Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program

Final Report

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By
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Evaluation Study Team

Principal Investigators:

Dr. Warren Galke National Center for Healthy Housing
Dr. Scott Clark University of Cincinnati Dept. of Environmental Health
Dr. Robert Bornschein University of Cincinnati Dept. of Environmental Health

Corresponding Author:

Mr. Jonathan Wilson National Center for Healthy Housing

Research Team:

National Center for Healthy Housing
10227 Wincopin Circle, Suite 100
Columbia, MD 21044

Mr. Jack Anderson
Ms. Jill Breysse
Dr. Sherry Dixon
Mr. Nick Farr
Dr. Warren Galke
Mr. Ron Jones
Ms. Pat McLaine
Ms. Rebecca Morley
Ms. Heidi Most
Ms. Laura Titus
Mr. Jonathan Wilson

University of Cincinnati
Dept. of Environmental Health
PO Box 670056
3223 Eden Avenue
Cincinnati, OH 45267-0056

Dr. Robert Bornschein
Ms. LaToya Bridgeman
Dr. Ralph Buncher
Dr. Mei Chen
Dr. Scott Clark
Ms. JoAnn Grote
Dr. Dale Johnson (deceased)
Mr. William Menrath
Mr. DeLing Nui
Dr. Lee Rafales
Ms. Sandy Roda
Dr. Paul Succop
Mr. Michael White

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Participating HUD Lead Hazard Control Grantees:
(Agency descriptions provided in Chapter 3)

Alameda County, CA	Milwaukee, WI
Baltimore, MD	State of Minnesota
Boston, MA	State of New Jersey
State of California	New York, NY
Chicago, IL	State of Rhode Island
Cleveland, OH	State of Vermont
Commonwealth of Massachusetts	State of Wisconsin

HUD Grant Technical Representatives and Advisors

Dr. David E. Jacobs

Dr. Warren Friedman	Dr. Barbara Haley	Dr. Joey Zhou
Mr. Ellis Goldman (deceased)	Mr. Stevenson Weitz	

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Introduction

Protecting children from lead-based paint hazards in housing remains an urgent need. Despite significant improvement, the Centers for Disease Control and Prevention estimates that nearly half a million children in 1999-2000 still have excessive exposures to lead.

This study is the largest and most comprehensive of its kind ever. It examined over 3,000 houses located in over a dozen jurisdictions across the country where the U.S. Department of Housing and Urban Development (HUD) provided funding to address lead-based paint hazards in privately owned low-income housing where the risks are greatest. The study looked at virtually all of the modern ways of controlling lead-based paint hazards and their relative effectiveness.

The study provides evidence that the lead hazard control activities as practiced by the participating programs can substantially reduce dust lead levels on floors, window sills and troughs and in most cases, the lead-in-dust remains well below pre-treatment levels for at least three years. More importantly, the activities were also associated with substantial declines in children's blood lead levels (37% two years after treatment). The findings of this study should be disseminated so that all those engaged in lead hazard control work can benefit from them.

Background

In 1993 and 1994, HUD awarded funds to 30 grant recipients (grantees) under the HUD Lead-Based Paint Hazard Control Grant Program. HUD required all 11 grantees in 1993 to participate in an evaluation of the program. Three grantees that were awarded funds in 1994 agreed to join the evaluation. The participating grantees included State or local governmental agencies in the following locations: Alameda County, CA; Baltimore, MD; Boston, MA; California; Chicago, IL; Cleveland, OH; Massachusetts; Milwaukee, WI; Minnesota; New Jersey, New York, NY; Rhode Island; Vermont; and Wisconsin.

Each grantee in the Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program collected comprehensive environmental data on all treated dwellings. Grantees also attempted to recruit families residing in the dwellings into the evaluation. Families that consented to participate agreed to be interviewed and allowed blood to be drawn from children between 6 months and 6 years of age at enrollment were eligible. Local Institutional Review Boards in the jurisdictions of the grantees reviewed and approved the study designs.

Information was gathered at four periods of time for all of the grantees: before the lead hazard control work, within 6 weeks after work, 6 months after work and 12 months after work. In order to assess the longevity of the treatments, HUD awarded funds to nine of the grantees to collect additional longitudinal data in approximately 40 percent of the dwellings two years and three years after work was completed.

Data collection began in January 1994. Data were collected from over 3,000 dwellings; of these units, 2,682 dwellings were treated and had final clearance results. The last dwelling unit was treated in October 1997 and the last 12-month data were collected in October 1998. The last dwelling eligible for the 3-year evaluation was treated in June 1996 and final data were collected for these units in June 1999.

The design of the HUD Lead Hazard Control Grant Program encouraged grantees to implement hazard control measures of their choice and did not include the use of control groups. The evaluation was designed to compare the effectiveness of the different classes of interventions that grantees used. The primary measures of effectiveness were dust lead loadings and blood lead concentrations; the methodology for collecting these measures is described at the end of this summary as well as in the body of the report.

Key Findings

Pre-Intervention Conditions:

- *Dwellings in the Evaluation tended to be older and have lower occupancy rates and much lower market values than those in the general US housing stock.* The majority of buildings were pre-1930, occupied rental units located in multi-unit buildings.
- *Paint lead and dust lead levels were higher than in average U.S. dwellings, as identified in the National Survey of Lead and Allergens in Housing.* This finding was expected since grantees targeted higher risk housing. However, before lead hazard control (pre-intervention), dust lead loadings were lower than expected, especially on floors. Contractors voiced concerns about passing the original floor clearance standard of 200 $\mu g/ft^2$, yet less than 25% of enrolled dwellings exceeded the standard *pre-intervention*.
- *Building components with higher paint lead levels were more likely to be deteriorated.* Exterior surfaces tended to have higher paint lead levels (Median of all dwellings: 2.2 mg/cm^2) than interior surfaces, and windows tended to have the highest paint lead levels (Median: 2.0 mg/cm^2) of all interior surfaces.
- *Occupancy status influenced floor and window sill dust lead, especially floor dust lead, with larger loadings observed in vacant dwellings.* For interior floors, the geometric mean dust lead loading in vacant dwellings was 132 $\mu g/ft^2$ compared to 17 $\mu g/ft^2$ in occupied dwellings. For window sills, the geometric mean dust lead loading in vacant dwellings was 1,001 $\mu g/ft^2$ compared to 278 $\mu g/ft^2$ in occupied dwellings. Anecdotally, grantees reported that vacant dwellings tended to be vacant for many months prior to enrollment.
- *Interior entry floors had significantly higher dust lead loadings than other interior floor surfaces.* In occupied dwellings, the geometric mean dust lead loading on entry floors was 23 $\mu g/ft^2$ compared to 17 $\mu g/ft^2$ on interior floors. Further analysis suggests that entry floors serve as a pathway of leaded dust from the building exterior to the interior.
- *Pre-intervention paint, dust and soil lead levels varied by grantee.* Some of these differences may be explained by differences in the recruitment strategies (i.e., targeting higher risk communities vs. targeting units where children were lead poisoned), but some appear to be the result of differences from city-to-city in the application of lead-based paint and the availability of other lead exposure sources. The results suggest that grantees should consider local conditions when developing their lead hazard control strategies.
- *The enrolled population had a lower level of education, lower income and a higher percentage of non-white individuals than the general US population.* This finding matches expectations for a population more at-risk of lead poisoning who predominantly lived in central city areas in the Northeast and Midwest.

- *Nearly half of the children in the Evaluation had an initial blood lead test that was at or above the CDC level of concern (10µg/dL).* Pre-intervention, 46% of children tested had a blood lead level greater than or equal to 10 µg/dL and 15% of children had a blood lead level at or above 20 µg/dL.
- *A high percentage of the children enrolled in the study were previously lead poisoned.* Seventy-seven percent of children enrolled in the Evaluation had a blood test for lead prior to enrollment. Forty percent of these children were reported to have been lead poisoned. With 85% of all children living in the enrolled dwelling more than 6 months, the dwelling was a potential source of lead exposure for most of these children.
- *The findings for blood lead were not based on a random sample of children in the communities studied, and reflect grantee enrollment strategies.* Not only were the children in this study more at risk, but a number of them were selected because they were lead poisoned. Thus, it not surprising that 46% of children had blood lead levels above the CDC level of concern as compared with less than 5% of the US child population.

Interventions and Costs:

- *Costs for interior lead hazard control work increased with the intensity of the interventions. Cost data reflect lead hazard control costs in the mid-1990s. Median costs were as follows:*

Interior Strategy	*Primary Activity*	*Median Cost*
02	Cleaning Only/Spot Painting	$ 430
03	Full Paint Stabilization	$ 4,930
04	Partial Window Treatments	$ 6,120
05	Full Window Abatement	$ 6,800
06	Full Lead Abatement	$ 9,570
07	Full Lead Removal	$ 4,110
All		$ 5,960

Interior Strategy 07 did not follow the increasing trend in costs because it was most commonly conducted in homes with a limited number of leaded components. Note: Partial window treatments include window jamb liners, sash replacement or paint removal, as well as other treatments.

