the $LDIST_{it}$, which consist of a vector of logged distances from the dwelling to the Superfund site interacted with yearly dummies in order to permit year-varying elasticities of housing prices with respect to distance to the site. Geographic Information Systems techniques were used to measure distances from the homes to the closest Superfund site in the specific year, t, that the sales price was observed and the distance to other local amenities or disamenities as they existed in year T.

As discussed previously, n obvious disadvantage of our sample described in previous chapters is that in all of our data sets we only observe selling prices for the most recent sale of a house. If a house is in an area where turnover is high, there will be more recent sales and fewer earlier sales. For analytical purposes, it would be preferable to have data on all sales in all years and selling price in those years, but such data do not exist. Data could be purchased from Experian every year, if a future study could be anticipated, but retrospectively, the data are not available. The data are collected primarily for current marketing purposes and records are updated without saving their previous values. Historical modeling is not a use anticipated by the providers of the data. Consequently, there may be some systematic sampling. We observe earlier transactions prices only for houses which are still occupied by the owners who purchased them at that earlier date. We do not observe many early transactions prices for houses in neighborhoods where there has been a lot of turnover. It must be a maintained hypothesis that rates of turnover are uncorrelated with identification and cleanup of Superfund sites. This may be a strenuous assumption, but there are few alternatives. So it will be necessary to speculate upon the types of biases this non-random selection is likely to produce in the effects of distance from a Superfund site on housing transactions prices.

However, a distinct advantage exists of only having one observation for each home in the sample. By only having one observation per house and controlling for area-wide price index with dummy variables, we ensure that each observation is independent. Therefore, the coefficient b_{1t} (the effect of distance from the Superfund site on property values) can be observed over time by looking at the hedonic estimates for each year over the 20-30 years of observations that have been obtained for each of the sites. To dampen noise, we average b_{1t} the coefficients over three-year intervals. To get time trends in property values as affected by the site, we normalize both by the initial three-year period property value effect, t=0, and by distance. Thus, we ask the question, at a minimum distance from the site, $DIST_{\min}$, how do property values compare to price at distance $DIST_{\max}$ (the boundary of the available data), which was chosen to be sufficiently far away such that no effects of the site should be present, and to the magnitude of this effect in the initial period. The relative property value effect, normalized by base period and by property values at a large distance is defined as

$$R_t = \left(\frac{DIST_{\min}}{DIST_{\max}} \right)^{b_{1t} - b_{10}} \tag{10.3}$$

Thus, the index for each site starts at 1.0 (or 100% in the figures below) and either decreases or increases in successive three-year periods from this value. Table 10.1 presents the results for each of the case studies.

As can be seen in the Figures 10.3, 10.4 and 10.5 presented below, relative property values of the three metropolitan case studies (OII in Los Angeles, Industri-Plex and Wells G&H in Woburn, and Montclair, New Jersey) tend to follow an overall declining trend consistent with the notion of progressive stigmatization of the site as suggested by arguments from psychology. This result is in contrast to a number of earlier studies that examined property values over shorter time periods (Carroll et al., 1996; Kiel, 1995; Kiel and Zabel, 2001).

Table 10.1 Distance Coefficients

	Time period	Avg. Distance Coefficient	Normalized Value
OII Landfill	1970-1972	-0.133	100.00%
	1973-1975	-0.136	100.79%
	1976-1978	-0.086	86.25%
	1979-1981	-0.099	89.65%
	1982-1984	-0.015	68.94%
	1985-1987	-0.039	74.28%
	1988-1990	0.013	63.03%
	1991-1993	0.015	62.65%
	1994-1996	0.015	62.65%
	1997-1999	0.027	60.46%
Montclair	1987-1989	-0.022	100.00%
(Outside)	1990-1992	0.009	90.65%
	1993-1995	0.031	84.81%
	1996-1997	0.064	76.51%
Montclair	1987-1989	0.102	100.0%
(Inside)	1990-1992	0.174	92.9%
	1993-1995	0.094	100.8%
	1996-1997	0.191	91.1%
Woburn	1978-1979	-0.166	100.00%
	1980-1982	-0.115	87.96%
	1983-1985	-0.154	97.01%
	1986-1988	-0.157	97.85%
	1989-1991	-0.134	92.35%
	1992-1994	-0.111	87.12%
	1995-1997	-0.106	86.04%
Eagle	1976-1982	-0.814	100.00%
	1983-1988	2.134	83.88%
	1989-1994	4.815	71.48%
	1995-1999	1.966	84.72%