- *Grantees most often selected Interior Strategy 05 - full window abatement (window replacement or window paint removal) plus other interior treatments for their interior intervention.* Fifty-five percent of dwellings were treated with Interior Strategy 05 as compared with: Strategy 02 (8%); Strategy 03 (13%); Strategy 04 (16%); and Strategies 06/07 (7%).
- *Costs varied widely within Interior Strategies.* Factors that influenced the variability of costs included the size and type (single-family/multi-family) of the dwelling; the percentage of leaded interior paint in poor condition; the number of dwellings treated by the contractor for the grantee; and whether hazardous waste requirements were placed on the contractor.
- *Grantees treated the exterior of the buildings at 70% of the dwellings and conducted soil or site work at 13% of the dwellings.* The most common combination of strategies was Interior Strategy 05 along with treatments to the exterior and no soil treatment (41%).

- Exterior work most frequently included paint stabilization (84% of treated buildings), followed by component enclosure (29%), component replacement (26%) and paint removal (25%). The median cost of exterior work was $1,870.
- Site work most frequently included mulch/seed/sod/plant (90% of treated buildings), followed by soil enclosure (22%), soil removal (10%), and structure removal (3%). The median cost of site work was $1,080.
- The following individual treatments were used over 800 times by building component:

Component	Paint Stabilization	Paint Removal	Enclosure	Replacement
Wall/Ceiling	√		√	
Floor/Stair	√		√	
Doors	√			√
Trim	√	√		√
Windows	√		√ (jambs)	√
Exterior	√			

Effects of Interventions on Clearance Dust Lead:

- *Seventy-six percent of all 2,842 dwellings treated by grantees passed the initial clearance testing (using the local dust lead standards applicable at the time).* The findings offer strong evidence that clearance was achievable on the first attempt in the vast majority of interventions. During the period of the Evaluation, grantees generally used clearance standards of 200 $\mu g/ft^2$ on floors, 500 $\mu g/ft^2$ on window sills and 800 $\mu g/ft^2$ on window troughs.
- *Dwellings that initially failed clearance testing required an average of 1.13 recleanings and follow-up clearance tests to achieve final clearance.* Even when dwellings failed initial clearance, final clearance was generally successful after only one additional recleaning and retest.
- *Interior Strategy 05, the strategy that included window abatement, was associated with lower initial clearance dust lead loadings and lower failure rates on both window sills and window troughs, after controlling for other factors. Interior Strategy 02, the lowest intensity strategy that included cleaning and spot painting, performed as well or better than other strategies in similar models based on floor dust lead loadings and failures.* Initial clearance dust lead loadings and failure rates did not decline with treatment intensity. Interior Strategy 06, full lead abatement, was associated with higher clearance dust lead loadings on both floors and window troughs than most other strategies, after controlling for other factors. As reported above, Interior Strategy 02 had lower dust lead loadings on floors than other strategies. This same strategy had similar effects on window sill dust lead loadings, as long as pre-intervention dust lead levels were below 250 $\mu g/ft^2$.
- *Creating smooth and cleanable surfaces was an important determinant of lower clearance dust lead levels.* Surfaces in better condition at clearance had lower clearance dust lead loadings and lower failure rates, when controlling for other factors including Interior Strategy. In fact on *entry floors,* no elements of the interior lead hazard control interventions other than creating good floor conditions had a significant effect on entry floor clearance failure rates.

Occupant Protection:

- *Grantees generally followed HUD guidance on occupant protection and occupants were generally adequately protected.* 71% of households were relocated during the intervention, and when relocation did not occur, treatments tended to be of a more limited intensity. Twenty-two percent of relocated households reported that they returned to the dwellings during the intervention, although in most cases the return visits were less than one hour and did not include a child. Ninety-two percent of the households that did not relocate remained out of the work area and 80% reported that all dust and debris was cleaned up at the end of the day. Eighty-eight percent of relocated households and 85% of non-relocated households felt that they were adequately protected during the intervention.
- *Nine percent of the 869 children who had both pre-intervention and immediate post-intervention blood lead samples had blood lead increases equal to or greater than 5 μg/dL.* This can be compared to a study completed in the 1980s, in which over 50% of children in homes that had undergone the “traditional” form of lead abatement (without dust lead cleanup) exhibited a significant increase in blood lead (Farfel 1990). Analysis of children in the Evaluation with blood lead samples at pre-intervention and immediate post-intervention did not reveal any differential effects between interventions on the probability of a child experiencing a blood lead increase equal to or greater than 5 μg/dL, suggesting that the increase was probably not related to the intervention itself. Statistical analysis found that in a number of cases, the increases may simply have been a function of the child’s age or the season in which the blood sample was drawn (blood lead levels tend to increase during the summer.
- *When grantees felt that households did not need to be relocated or could be partially relocated, the children were as protected (when measured by change of blood lead increases) as when grantees felt that households had to be relocated.* The relocation status of the household did not have a significant effect on the probability that a child would experience a blood lead increase of 5 μg/dL or more from pre-intervention to immediate post-intervention. However, grantees did report that nine of the 81 children whose blood lead levels “spiked” may have experienced increases because of breakdowns in the occupant protection system. This suggests that grantees must remain vigilant in enforcing occupant protection practices and offering households the necessary support and incentives to stay out of the work areas.

Effects of Interventions on Dust Lead Loadings:

- *Lead hazard control activities undertaken by the grantees dramatically reduced the floor dust lead loadings and those levels were maintained for at least three years. The interventions were equally effective on window dust lead loadings.* Three years post-intervention geometric mean dust lead loadings on floors, window sills and window troughs were 9, 62 and 363 μg/ft^2, respectively. These levels represented declines of 78%, 89%, and 95%, respectively, from pre-intervention. Substantial declines were observed across all 14 grantee sites.
- *Although all interior strategies resulted in average floor dust lead loadings at one-year post-intervention that were well below the current hazard standard of 40 μg/ft^2, differential effects between Interior Strategies were identified.* Controlling for other factors, full interior lead abatement (Interior Strategy 06/07) was associated with the

largest relative reductions in floor dust lead loadings from pre-intervention to one-year post-intervention, while dwellings treated with window abatement (Interior Strategy 05) or full paint stabilization (Interior Strategy 03) had the smallest reductions.

- *Interior Strategy 05 was as effective at reducing floor dust lead loadings as most other strategies at clearance, but unlike homes treated with other interventions, something occurred in the Interior Strategy 05 homes between clearance and six months post-intervention that increased the geometric mean floor dust lead loadings.* Floor dust lead loadings in dwellings treated with Interior Strategy 03, 04, and 06/07 declined from clearance to six-months post-intervention, while loadings in dwellings treated with Interior Strategy 02 remained constant. The Evaluation was not able to identify the reason for the differences between interventions.
- *As with floors, Interior Strategies had different effects on post-intervention window dust lead loadings. The effects more closely matched original expectations that higher intensity interventions would result in larger relative reductions in window dust lead loadings.* Interventions where windows were abated (Interior Strategies 05 and 06/07) were associated with the largest reductions from pre-intervention to one-year post-intervention, while interventions where windows were only cleaned (Interior Strategy 02) had the smallest reductions.
- *Dust lead loadings on window sills and troughs all increased dramatically from clearance to six months post-intervention and then declined through three-years post-intervention, regardless of Interior Strategy.* Window dust lead loadings were higher at three years post-intervention than at clearance, but were substantially lower than pre-intervention. Because similar changes occurred in both dwellings where windows were abated and where they were unabated, it does not appear as though the windows themselves were a likely source of the immediate increase in dust lead.
- *While window abatement was demonstrated to be the most effective measure to reduce dust lead loadings on windows, this treatment must be performed in conjunction with other treatments that influence predictors of floor dust lead (e.g., floor surface type and condition, door and trim paint lead, and general interior building condition, as well as exterior dust/soil lead) in order to most effectively reduce floor dust lead levels.* Although pathway analysis suggests that window dust lead influences floor dust lead, only treating "up-stream" hazards would not result in substantial "down-stream" dust lead reductions. Furthermore, window dust lead loadings increased substantially shortly after clearance without influencing the floor dust lead loadings up to three years after treatment. These findings support the current requirement to address all interior, exterior and soil lead hazards in an integrated manner.
- *Both exterior and soil lead hazard control work influenced reductions in post-intervention floor dust lead loadings.* Interior floor dust lead loadings in dwellings not receiving exterior treatments were predicted to be 32 percent higher than the dwellings receiving exterior treatments, while floor dust lead loadings in dwellings not receiving soil work were predicted to be 45 percent higher than dwellings receiving soil treatments. For the average dwelling, the floor dust lead loading at one-year post-intervention was 3-4 $\mu g/ft^2$ higher if the dwelling did not receive one of the interventions to the outside of the building or its immediate surroundings.

- *Exterior entry dust lead loadings were found to contribute directly to interior entry floor, floor, and window sill dust lead loadings.* This finding suggests that treatments to control exterior entry dust lead may reduce interior dust lead loadings.
- *Site treatments (mainly interim soil controls) were associated with lower post-intervention exterior entry dust lead loadings.* Because of the impact of exterior entry dust lead levels on interior dust lead levels, these treatments also reduced dust lead loadings on window sills, interior entries and other interior floors.
- *Evidence of blow-in or track-in of lead from street dust was not observed.* The study shows that street dust does not serve as a significant source of lead in exterior entry dust because exterior entry dust lead concentrations were about four times as high as street dust lead concentrations. Therefore, street dust lead did not appear to be tracked into dwellings. Furthermore, street dust lead was not associated with window sill or trough dust lead loadings.
- *Window replacement was associated with lower window sill and window trough dust lead loadings one-year post-intervention compared to installation of window jamb liners, window paint stabilization or cleaning only.* At three years post-intervention, available data were more limited, but window sill and trough dust lead loadings were lower in dwellings with window replacement than those with cleaning only, after controlling for other factors.
- *Although rooms treated with paint removal are likely to have more dust lead at clearance, there did not appear to be a long-term detrimental effect of paint removal activities.* Rooms treated with paint removal had clearance dust lead loadings on bare floors that were 60% higher than loadings in rooms not treated with paint removal. However, at one and three years post-intervention, the geometric mean dust lead loadings were no longer significantly different for rooms treated with paint removal or not, after controlling for other factors.