Figure 10.3 Relative Property Value over Time for OII Landfill, California

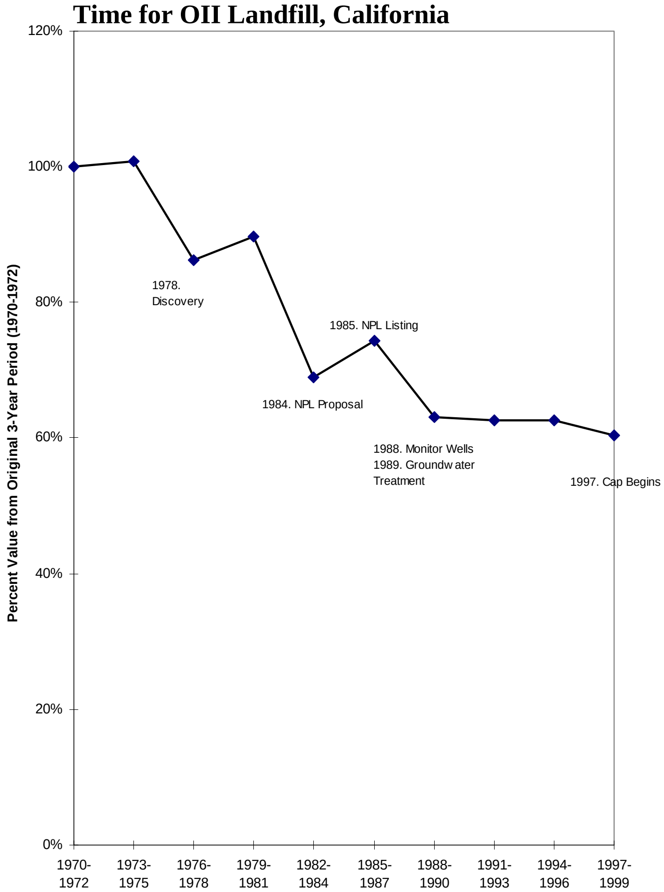


Figure 10.4 Relative Property Value over Time for Montclair, New Jersey (outside of area)