Treatment Longevity:

- *Lead hazard control treatments tended to hold up for the three-year period for which they were observed.* The median dwelling in the Evaluation had only one physical failure two and three years post-intervention. Ten percent or less of the roughly 66,000 treatments analyzed were in a state of failure at any of the post-intervention phases (6 months: 4%, 1 year: 6%, 2 years: 9%, and 3 years: 10%).
- *Failures appeared to level off two years after clearance.* The percentage of failures rose quickly over the first year, then more slowly over the next two years. Since most if not all of the treatments were expected to least three years, the early rise in failure rates suggests that these failures were more attributable to poor installation or poor surface preparation than to product failure.
- *Components subject to abrasion, impact or weather were more likely to experience paint failure than other components.* During each post-intervention phase, paint stabilization of doors, windows and exterior components was more than twice as likely to fail than paint stabilization of interior trim and interior walls and ceilings.
- *Installation of window jamb liners was the treatment category that had the highest percentage of failures in each phase.* Six months after installation, 17 percent of rooms where jamb liners were installed had at least one jamb liner failure, while three years

after intervention, nearly half of the rooms with jamb liners failed (46%). This was twice the failure rate of the next most frequent failure (door paint stabilization). Over half of the jamb liner failures were attributed to inadequate installation and 29 percent failed because they were physically damaged.

- *Although further study is needed, the Evaluation suggests that encapsulation does not perform better than paint stabilization.* Strong conclusions are not possible because only 358 trim components and just over 100 wall/ceiling components were encapsulated (as compared with 10,025 trim and 7,949 wall/ceiling components that were paint stabilized). However, by two years after clearance, encapsulants had similar failure rates as paint stabilization on these components.

Effects of Interventions on Blood Lead Levels:

- *Interventions selected by grantees were quite successful in reducing blood lead levels.* Blood lead levels were significantly lower at each successive post-intervention phase until three-years post-intervention, at which time blood lead levels were not significantly different than at two-years post-intervention. At two-years post-intervention, geometric mean blood lead levels were 37 percent lower than at pre-intervention. Blood lead levels were 18 to 30 percent lower one-year post-intervention, which corresponds to declines in blood lead levels observed in previous studies of lead hazard control interventions (18-34%) (USEPA, 1995).
- *Children with pre-intervention blood lead levels as low as 10 µg/dL (the CDC level of concern) experienced substantial declines in blood lead level following interventions.* Previous studies had not observed substantial declines unless a child's pre-intervention blood lead level was above 20 µg/dL.
- *The results support the hypothesis that declines in residential dust lead loadings (as well as correction of deteriorated lead-based paint) resulted in lower blood lead levels.* Although the link between dust lead and blood lead that was observed pre-intervention was not significant one-year post-intervention, it is likely that the relationship could not be observed because the child's body burden of lead became a better predictor of post-intervention blood lead. The correlation between pre-intervention blood lead levels and floor dust lead loadings (0.29, $p<0.01$) was very similar to the correlation one-year post-intervention (0.32, $p<0.01$).
- *No differential interior strategy effect was noted for declines in blood lead.* The hypothesis that differences in lead hazard control intervention intensity would yield differences in blood lead levels was not demonstrated. For the four interior strategies that were examined in the one-year post-intervention blood lead models (Interior Strategies 02-05), *window sill and window trough dust lead* loadings were significantly lower in dwellings where windows were abated (Interior Strategy 05). However, *interior floor dust lead* loadings were <u>not</u> significantly lower in these same dwellings. Assuming interior floor dust lead is the primary exposure pathway of dust lead to a child, as established by the pre-intervention model and previous research, this finding may suggest a reason why Interior Strategy 05 did not prove to be more effective than the other interior strategies.
- *Exterior lead hazard control in the presence of high exterior paint lead loadings was related to differences in one-year post-intervention blood lead.* Children living in dwellings where the exterior paint lead levels were above 7 mg/cm^2 and the exteriors

were treated had lower post-intervention blood lead levels than children living in dwellings without these conditions.

- *Important factors that modified the effects of strategies on blood lead levels included pre-intervention blood lead levels, parental report of previous lead poisoning, child's age, and season.* When controlling for all other factors, children who were reported to be lead poisoned prior to enrollment and/or had higher pre-intervention blood lead levels also had higher post-intervention blood lead levels. Even after intervention, children's blood lead levels tended to peak for children 24 months of age and when children were tested in the summer. This supports the finding that body burden is significantly related to blood lead level.

Measures of Effectiveness

Dust Lead Loading

Inspectors trained in the Evaluation's standard single-surface dust wipe collection protocol collected floor samples from the interior entry to the dwelling, and doorways in the youngest child's playroom (or living room), that child's bedroom, a second child's bedroom and the kitchen. Interior window sill samples were collected from the youngest child's bedroom and kitchen. Window trough samples were collected from the child's playroom and second child's bedroom. The inspector determined the exact sampling locations based on the availability and operability of windows and the presence of a second child's bedroom. Inspectors returned to the same sampling locations in each phase of the evaluation. Inspectors alternated the exact location of the sampling from one side to the other of the doorway or window in each phase, to reduce the possible influence of the previous sampling.

Each grantee selected its own laboratory (or laboratories) to analyze the dust samples. Each laboratory provided evidence that it was proficient under the American Industrial Hygiene Association's Environmental Lead Proficiency Analytical Testing Program. Laboratories were not required to be accredited under the EPA National Lead Laboratory Accreditation Program because the study began early in that program's existence and few laboratories were as yet recognized. Lead was measured by flame atomic absorption, graphite furnace atomic absorption, or inductively coupled plasma-atomic emission spectrometry.

Grantees submitted both blank wipe samples and double-blind quality control samples to the laboratories on a regular basis. The quality control samples were prepared by the Wisconsin State Occupational Health Laboratory by applying set quantities of NIST Standard Lead Paint Dust (Standard 1578) to a wipe. Dust samples analyzed during a period when a laboratory's values exhibited a pattern of deviation by more than 20 percent from the target values are excluded from this report.

The method detection limits of the laboratories varied from 1 to 25 $\mu g/ft^2$. Midway through the evaluation, it was determined that many dust lead results (e.g., about one-half of the post-intervention floor dust lead values) were falling below the limits of detection. Because the values would restrict the observations of changes in dust lead levels, the evaluators asked the laboratories to provide the instrument reported value for future samples and previously reported samples. The instrument value, when available, is used in this report. Where the instrument value was not available, values below detection limits were assigned a value using imputation.

Blood Lead Concentration

Trained phlebotomists obtained blood specimens from participating children, primarily by venipuncture. On a case-by-case basis, a phlebotomist could make a determination that a venous sample was unattainable and collect a capillary sample instead. Three grantees received approval to use capillary sampling (fingerstick) as their primary blood collection method. Phlebotomists at these sites received training in proper fingerstick techniques.

Each grantee selected its own laboratory (or laboratories) to analyze the blood specimens. Each laboratory was required to meet the proficiency standards set under the Clinical Laboratory Improvement Act of 1988. Lead was measured by either graphite furnace atomic absorption spectrophotometry or anodic stripping voltammetry. The limits of detection varied by laboratory from 1 to 5 µg/dl. Undetectable levels were assigned a value using imputation.

Grantees submitted blinded quality control samples to the laboratories on a regular basis. CDC prepared the quality control samples from whole bovine blood pools. The evaluation quality control officer worked with any laboratory whose performance fell outside of the quality control standards set in the study protocols (more than 3 µg/dl different from the target value). Blood samples analyzed during a period when a laboratory fell outside of the standards are excluded from this report.

1.0 INTRODUCTION

1.1 BACKGROUND

The Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program (the Evaluation) is the largest and most comprehensive study of lead hazard control in housing ever undertaken in the United States. Data collection efforts were initiated in 1994 by Grant recipients (grantees) from 14 State and local governments across the nation and continued until the fall of 1999. With over 200 jurisdictions participating in the Grant Program as of the end of FY2001, the number of dwelling units and families served by the program is much larger than the numbers contained in this report. The Evaluation is a cooperative effort of these 14 grantees, the National Center for Healthy Housing (the Center, formerly known as the National Center for Lead-Safe Housing) and the University of Cincinnati Department of Environmental Health (UC). The Center, a nonprofit organization devoted to helping public and private entities find effective and affordable ways to reduce lead hazards in housing, has overall responsibility for the Evaluation. The United States Centers for Disease Control and Prevention (CDC) also contributed to the design and implementation of the Evaluation.