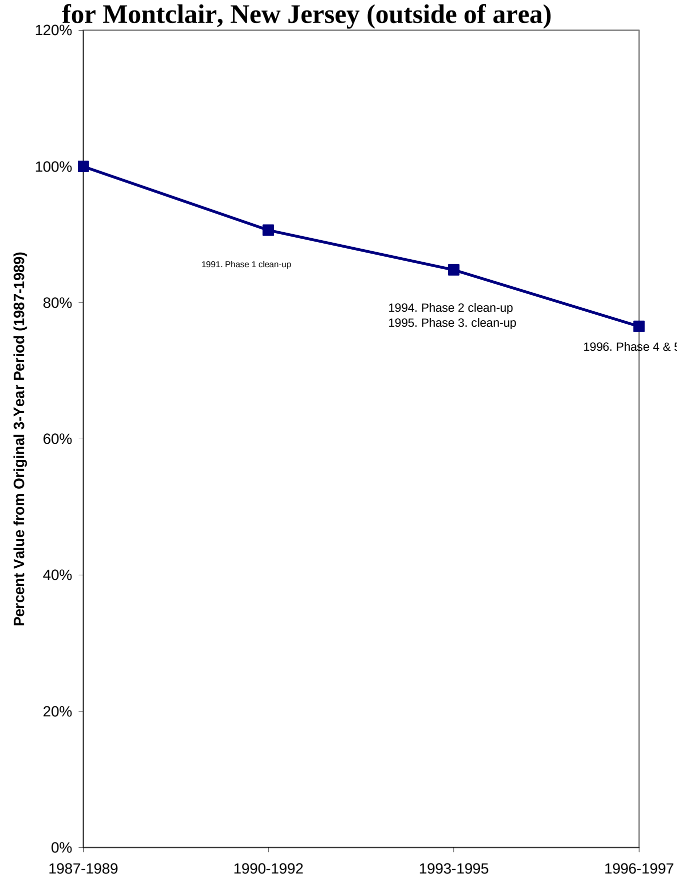
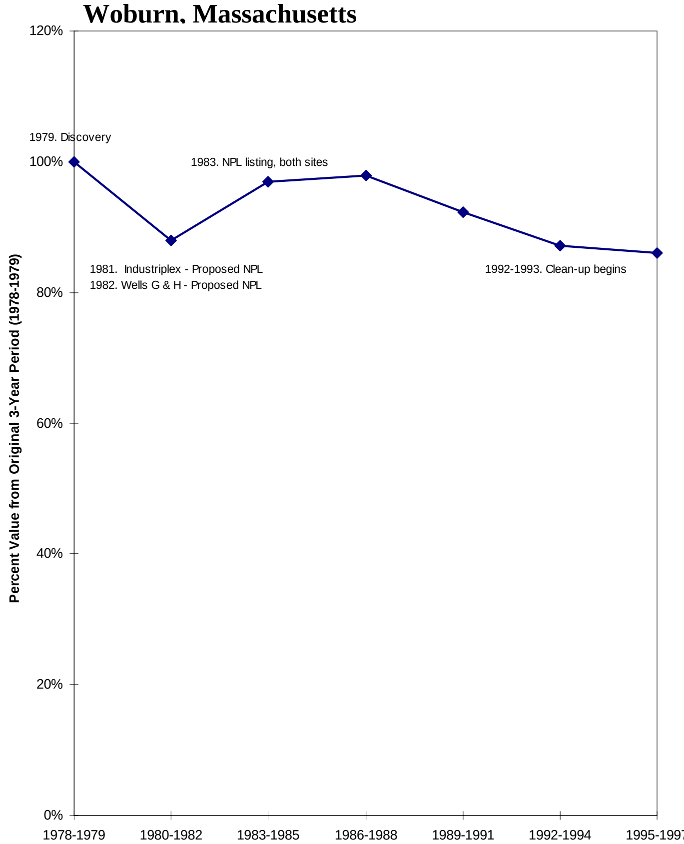


Figure 10.5 Relative Property Value over Time for Woburn, Massachusetts



What explains the long term downward trends observed in relative property values shown in Figures 10.3-10.5? If the trend is driven by f, the fraction of home owners and potential buyers who shun homes near the site, a model of the determination of f over time is needed. From the discussion of the psychology of risk perception and stigma, the determination of the fraction of shunners will be driven by media attention and perceptual cues resulting from activity at the site, which are in turn driven by “events” such as EPA announcements, discovery, NPL-listing, and cleanup. Thus, it is plausible that the percentage change between periods in the fraction of the population who shun the site is a linear function of events of type j occurring during the prior interval, characterized by the discrete dummy variable (or index summarizing a number of dummy variables), $E_{j,\,t-1}$, thus

(10.4)
$$f_t - f_{t-1} = \alpha + \sum_j \beta_j E_{j,t-1}$$

So, in a period with no events, $E_{j,\,t-1} = 0\ \forall j$, we hypothesize that α is negative and f will decline, thereby raising home values, because some people who know about the site will leave the area (perhaps because of job opportunities elsewhere) and some new potential buyers will move into the area who will have no awareness of the site. Other events, such as cleanup activities, might, (a) raise awareness and thereby increase the fraction of the population who shun the site, or alternatively, (b) reduce the fraction of shunners by convincing people who know about the site that it is now safe. This latter possibility is unlikely in that the notion that, "once contaminated, always contaminated" is part of the psychology of stigmatization. Note, also, that changes in perceived risk for those who may not shun the site will likely follow a similar model.

There is no available data on f, so the model specified above cannot be estimated directly. However, if one assumes a constant elasticity of demand, $\eta<0$, and risk neutrality, a simple transformation exists between f_t and R_t as defined above: $f_t = 1 - R_t^{-\eta}$. Thus, the equation describing movement in f_t can be rewritten as:

(10.5)
$$R_t^{-\eta} - R_{t-1}^{-\eta} = -(\alpha + \sum_j \beta_i E_{j,t-1})$$

To employ this transformation we need to know the relevant elasticities of demand that depend. Since we do not have this information, we assume that the elasticities are all -1.0, consistent with a linear approximation of the relationship between f and the change in R. over time.