Using standard forms and procedures developed for the Evaluation, the grantees have collected extensive data on environmental, biological, demographic, housing, cost and hazard identification and hazard control aspects of their activities. Under grants from HUD, the Center and UC designed the data collection forms and procedures and provided training and technical assistance to the grantees. UC performed the central data management role, including training and technical guidance in forms completion and submittal, quality control of laboratory and other data, and development and management of central data files and design and execution of an exterior dust and soil lead project for selected Evaluation housing. The Center and UC worked jointly on data analysis and reporting.

Planning for the Evaluation began in 1993, at the outset of the HUD grant program, to provide the earliest possible information to lead hazard control policy makers and program managers.[1] The Evaluation is broad and complex, as are the programs it was designed to evaluate.

The overall goal of the HUD grant program is to prevent childhood lead poisoning by reducing lead hazards in privately owned low-income housing. The main objectives of the program, as stated in the 1992 Notice of Funding Availability (NOFA) (HUD 1992), are to:

> " (a) Encourage State and local governments to initiate or expand lead-based paint inspection, abatement, and training certification programs in order to reduce the health hazards associated with exposure to lead-based paint and lead dust, especially as these hazards affect young children in low- and moderate income households;
>
> (b) Encourage State and local governments to plan and implement cost-effective testing, abatement, and financing programs, including the testing of innovations that can serve as models for other jurisdictions interested in addressing this problem. Because of the high costs of eliminating lead-based paint hazards,

[1] Interim reports with findings were issued in March 1996, February 1997 and March 1998.

> particular encouragement is offered for programs that can safely reduce average per-unit abatement costs; and
> (c) Document the health effects of lead-based paint abatement activity by testing blood-lead levels of young children before and after abatement has taken place."

In addition:

> "grantees will be afforded considerable latitude in designing and implementing the methods of [lead-based paint] LBP hazard reduction to be employed in their jurisdictions. HUD is interested in promoting innovative and creative approaches that result in the reduction of this health threat for the maximum number of low- and moderate-income residents, and that demonstrate replicable techniques that are better, faster, less expensive or more effective than current practices."

Congress, which initiated funding for the grant program as part of the Fiscal Year (FY) 1992 HUD appropriations bill, specified that the first round of funding constituted a demonstration program to examine the efficacy of various lead hazard control strategies. Congress stated that pre- and post-intervention dust-wipe sampling as well as initial and follow-up blood tests of occupants' children be conducted in order to assist in quantifying the health benefits of intervention. Congress also wanted intervention and cost information to be collected on a house-by-house basis.

Approximately one year later, Congress passed the Title X of the 1992 Housing and Community Development Act, which required HUD to conduct research on:

- the efficacy of interim controls in various hazard situations;
- the relative performance of various abatement techniques;
- the long-term cost-effectiveness of interim control and abatement strategies; and
- the effectiveness of hazard evaluation and reduction activities funded by this act.

The overall purpose of the Evaluation was to measure the relative cost and effectiveness of the various methods used by State and local government grantees to reduce lead-based paint hazards in housing. The effectiveness in individual grantee's programs was not part of the Evaluation's purpose. The nine objectives of the Evaluation were to identify and describe the:

1. Dwelling unit level costs of applying various environmental intervention strategies and the relationship between those costs and the pre-intervention characteristics of the dwelling unit;
2. Costs of various lead hazard control treatments for different building components;
3. Proportion of dwelling units undergoing environmental interventions that exceed initial post-intervention dust clearance standards, the treatments (including cleanup methods) and strategies associated with these exceedances, and the nature and costs of remedial treatments required to meet clearance standards;
4. Changes in dust lead loadings that occur from immediately post-intervention to 6 and 12 (and in some cases 24 and 36) months post-intervention and the strategies and treatments associated with variation in dust lead re-accumulation rates;

5. Factors (such as pre-intervention housing characteristics) that appear to modify the effect of different hazard control treatments and strategies on short-term and longer-term changes in dust lead loadings;
6. Changes in the integrity of paint, encapsulants, and enclosures that occur from immediately post-intervention to up to 36 months post-intervention;
7. Changes in blood lead levels among children living in dwelling units before and after intervention and among children who move into or are born into dwellings after intervention;
8. Factors associated with significant (i.e., greater than or equal to 5 micrograms per deciliter (µg/dL)) changes in blood lead levels between pre-intervention and immediate post-intervention measurements; and
9. Relationship between changes in dust lead loading and changes in blood lead levels between pre-intervention and 6-, 12-, 24- and 36-month post-intervention measurements.

1.2 Overview Of Report

This final report of the Evaluation offers findings based on data that grantees submitted as of June 1, 2000 and updates preliminary findings reported in previous interim reports, presentations and in an interim publication (Galke 2001).

The Evaluation report is organized as follows:

- Section 2.0, Description of Grantee Lead Hazard Control Programs. A description of the lead hazard control programs of each of the 14 grantees is presented, including grant administration, enrollment methods and targeted communities, and general types of interventions. These descriptions are of the programs as they existed at the time of the Evaluation and do not necessarily represent their current designs.
- Section 3.0, Study Design and Quality Control Methods. The design of the Evaluation is summarized. The description includes discussion of the enrollment, informed consent and data collection procedures; the data management process; and the data quality assurance and quality control plan and outcomes. The statistical analysis plan is summarized.
- Section 4.0, Pre-Intervention Characteristics and Conditions of Housing and Families. The distribution of and variability in pre-intervention housing and demographic characteristics and pre-intervention exposure-related factors potentially impacting the effectiveness of various interventions are summarized and discussed, and compared with those of the nation in general.
- Section 5.0, Description of Interventions. Methods used to collect testing and intervention data are summarized, and the different strategies that categorize lead hazard control work are described. Concurrent non-lead construction work is also discussed, including potential interaction between such work and lead hazard control interventions.
- Section 6.0, Costs of Lead Hazard Control Activities. The costs for work done during the Evaluation are summarized at two different levels, overall lead hazard control costs for dwelling units and specific lead treatment costs.

- Section 7.0, Observed Outcomes Immediately Post-Intervention. The outcomes of the Evaluation that were observed immediately post-intervention are explored. These outcomes include the effects of interventions on initial clearance dust lead loadings and the rates of clearance failure, and the success of grantee occupant protection plans. In addition, changes in blood lead levels of children within six weeks of the lead hazard control intervention are investigated to determine if “significant” increases (set at greater than or equal to 5 µg/dl for the purposes of this report) occurred, and if so, why they occurred.
- Section 8.0 Effects of Interventions on Dust Lead Loadings. The longitudinal effectiveness of different intervention strategies on dust lead loadings is investigated. Various analytical models are used to identify factors that significantly affect dust lead loadings up to three years post-intervention. For a subset of the dwellings, the influence of exterior dust lead and soil lead on interior post-intervention dust lead loadings is explored. Although data limitations prevented counts of treatment failures to be included in the dust lead models, descriptions of treatment failures are presented.
- Section 9.0, Effects of Interventions on Children’s Blood Lead Levels. The longitudinal effectiveness of different intervention strategies on blood lead levels is investigated. Various analytical models are used to identify factors that significantly affect average post-intervention blood lead levels and changes in blood lead levels up to two years post-intervention. As in the dust lead discussion in Section 8, data limitations prevented counts of treatment failures to be included in the blood lead models.
- Section 10.0, Conclusions: Cost-Effectiveness of Interventions. An overview of the effectiveness findings of the previous two chapters is presented, and the advantages and disadvantages of the lead hazard control strategies are summarized, including their costs.
- Appendix A. Evaluation Data Collection Forms.
- Appendix B Summary of Laboratory Quality Assurance/Quality Control (QA/QC) Results. Laboratory performance on blood and environmental sample analyses is examined and decisions based on such performance are presented. The results of QA/QC checks on collected data are presented. This appendix also describes efforts to address laboratory results that were initially reported as below the detection limits of the laboratory. These efforts included obtaining laboratory instrument output data where available and developing a statistical method for estimating remaining below detection limit data.

Additional Materials include:

- Compendium to the Final Report. The compendium includes over 100 tables reporting findings by grantee. It also contains more details on statistical analysis methods and results.
- Public Use Dataset Resource Document. This documents contains the updated Evaluation protocols and the data dictionary for use with the public use dataset. It also includes the quality control/quality assurance plan for the study.
- Public Use Dataset. A public use dataset will be made available to researchers and other people interested in examining these data in new or alternative ways.

2.0 DESCRIPTION OF GRANTEE LEAD HAZARD CONTROL PROGRAMS

OVERVIEW OF GRANTEE PROGRAMS

This report is a testament to the hard work of the 14 grantees and the contributions of thousands of families in this Evaluation. Although national in scope, this Evaluation was locally driven and implemented. Once trained in the protocols specifically prepared for this Evaluation, grantees designed their own lead hazard control programs, including the methods of recruitment and the treatments that were implemented. This was done so that at the end of the project, the data would not only provide the basis for the findings of the Evaluation, but could allow grantees to use their data to inform their own programs.

Although the Evaluation was locally driven, in its NOFA, HUD listed several conditions that each grantee was required to meet in implementing its lead hazard control program, including:

- Written procedures for all phases of testing and abatement;
- Abatement waste disposal procedures in accordance with EPA's Resource Conservation and Recovery Act (RCRA) of 1976;
- Worker protection procedures in accordance with the Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing (HUD 1990);
- Occupant protection requirements in accordance with the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (URA); and
- Compliance with post-abatement dust wipe test clearance thresholds contained in the HUD Interim Guidelines.