Table 10.2 Number and Description of Events

	Number of Events			
Event Type	**OII**	**Montclair**	**Woburn**	**TOTAL**
EPA Action	11	3	14	**28**
State Government Action	6	1	4	**11**
Local Government Action	10	1	0	**11**
Public Action	2	1	9	**12**
Potentially Responsible Party Action	7	0	0	**7**
Remediation Action	6	4	3	**13**
EPA Announcement	12	3	8	**23**
Site Incident	5	2	12	**19**
TOTAL	**59**	**15**	**50**	**124**

Table 10.2 presents a psychological model using the data shown in Figures 10.3, 10.4, and 10.5 of relative property values over time for the three metropolitan sites. Note, as mentioned earlier, Eagle Mine was excluded from this analysis because the socio-demographic information for the homes were unavailable. Since all of the home sale observations were independent, a simple linear regression could be used with 18 observations of changes in relative property value ($R_t^{-\eta} - R_{t-1}^{-\eta}$) over the three-year periods for the three sites. For Discovery, NPL Listing, and the Beginning of Major Phases of Cleanup, dummy variables were used. The variable "Events" was derived by summing the number of major announcements and actions described in EPA published reports for the relevant three-year interval for each of the three case

studies (Table 10.4). Note that such events will be highly correlated with and drive important perceptual cues defined in Chapter 7 such as noise, odor, truck traffic, visible on site activity, and media coverage. Events are defined as follows:

- **EPA Action –** Includes site investigations, orders, notifications/decisions, remediation, legal actions, and regulations by the EPA.

- **State Government Action –** Includes site investigations, orders, resolutions, remediation, lawsuits, reports, and regulations by state agencies.

- **Local Government Action –** Includes site investigations, orders, resolutions, remediation, lawsuits, reports, and regulations by local cities, county, and school districts.

- **Public Action –** Include the creation of public interest groups, major meetings and protests, lawsuits by the residents, and the hiring of technical advisors for the community.

- **Potentially Responsible Parties Action –** Include site operation and closure, committees formed, and lawsuits by PRPs.

- **Remediation Action –** Includes containment of contaminations, remediation efforts and site improvements.

- **EPA Announcement –** Includes official Consent Decrees, Record of Decisions (RODs), and announcements of settlements with PRPs.

- **Site Incident –** Includes general site facts, reports and studies regarding the contaminants and occurrences at the site.

The analysis across the three sites shows that discovery, cleanup itself, and the number of events all negatively affect property values by drawing attention to the site and possibly increasing the number of owners and potential buyers who shun the site thereafter (Table 10.3). Thus, the effect of any events, publicity or site information, good or bad, appears to increase the fraction of the current home owners and potential buyers that stigmatize and consequently shun the communities neighboring the sites. In other words, at least within the observed period of the studies, all news is bad news and causes relatively permanent property value losses as an increasing fraction of original owners leave and more potential buyers shun the site. The only good news in the study is that property values did significantly recover for a short period after sites were listed on the NPL. But, it is likely that as soon as it was realized that EPA could not immediately clean up the sites, the process of stigmatization began with consequent reduction in property values. Given the small sample size, it is remarkable that all of these coefficients are significant at better than the 1% level.

Table 10.3 Psychological Model, Dependent Variable $R_t - R_{t-1}$

Model	**B**	**t**	***p***
(Constant)	0.078	3.578	0.003
Discovery	-0.160	-4.493	0.001
NPL – Listing	0.105	4.097	0.001
Clean-up Begins	-0.096	-4.753	0.001
Number of Events	-0.016	-6.156	0.000

N=18
R^2 = 0.855

Rather than property losses reversing immediately once cleanup begins, we see no permanent recovery in property values within the time period of our data and speculate that recovery will only occur as the local population gradually moves away, events cease, and perceptual cues and media attention disappear, so more buyers are uninformed. Note that McClelland et al. (1990) found that most buyers were uninformed in spite of reporting requirements. The positive intercept in the psychological model (significant at the 5% level) indicates that property values will increase at a linear rate of about 12% every three-years if no actions are taken and no news is generated by the site. Thus, at OII one could expect a complete recovery in about a decade if no news is generated from the site and recovery might occur in about half that time for the other sites.

The sites excluded from the model are also of some independent interest. First, although Eagle Mine (see Figure 10.7) has very different characteristics from the three sites discussed above, it shows a similar pattern in that relative property values decline for most of the period analyzed. Given the small amount of data available along the Eagle River, we are forced to use six-year rather than three-year periods for the analysis but do confirm the general pattern shown above. Second, the "inside" Montclair property value estimates do not use distance as an explanatory variable since the homes themselves are within the Superfund site. Yearly dummy variables averaged over the same three-year intervals used in the outside-Montclair analysis show that, unsurprisingly, cleanup itself does have a positive impact on property values (Figure 10.6). Third, another interesting result in the property value studies is the effect of including socio-demographic variables. As shown in Figure 10.8, these make a large difference in the magnitude of property losses at the Woburn site. Negative socio-demographic trends, that may be the result of the progressive stigmatization of the site, also take a substantial toll on property values (that are not included in the psychological model), but possibly should be included in any damage assessment. These results suggest a different trend than observed by Kiel and Zabel (2001) which did not account for these socio-demographic affects.

Since economic benefits are based on discounted present value, the benefits of delayed cleanup for homes surrounding sites are likely to be negligible where cleanup takes 20 years and another 5-10 years may be needed after cleanup is complete for property values to recover. The principal policy conclusion becomes evident from the results of the psychological model which suggest that the promise of a prompt cleanup raises property values, while an increase in the number of events that are the root causes of perceptual cues and media attention decreases property values. Thus, an expedited cleanup should occur as quickly as possible after a site has been determined to be hazardous and this cleanup should be conducted in a way that does not arouse excessive attention. Otherwise the neighborhoods surrounding the site will likely be stigmatized resulting in quasi-permanent economic damages.

Figure 10.6 Relative Property Value over Time for Montclair, New Jersey (inside of area)