Grantees were also prohibited from utilizing dangerous methods of paint removal, including open-flame burning and uncontrolled abrasive blasting, or machine sanding without HEPA attachments.

Eleven of the 14 grantees were from the first round of Grant awards (FY 1992 appropriations), and three were from the second round (FY 1993 appropriations). Under the Congressional mandate, HUD required all first round recipients to participate in the Evaluation. Three grantees from the second round (Chicago, New York City and Vermont) were invited to participate on a voluntary basis. They were chosen to increase representation in the Evaluation of rural areas, and of large urban areas with multi-unit housing. A list of participating jurisdictions is found in Table 2-1. Although Milwaukee was a subgrantee of the State of Wisconsin, its program differed in structure and timing from that of Wisconsin; therefore, it was treated as a separate site for Evaluation purposes. Therefore, although there were only ten Grant awards in the first round, there were 11 Round I grantees in the Evaluation.

TABLE 2-1:Funding Amounts and Jurisdictions for Grantees Participating in the Evaluation

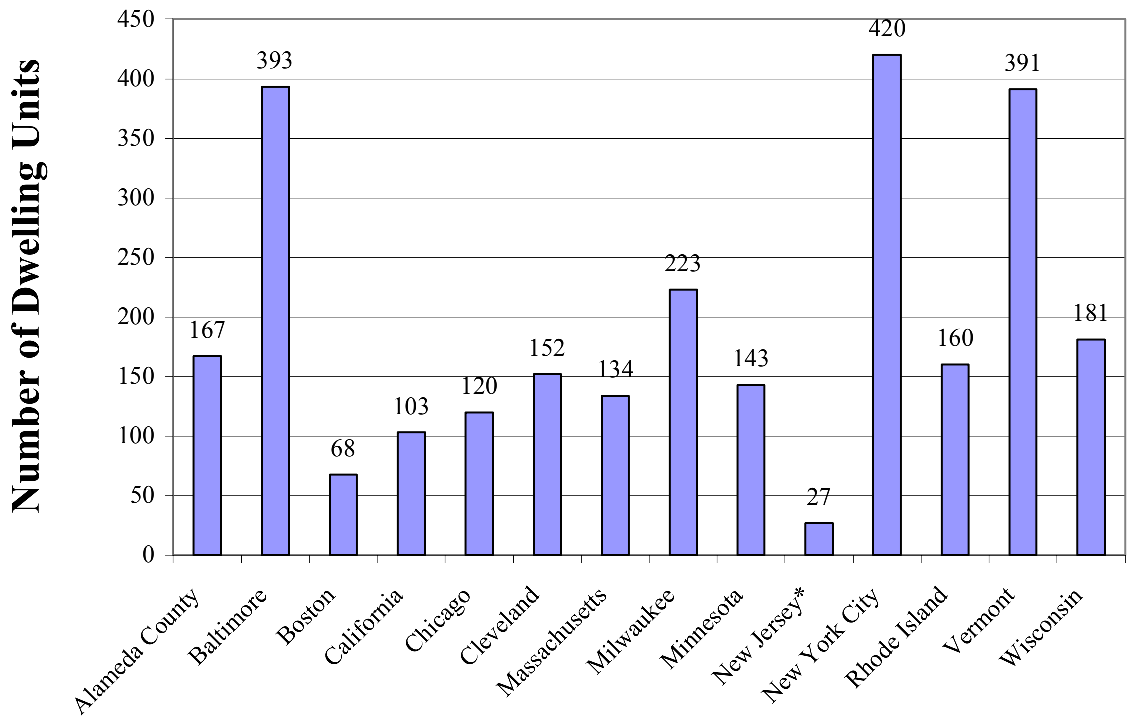
GRANTEE	FUNDING (In Millions)	JURISDICTION	HUD FUNDING ROUND
Alameda County, CA	$4.41	Local	1st
Baltimore, MD	5.85	Local	1st
Boston, MA	3.66	Local	1st
California	6.20	State	1st
Chicago, IL	6.93	Local	2nd
Cleveland, OH	3.88	Local	1st
Massachusetts	6.00	State	1st
Minnesota	2.79	State	1st
New Jersey	4.25	State	1st
New York City, NY	6.75	Local	2nd
Rhode Island	4.07	State	1st
Vermont	3.20	State	2nd
Wisconsin	6.34	State	1st
Milwaukee*		Local	1st
Total	**$64.33**		

*Milwaukee is a subgrantee of the State of Wisconsin, but it was treated as a separate site for Evaluation purposes.

Because the Evaluation is national in scope, results for the 14 grantees have generally been grouped together in this report to summarize findings and identify trends on a national basis. However, because grantees were given considerable latitude in designing and implementing their lead programs, it is important to summarize each grantee's program so that grantee-specific impacts on Evaluation outcomes can be highlighted as appropriate. Each of the 14 grantee programs are briefly summarized below, including department(s) responsible for administering the program, a description of cities/neighborhoods targeted for inclusion (if any), dwelling unit enrollment methods, and general types of lead hazard control interventions selected. Major changes or evolutions that may have occurred in grantee programs over the course of the Evaluation are noted. Figure 2-1 lists the number of dwelling units treated and cleared in the Evaluation by grantee.

Early results regarding the effectiveness of lead hazard control interventions indicated that, as expected, treatments had not failed at 12 months post-intervention. HUD felt that longer periods of follow-up measurement were needed to evaluate effectiveness, so in 1995 HUD initiated an extension to the basic 12-month Evaluation. The collection of data at 24 and 36 months post-intervention is known as the extended Evaluation. In order to collect data in a timely manner, eligible grantees were required to have a target number of dwelling units with interventions

Figure 2-1: Number of Treated and Cleared Dwelling Units by Grantee



Data as of: June 1, 2000 - restricted to units that passed clearance
Data from: Forms 01, 11, 15, 19, 20
Data source: UC Table 12
*See Section 2.2.10 for details conserning the low enrollment in New Jersey

completed by June 1995. Nine grantees--Alameda County, Baltimore, Boston, California, Milwaukee, Minnesota, Rhode Island, Vermont, and Wisconsin--became participants in the extended Evaluation. Resource constraints and the desire to get representation from as many of the original 14 participating grantees as possible meant that, for some of the grantees, not all dwelling units treated by the deadline were funded for the extended Evaluation.

In a later project that was separately funded, data on post-intervention exterior dust and soil levels were collected from selected locations. Chapter 8 provides details on the design, methodology and results for this project.

Descriptions of the lead hazard control interventions use the terms "abatement" and "interim controls" as they are used in Title X of the 1992 Housing and Community Development Act. Abatement denotes a class of treatments that permanently removes or encloses/encapsulates lead-based paint hazards. HUD defines permanent treatments as treatments expected to last at least 20 years. Building component removal, surface enclosure, and complete paint removal are common methods of abatement. Interim controls include treatments that eliminate lead-based paint hazards, but do so in a manner that is not expected to last 20 years. Wet scraping and repainting, friction reduction on windows and doors, and cleaning are common interim control methods.

DESCRIPTION OF GRANTEE PROGRAMS

Note: The following descriptions are of the programs as they existed at the time of the Evaluation, and do not necessarily represent their current designs.

Alameda County

Administration. Administration of the lead hazard control program was the responsibility of the Alameda County Lead Poisoning Prevention Program (ACLPPP), which collaborated with Community Block Development Grant (CDBG) programs in the four participating cities. ACLPPP is part of the county's Community Development Agency. The program utilized a multi-disciplinary approach incorporating case management, community education and health marketing, environmental and housing services, economic development and training, and data management. The program developed a custom software system to monitor and manage services and to collect and analyze data through the various stages of case management, hazard assessment, and follow-up.

Targeted Areas. "High risk" census tracts in four Alameda County cities, Alameda, Berkeley, Emeryville, and Oakland, were targeted for inclusion in the Evaluation.

Enrollment Methods. Two types of properties were targeted for inclusion. The first group consisted of properties where children with elevated blood lead levels resided or spent significant amounts of time. After receiving reports of children with elevated blood lead levels, the program conducted public health investigations to determine the source of the lead poisoning. If the dwelling was the source, the property was slated for recruitment. Properties and owners were then eligible for financial and technical assistance. Additional incentives (e.g., forgivable loans) were also offered to owners if they agreed to participate in the Evaluation.

The second group of properties was identified in a target area consisting of "high risk" census tracts in the four participating cities. High risk was determined by assessing the correlation between percentage of median income, age of housing and ethnicity. A census tract was considered to have a significant risk factor if 50 percent of families had incomes below 80 percent of the area median income, if 50 percent of housing units were older than 1950, and if more than 65 percent of the population were minorities. Medical case management data indicated that these census tracts had the largest percentage of lead poisoning cases.

General Types of Intervention. Initially, ACLPPP developed four general levels of intervention based on identified risks. Level 1 focused on immediate dust hazards, especially on friction surfaces and in carpet on the interior of the house; Level 2 addressed defective paint conditions, especially on interior friction surfaces, but also exterior lead paint hazards on a limited scale and soil lead hazards around the house; Level 3 tested paint-on encapsulants on several surface types and clean up of driveways and sidewalks (potential sources of interior dust); and Level 4 involved comprehensive treatment of lead hazards through extensive replacement of interior trim, enclosure of deteriorated wall surfaces and encapsulation of lead paint hazards on exterior siding.

As these levels began to be implemented, ACLPPP refined them into a minimum standard that required all hazards to be addressed. This often required a mix of intervention strategies from cleaning, paint stabilization and permanent abatement. This modified process helped the program achieve a minimum standard across all properties while allowing property owners to select more extensive treatments if they desired. Buildings that were treated using this modified process received similar treatments, which included a mix of abatement and interim control work on interiors, minimal exterior work, and extensive treatment of the soil at some properties.

Baltimore

Administration. The Baltimore City Health Department had overall responsibility for Baltimore's Round 1 Grant, under a program entitled the Lead Abatement Action Project (LAAP). A substantial portion of the operational functions was subcontracted to Baltimore City Healthy Start, Inc., a quasi-public corporation under the Health Department. Healthy Start staff enrolled houses, addressed occupant needs, tested houses, developed work specifications, provided quality control, and conducted post-intervention hazard control monitoring and testing. The Health Department also partnered with Baltimore Department of Housing and Community Development staff, who assisted in the development of owner and contractor documents concerning lead hazard control and who conducted grant settlements with owners and **contractors.**

Targeted Areas. LAAP originally targeted three neighborhoods in the city. Two of these areas, Sandtown-Winchester and Middle East, contain a large percentage of investor-owned properties with histories of childhood lead poisoning. The third, Belair Edison, has predominantly owner-occupied units. The grant ultimately expanded to enroll homes citywide.

Enrollment Methods. LAAP recruited units by providing public information through property owner organization, community and neighborhood organizations, health providers, advocacy organizations, environmental enforcement program referrals, promotions at community fairs, and word of mouth. To enroll a house, the owner needed to request an initial screen and, if the house was approved, the owner completed a standard enrollment application. Selection of a qualified lead hazard control contractor was the responsibility of the owner, with advice, referral and approval by LAAP.

Baltimore enrolled predominantly scattered site, single-unit rowhouses. The majority of units were turnover rental or homeowner conversion projects (in association with a local Habitat for Humanity organization). Owner-occupied units and rental occupied units were also funded, and relocation benefits were provided to the occupants.

General Types of Intervention. Owners were required to bring buildings up to basic housing standards before work could begin. Many owners made a substantial out-of-pocket investment to meet these requirements. The LAAP intervention primarily consisted of intensive level treatments to eliminate lead hazards. The typical unit received window replacement, partial floor, wall and ceiling treatments, door adjustments or replacements, paint stabilization (interior and exterior), basement floor treatments, and cleaning treatments consisting of high efficiency particulate (HEPA)-vacuum and wet wash. No soil treatments were undertaken. A small number of units underwent substantial rehabilitation resulting in permanent abatement of lead hazards.

Boston

Administration. The City of Boston's Department of Neighborhood Development was the lead agency with overall responsibility for the Round 1 Grant and associated Evaluation activities. The Department's Lead Safe Boston (LSB) program was responsible for all programmatic and construction activities including, but not limited to, project enrollment, commitment, contract closing, construction management and contractor oversight, testing and reporting.

LSB partnered with Boston's Department of Health and Hospitals (DHH) to undertake all Evaluation-specific data collection and transmittal activities, including family interviews, blood draws, dust sampling and overall management of the data.

Targeted Areas. The majority of projects enrolled in the Evaluation were in the neighborhoods of Dorchester, Roxbury, and Mattapan, which have the highest percentage of lead-poisoned children in the city; however, overall, LSB drew projects from the entire city, which is comprised of twelve distinct neighborhoods.

Enrollment Methods. Every project that met the funding eligibility requirements set by HUD and Boston for the LSB program was targeted for possible enrollment in the Evaluation. This method cast the widest possible net to capture the highest number of eligible units, allowing a direct outreach effort by DHH staff in the field. Most dwelling units that were enrolled in the program had received an order to abate based on the identification of a lead-poisoned child residing in the building.

General Types of Intervention. In general, the LSB program interventions were governed by the Massachusetts Lead Law (105 Code of Massachusetts Regulations 460 and 454 CMR 22). Each enrolled project received a comprehensive lead paint inspection report, which met both state and Evaluation requirements. Based on inspection findings, specifications were developed for the lead hazard control work and the resulting work write-up was reviewed and approved by the property owners whose units were being deleaded. Interior treatments included component replacement using new wood trim milled to match historic trim, wet scraping of surfaces full height, off-site dipping and covering, and a full paint job to ensure that surfaces would be cleanable and easy to maintain. Some building exteriors were treated with vinyl siding, others were fully painted. Exterior trim was covered with aluminum coil stock if windows were not replaced. Many exterior porches were completely demolished and re-built due to the accelerated levels of decay, largely as a result of deferred homeowner maintenance. No soil treatments were performed.

California

Administration. The California Department of Community Services and Development (CSD) had overall responsibility for California's Round 1 Grant, which was administered by CSD's Lead Hazard Control Program. CSD managed contracts with community-based organizations (CBOs) and an interagency agreement with the Department of Health Services (DHS). Initially, CSC and DHS worked with the CBOs to identify and screen eligible units. However, the impractability of that process soon became evident.

So as not to hamper the progress of the program, participants began to focus on particular tasks. While maintaining overall responsibility for the grant, CSD began to focus on the environmental tasks—identifying and testing units, developing work plans, and completing clearances. DHS focused on health-related tasks, i.e., collecting the family and blood data, and on performing data management tasks. The CBOs took primary responsibility for intake, education, and completion of the lead hazard control work according to the work plans.

Targeted Areas. The grant program focused its efforts in low-income neighborhoods in six counties through four CBOs. The CBOs and the areas they targeted were: (1) the Maravilla Foundation, which provided services in Los Angeles County including the neighborhoods of East Los Angeles, South Central Los Angeles, City of Los Angeles "Korea Town," North Hollywood and San Pedro; (2) the Metropolitan Area Advisory Commission (MAAC), which served San Diego County, with the largest number of units included in the study located in National City, and other units located in the Logan neighborhood in the City of San Diego; (3) the San Francisco Economic Opportunity Commission (SFEOC), which served San Francisco County and had predominantly single-unit structures; and (4) Proteus Incorporated, which primarily served migrant and seasonal farm workers in the Central Valley including Fresno, Kings, and Tulare Counties. Only a handful of units for the extended evaluation came from this CBO. While the information about the work plans for the units from Proteus were included in the study, a problem with the results from the laboratory used at that time caused these units to be dropped from further study in the extended Evaluation.

Enrollment Methods. The exact enrollment methods varied by CBO but were generally based on finding target age children (i.e., 6 years old or less). In Maravilla's area, CSD met with the local health and housing departments to coordinate referrals of children with elevated blood lead levels living in units known to have lead-based paint. These units were then referred to Maravilla for enrollment. In SFEOC's area, SFEOC coordinated with its Head Start and child care programs to find units with children. These units were tested, and if lead was found, they were enrolled in the program. In MAAC's area, MAAC coordinated with owners of low-income rental property that it had previously served through its weatherization program.

General Types of Intervention. At the start of the program, abatement techniques (e.g., enclosure of exterior siding with T1-11 or encapsulants and window and door replacement) were utilized, with very high associated costs (i.e., $10,000 to $15,000 per unit). The program changed to a less costly method that entailed the stabilization and repainting of many surfaces (including exterior siding), thus allowing the completion of more units. The program, however, continued to replace windows and doors, frequently integrating weatherization funding to complete such replacements. Soil work was infrequently performed.

Chicago

Administration. The Chicago Department of Public Health (CDPH) had overall responsibility for Chicago's Round 2 Grant, formally known as the "Chicago Lead-Safe Homes Initiative" (the Initiative) and housed in CDPH's Lead Poisoning Prevention Program (CLPPP). With the exception of grant/loan approval, the Grant program used CLPPP staff for all program activities, including program administration and budgeting, identification and inspection of housing units, construction specification development, contractor bidding and awards, construction management and contractor oversight, and final clearance testing. The Chicago Department of Housing (CDH) administered the grants and loans made to participating owners. The program entered into subcontracts with five local community organizations to provide assistance in targeted neighborhoods. Two of the five later dropped out of the program, with one other agency and CLPPP assuming their duties. The community agencies coordinated blood sampling of enrolled children, arranged for relocation of the enrolled families during construction, scheduled and conducted Evaluation interviews with enrolled family adults and caregivers, provided lead poisoning prevention information to resident families, and worked with property owners during construction.

Targeted Areas. The grant program focused its efforts in 12 city neighborhoods: Austin, East Garfield Park, West Garfield Park, Englewood, West Englewood, West Town, Humboldt Park, Logan Square, Lower West Side, North Lawndale, South Lawndale, and New City.

Enrollment Methods. Chicago targeted homes with children having elevated blood lead levels. After being notified of a child having a blood lead level above 20 µg/dL, CLPPP sent one of their lead inspectors to perform a lead paint inspection and collect dust samples. If lead hazards were identified, CLPPP issued a violation notice to the owner based on a Chicago ordinance. Owners were required to appear at a compliance hearing and repair deteriorated lead-based paint within a certain timeframe. At the hearing, owners were given the opportunity to enroll in the grant program, including mandatory participation in the Evaluation. If owners agreed, then CLPPP attempted to enroll the household (i.e., family of the poisoned child). This compliance-driven system provided a ready supply of units and households for the Grant program and Evaluation.