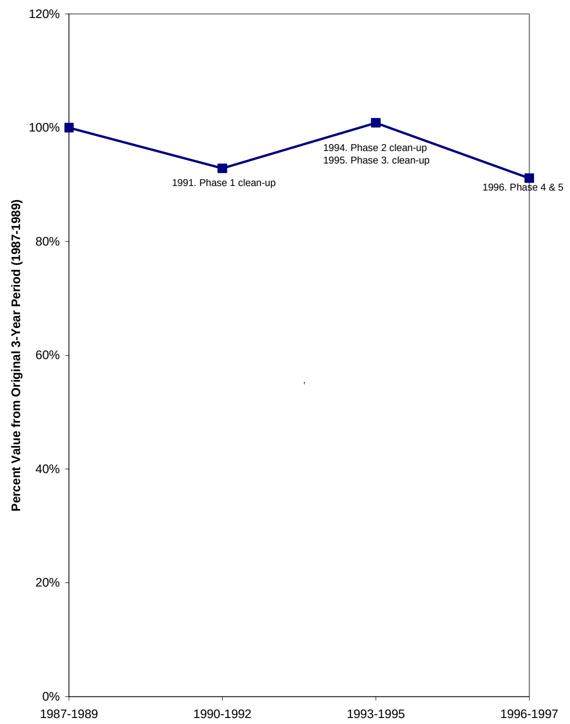


Figure 10.7 Relative Property Value over Time for Eagle Mine, Colorado

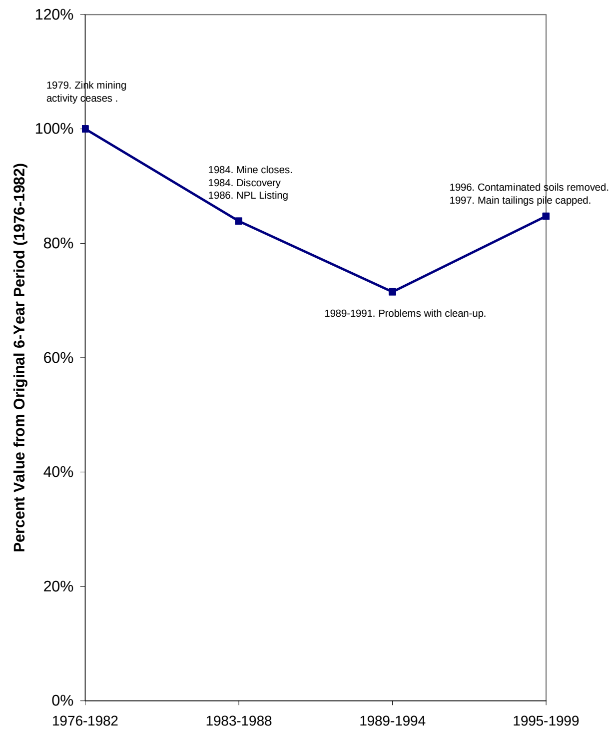
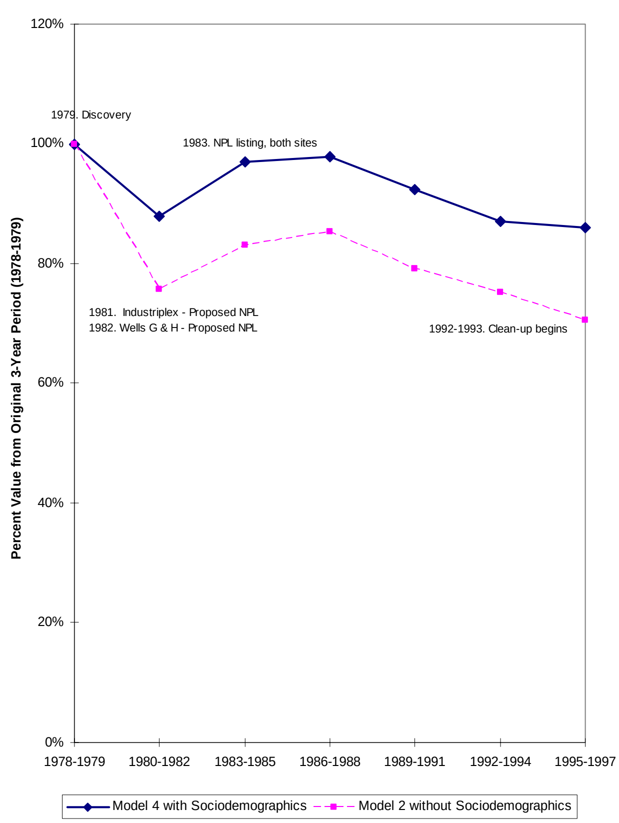
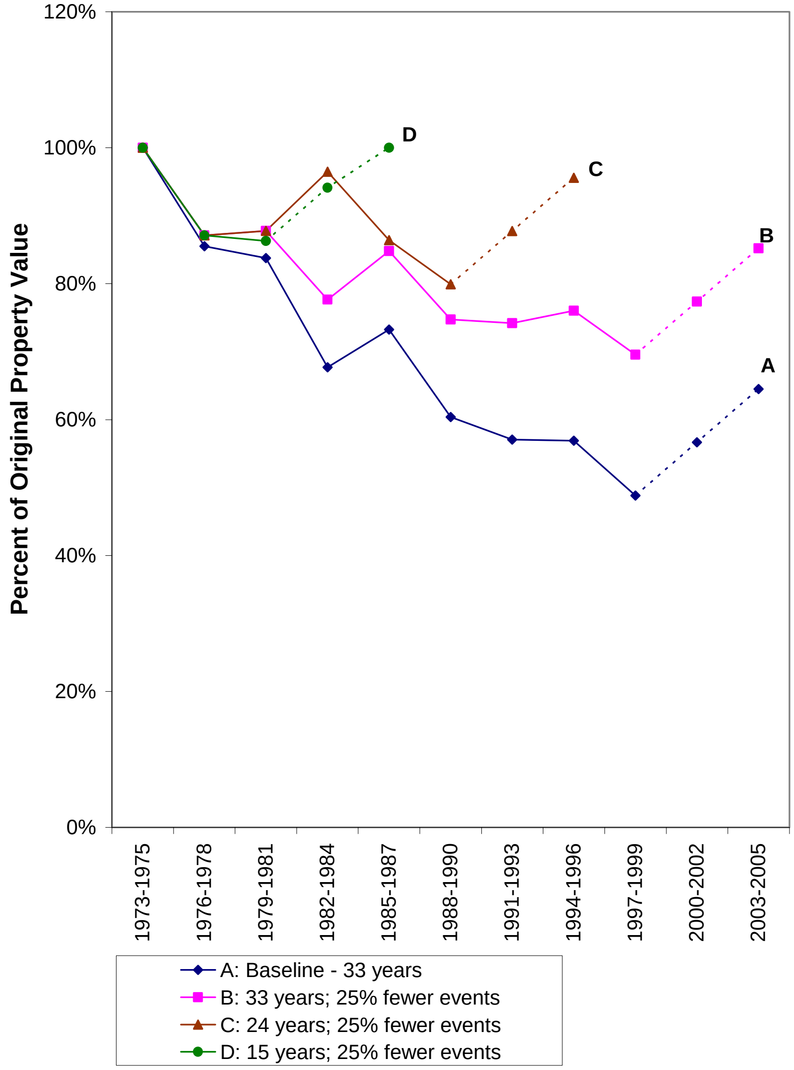


Figure 10.8 Relative Property Value over Time for Woburn, Massachusetts with and without socio-demographic variables



Using the history of the OII and the corresponding events and dates in a simulation, the potential benefits of these policies becomes evident (Figure 10.9).

Figure 10.9 Policy Simulations using the OII Landfill History



As shown in Table 10.4, this simulation considers four different scenarios and includes an extrapolation of a recovery in property values after cleanup is complete where there are no further events. Given the legislative history of Superfund, some of these scenarios are clearly fanciful, but the results are nevertheless suggestive as to what potential benefits could be obtained by expediting the cleanup process and reducing the number of events that drive perceptual cues, media attention, and social amplification. These results support several of the suggestions made by Kunreuther and Slovic (Chapter 21, 2001) for reducing stigma. In particular, they suggest prevention of the occurrence of stigmatizing events and the reduction of the number of stigmatizing messages and thus reducing social amplification.

Table 10.4 Cleanup Scenarios

	Time Horizon	Events	Discovery	NPL Listing	Cleanup time periods	Recovery time periods	Final % of Original Value
Scenario A	33 years	All	1978	1985	1988-1990 & 1997-1999	2002-2005	64.5%
Scenario B	33 years	25% Fewer	1978	1985	1988-1990 & 1997-1999	2002-2005	85.2%
Scenario C	24 years	25% Fewer	1978	1982	1985-1987 & 1988-1990	1990-1995	95.6%
Scenario D	15 years	25% Fewer	1978	1979	1979-1981	1982-1987	100.0%

Note that these results directly contrast with those of Gayer, Hamilton and Viscusi (2000) and Gayer and Viscusi (2002) who argue that media attention supports learning that leads to a lowering of public risk perceptions more consistent with scientific evidence for smaller sites. No credible evidence supports a significant long-term health risk to residents living near OII (McClelland et al. 1990). Yet the actual property value losses are enormous. One difference is that this study focuses on prominent sites while the two studies cited above focused on less prominent sites. Note that most potential benefits from cleanup are likely to come from prominent sites.

It is interesting to note that Carol Browner did in fact institute reforms to USEPA policy in 1995 to at least partly attempt to avoid the pattern shown in this study. EPA began to work with PRPs in an attempt to negotiate sufficient cleanup at potential Superfund sites to avoid having sites listed on the NPL. These reforms may, in fact, have represented an optimal response given the difficulty stigma presents for neighborhoods surrounding Superfund sites. It should also be noted that the enormously costly process of litigation and delayed cleanup that has occurred under the Superfund program has provided strong incentives for industry to avoid creating new hazardous waste sites. However, for residents living near very large Superfund sites, as they have often stated, the program has failed in spite of EPA's best efforts. In this regard, it should be noted that when CERCLA was passed, little or none of the work in psychology necessary to understand the phenomena described here had been completed. In fact, much of the relevant work was motivated by Superfund sites and other hazardous facilities.

This study raises several questions for future research. First, are smaller sites truly different as the work by Gayer, Hamilton and Viscusi suggests? Second, although the psychological model developed here is statistically significant, it is based on data from just three sites. Additional work to incorporate both larger sites, as well as smaller sites, and additional explanatory variables would be worthwhile in our judgment. Finally, more research to understand and prevent stigmatization is warranted.

Chapter 11

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