General Types of Intervention. After some initial delays in defining a construction strategy, a construction specialist subcontractor was hired to oversee all aspects of lead hazard control interventions, and helped CLPPP settle on a fairly uniform construction specification that combined abatement and interim controls for both interior and exterior surfaces. At first, the program experimented with window repair but then found that full window replacement was more efficient and not much more expensive. The program also began enclosing damaged plaster surfaces with gypsum board (i.e., drywall), rather than repairing them. Other wooden components, such as doors and trim, were replaced if simple paint stabilization was deemed insufficient. All other interior painted surfaces, including enclosed rear porches, were then stabilized and repainted with a high quality latex paint. On the exterior, particularly on uncovered porches and stairways, deteriorated surfaces were stabilized and repainted. The program did not treat exposed soil.

Cleveland

Administration. The Cleveland Department of Public Health administered and managed the lead hazard control program, including overall program design, enrollment, medical monitoring, inspections, specification approval, abatement monitoring and clearance. The lead program subcontracted with three non-profit housing rehabilitation agencies—Cleveland Housing Network (CHN), Union-Miles Development Corporation (UMDC), and Famicos Foundation—to write specifications and manage abatements. Environmental Health Watch (EHW), a local non-profit environmental education and advocacy group, managed the evaluation component, entering data, managing the evaluation database, and conducting post-intervention inspections.

Targeted Areas. There were two lead hazard control projects: the Scattered-Site Project (SSP) and the Intensive Neighborhood Project (INP). For the SSP, households throughout the city were targeted for enrollment based on the presence of a lead-poisoned child identified through Cleveland's screening and case management system. Based on an analysis of lead poisoning rates and the willingness and capacity of local non-profit housing agencies to participate, the INP targeted households in two neighborhoods, Union-Miles and St. Clare-Superior.

Enrollment Methods. Approximately 42% of Cleveland units were enrolled under the SSP, with the remaining 58% enrolled under the INP. In addition to targeting households with lead-poisoned children, SSP further focused resources on enrolling any owners who lived within the city limits. Once these criteria were met, field staff visited owners and tenants, if applicable, to determine interest and low-income eligibility (80% of median income for both owners and tenants). Non-profit owners were exempt from the low-income requirement. Once the target household was enrolled, residents of other units within the same building were enrolled. Buildings had to have no more than four units and the scope of work had to be within the budget of the project.

The INP had two components. The first was the Union-Miles INP, which was located in a small area of often contiguous houses and had a significant emphasis on resident education and involvement. Field staff conducted door-to-door surveys to identify dwellings that had child residents or frequent child visitors, gross exterior hazards, or were located adjacent to a home with child residents or visitors. Once these criteria were met, field staff re-visited dwellings to determine if owners and tenants met low-income eligibility requirements. Owners did not have to be Cleveland residents. Once a target household was enrolled, other residents in the same building were enrolled.

The other component, the St. Claire-Superior INP, involved additional lead remediation in previously or concurrently rehabilitated units managed by Famicos, a large non-profit community development agency. All occupied units, including a 29-unit low-income apartment building, were enrolled by Famicos staff and chosen based on rehabilitation opportunity points, in which lead funds could be added to other rehabilitation funds that had already been spent or allocated for the building.

General Types of Intervention. The original SSP treatment strategy usually involved interim controls such as interior and exterior spot scraping and priming (no finish painting), enclosure of window wells, final cleaning, and covering or seeding of bare soil. At the end of the first year of intervention activities, this strategy was modified, primarily to more permanently treat exterior paint and windows. In addition to final cleaning and covering/seeding of bare soil, interventions were modified to include vinyl siding, window replacement, enclosure of lead-painted floors, and finish-painting of interiors. Throughout the SSP, CHN was sometimes able to arrange for concurrent work—designed to address problems such as weatherization, moisture, heating, electrical—to be paid for by other funding sources.

INP treatment strategy utilized a range of less intensive and less costly interventions including vinyl siding, replacement windows, final cleaning, and/or covering or seeding of bare soil. The above activities were conducted singly or in combination depending on the housing condition and project priorities. In the Famicos INP, lead work was coordinated with other previous or planned rehabilitation activities.

Under the Union-Miles INP, prior to the start of work, residents were required to attend two classes that addressed childhood lead poisoning issues, proper cleaning techniques, preparation of homes for lead hazard reduction work, and maintenance of a lead-safe home. Participants returned for additional classes and transformed the class into a regularly scheduled neighborhood meeting. They took responsibility for distributing prevention information and teamed up to conduct lead-safe cleaning in homes that were not eligible for the program. Some owners of treated homes made non-abatement improvements on their own. UMDC arranged for some free materials and paint to be provided and gave technical assistance for such work. In some instances, owners of non-abated homes also made visible improvements to their own properties.

Massachusetts

Administration. The Department of Housing and Community Development (DHCD) had primary responsibility for administering the lead hazard control grant program and worked with four subgrantees: Brockton, Chelsea, Lawrence, and Worcester. DHCD also collaborated with the Department of Public Health and the CLPPP, which managed the overall Evaluation data collection effort and coordinated the work of the four subsites and two large building programs.

Targeted Areas. Four cities were involved in the Evaluation in neighborhood-based programs: Brockton, Chelsea, Lawrence, and Worcester. Also included was a large building program involving two large multi-unit complexes in Gloucester and Roxbury.

Enrollment Methods. Dwelling units were recruited by subgrantees through advertising in local publications, conferences with owners, community presentations, and contacts with other community groups. Enforcement of the Massachusetts Lead Law also played a role in recruitment, generally as referrals through local CLPPP programs or heath care providers. Many of the buildings were under existing orders to abate their units because of the presence, at some time, of a lead-poisoned child. After dwellings had been recruited, program staff approached occupants for recruitment into the Evaluation. Properties with occupants enrolled were included in the Evaluation.

General Types of Interventions. In accordance with the Massachusetts Lead Law, substantial abatement was performed on all units. In some situations, this law allowed a form of interim control, in which some selected surfaces—i.e., those that were not protruding and abrasion or friction surfaces--were made intact. All other surfaces, however, had to be abated by paint removal, enclosure, approved liquid encapsulants, or component replacement. All of the methods were used, although the most typical were paint removal and component replacement. No soil treatments were conducted.

Milwaukee

Administration. The Milwaukee Department of Health was responsible for the administration of the lead grant. They received support from Milwaukee's Department of Housing and Community Development (DHCD), which was responsible for writing scopes of work and working with contractors for buildings undergoing high levels of intervention (defined below). The collaboration with DHCD on these higher treatment levels was difficult due to the lengthy time required to bring buildings receiving federal rehabilitation funds into the lead program. Later in the Evaluation, the number of buildings receiving these high treatment levels was reduced, and the number of units receiving lower intervention levels was increased.

Targeted Areas. Milwaukee's program did not formally target specific neighborhoods but conducted work in several of the lowest income neighborhoods in the city, focusing on treating older housing in deteriorated condition.

Enrollment Methods. The city had four levels of lead hazard intervention, as defined below. For the two lowest intervention levels, the Health Department's Stellar database was used to identify children with elevated blood lead levels. For the third and fourth levels of intervention, applications for federal general rehabilitation funds were used to enroll buildings. Milwaukee did take referrals within the Health Department if someone called but did not conduct any direct outreach.

General Types of Intervention Performed. The city's four levels of intervention were:

- Level 1: Cleaning intervention and education provided by Health Department staff.
- Level 2: Interim controls, including minimal-to-moderate lead hazard control measures (e.g., minimal scraping and painting of paint hazards, limited encapsulation) with no concurrent work.
- Level 3: Some abatement strategies, including intensive scraping and painting and enclosure/encapsulation; deteriorated and non-deteriorated lead-based paint treatment; and variable concurrent work.
- Level 4: Substantial housing rehabilitation and abatement, including intensive scraping and painting, extensive component encapsulation and/or enclosure, and intensive concurrent work.

Although some pre-intervention soil samples were collected, no soil treatments were performed. Milwaukee's program was unique in its conscious decision to have these four distinct levels of lead hazard control Efforts were made to assign these four treatment levels in housing with similar conditions so that the effectiveness of the levels could be compared. Milwaukee also had one of the lowest cost intervention levels. Their Level 1 cleaning intervention involved mainly the cost of cleaning materials and staff time required to visit a unit, show residents how to clean, and provide other education on lead safety.

Minnesota

Administration. Although the grant was administered by the Minnesota State Housing Finance Authority, most of the programmatic responsibilities were delegated to three subgrantees: St. Paul Department of Health, Minneapolis Department of Health and Family Support, and Duluth Housing and Redevelopment Agency.

Targeted Areas. Specific neighborhoods were not targeted in any of the three subgrantee cities.

Enrollment Methods. St. Paul and Minneapolis targeted homes with children having elevated blood lead levels. Although Duluth originally planned to address children having elevated blood lead levels, no children with blood lead levels exceeding 19 µg/dL were found. Therefore, the Duluth program switched to a direct outreach to low-income families, targeting low-income families with deteriorated housing conditions in areas that were identified in the Community Action Program's database, with mailings and advertisements in the local newspaper. People who applied to use funds under Duluth's CDBG program were informed about the lead program and encouraged to apply.

General Types of Intervention. All three grantees addressed all deteriorated lead paint hazards using some type of interim control, including paint stabilization and friction control. Treatments included the repair or replacement of all friction surfaces (e.g., windows, doors, and floorboards), repair or covering of interior lead-based paint, some exterior repair (e.g., enclosure with vinyl siding or other coverings) and repainting of leaded surfaces, repair or replacement of floor coverings, and some soil remediation. In Minneapolis, thirty units underwent a clean-only intervention.

Both St. Paul and Minneapolis signed a fixed-price contract with one contractor to perform all lead hazard control work; each directly paid the contractor. The contractor and the program manager agreed on the scope of work for each home from a set of specifications that were developed precisely for the program. This system proved efficient in the beginning when only a few contractors were certified. As more certified contractors became available, the cost of the bidding approach decreased, and the two grantees moved to bidding out the work to more contractors, including community action programs and non-profit weatherization groups. On the other hand, Duluth bid out their lead jobs. To ensure that the homes of lead-poisoned children were at least cleaned of immediate lead hazards in a timely manner, Minnesota state law required that such homes be addressed with a SWAB team within a week of being identified. St. Paul found that in most cases the contractor could respond just as quickly so did not use a SWAB team approach.

New Jersey

Administration. The Division of Housing and Community Resources in the New Jersey Department of Community Affairs (DCA) had responsibility for New Jersey's Round 1 Grant.

Targeted Areas. Although the Grant originally included 11 subgrantee cities: Asbury Park, Beverly, Camden, Elizabeth, Englewood, Irvington, Jersey City, Newark, Paterson, Pemberton Township, and Woodbine. Subsequently, however, Asbury Park, Beverly, and Pemberton Township withdrew.

Enrollment Methods. The primary focus of this Grant program was to integrate lead hazard control with moderate to comprehensive housing rehabilitation in the subgrantee cities. Property owners already eligible for rehabilitation funding were also offered the opportunity to obtain funding for lead hazard control. The presence of an elevated blood lead child was not a factor in enrolling either dwelling units or households. Many units were already vacant when enrolled. Although new families who moved in upon completion of the work were asked to participate, none did.

DCA worked hard to convince the local subgrantees of the merit of including lead in their rehabilitation programs and made presentations at property owner meetings convened by the subgrantees; however, only 28 units were enrolled in the Evaluation--26 in a garden-style apartment building in Paterson and two in a duplex in Irvington.

General Types of Intervention. Once units were identified, a subcontractor to DCA performed a lead paint inspection and collected dust samples according to the HUD Evaluation Protocol and developed lead-related construction specifications based on the program's goal of making dwelling units lead free or to abate all lead hazards. Interior and exterior surfaces in the 23 enrolled units were fully abated. There were no soil treatments or interventions.

The construction process was slow, in part due to the fact that DCA's abatement contractor regulations were not signed until 1995 and did not become effective until January 1996. It then took at least six months before a cadre of contractors was trained and approved for the program's contractor bidding list. Housing rehabilitation programs in the subgrantee cities experienced an overall slow down in work during this period.

New York City

Administration. Although the New York City Department of Housing Preservation and Development (HPD) was responsible for the administration of the Grant, duties were split between HPD and the City Health Department. HPD inspectors performed initial x-ray fluorescence (XRF) testing, initial visual inspections and dust wipe sampling. Health Department staff collected blood samples, conducted household interviews, and performed some post-intervention dust wipe sampling. Outside contractors performed the interventions. Both departments were involved in quality assurance/quality control (QA/QC) of forms, but the Health Department was responsible for data entry. While many staff changes occurred, these basic departmental responsibilities remained constant over the course of the Evaluation.

Targeted Areas. HPD's program blended lead grant funds with their ongoing housing rehabilitation program and generally made funds available in various neighborhoods throughout the city. One initiative, however, called the Primary Prevention Program (PPP), targeted neighborhoods having a high incidence of elevated blood lead levels, including Bedford Stuyvesent and portions of Crown Heights, Fort Greene, and Bushwick.

Enrollment Methods. Although the PPP originally intended to use local health clinics to identify expectant or new mothers and help focus on families with newborn babies living in deteriorated housing, progress was very slow and insufficient units were identified; therefore, HPD switched to a more direct and aggressive outreach program, focusing on three enrollment methods:

1. Buildings that were receiving funds through the Neighborhood Reinvestment Program (NRP) for total rehabilitation received $10,000 per unit in lead funds for lead-safe demolition and renovation.
2. Two buildings that were receiving funds for moderate rehabilitation through the Participation Loan Program (PLP) also received $5,000 per unit for lead hazard control.
3. Under the PPP, notices were sent to all owners of buildings with three or more units built prior to 1960 in the target neighborhoods explaining the program and asking for their participation. Notices were also sent to community organizations and churches, and flyers were widely distributed. HPD and the Health Department staff held several public meetings at HPD to explain the program and began to build a database of potential buildings. This publicity generated many word-of-mouth referrals, and in the end, more buildings were identified through word-of-mouth than from informational meetings.

General Types of Interventions Performed. The NRP involved gut rehabilitation, where the entire interior of the unit was removed, including a sizeable percentage of the plaster walls. If the plaster was not removed, it was covered by wallboard. Lead funds were used to gut the building in a lead-safe manner and to provide funds for the windows, doors and other features of the unit that would contribute to lead safety. In the PLP, units were moderately rehabilitated, i.e., only very deteriorated plaster was removed or covered with wallboard, and most windows were replaced. The scope of work for the PPP was more limited: all interior surfaces were scraped and painted, some windows were replaced if very deteriorated, and emphasis was put on reducing lead on deteriorated, friction, and impact surfaces. New York did not conduct any soil work.

Rhode Island

Administration. For most of the Round 1 grant period, the program was administered by the Rhode Island Department of Health. The Health Department managed all aspects of the project including housing related activities. A unique characteristic of the Rhode Island program was its reliance on outside contractors to do the inspections, risk assessments and job specifications as well as lead hazard control work. Program officials consciously chose this method in order to help "grow" the industry in Rhode Island.

When the Rhode Island Housing and Mortgage Finance Corporation was awarded a Round 3 Grant in late 1997, they also assumed responsibility for program administration for the Evaluation. At that time, all Round 1 interventions were complete, but follow-up inspections and data management were ongoing. Inspectors transferred to the Housing agency, while the project manager and data manager continued to function out of the Health Department. Responsibilities for phlebotomy were contracted out to a local hospital to complete post-intervention sampling.

Targeted Areas. Rhode Island worked through 22 local housing offices located across the state.

Enrollment Methods. Eighty percent of the children in the Rhode Island Evaluation were recruited because they had elevated blood lead levels. Owners of buildings were cited for violations due to this lead poisoning. The Providence Housing Court had information on the lead program and ordered participation if owners were brought to the court for violations. In addition, local housing offices identified some houses through their housing rehabilitation programs. For a unit to be enrolled, it had to meet Section 8 Housing Quality standards, and the owner could not own more than 12 units.

The program originally intended that local housing agencies would take an active role in identifying potential properties. When this did not occur, the program changed its focus to fixing the homes of lead-poisoned children.

Over the course of the Evaluation, the program also changed its relocation policy from one of using hotels to one of using transitional housing operated by a non-profit group. Instead of paying for alternative housing, they also gave stipends to people who stayed with friends and family.

General Types of Interventions Performed. The typical lead hazard reduction activities included replacement of windows, doors, and molding; interior and exterior scraping and painting or siding of exteriors; and soil remediation. The average cost was approximately $8,000 to $10,000 per unit. Scopes of work were prepared by outside risk assessors and approved by program staff.

Vermont

Administration. The Vermont Housing and Conservation Board was responsible for program administration. Community nurses from the Health Department conducted household interviews, drew blood samples, and collected some dust wipe samples.

Targeted Areas. Vermont's funds were available and used throughout the state. In accordance with Act 156 of the 1996 Vermont Lead Law, one low-level program targeted the Old North End of Burlington for a special low-level project utilizing "Essential Maintenance Practices (EMP)," as described below.

Enrollment Methods. Vermont enrolled units from several different sources, including the Vermont Health Department, which referred families with lead-poisoned children; non-profit housing developers that learned of the program when they applied for federal HOME funds; and unsolicited applications. The EMP units were recruited through a mailing to owners in the target neighborhood.

General Types of Interventions Performed. Vermont performed a wide range of treatments. Most of the units receiving HOME funds underwent moderate to full rehabilitation, while other units generally underwent only those treatments necessary to reduce lead hazards, typically including window treatments (replacement or repair), treatment of friction surfaces, stabilization of loose and flaking lead-based paint, and exterior repainting. EMP units were cleaned, limited areas of paint were stabilized, and caps were installed over window troughs. A unique aspect of Vermont's program was that almost every private homeowner undertook at least part of the intervention work, most often repainting, but sometimes rebuilding and other more extensive renovation work. Although some pre-intervention soil samples were collected, Vermont rarely performed soil treatments.

Vermont originally intended to spend only $1,599 per unit on intervention but soon discovered that this amount was insufficient and increased it to $3,000 by the end of Round 1. By the end of the Evaluation, excluding the EMP project, interventions cost between $7,000 and $8,000 for an apartment in a multi-family building and between $8,000 and $10,000 for a single-unit home.

Wisconsin

Administration. Although the program was administered by the Wisconsin Division of Health, whose staff inspected, tested and completed preliminary specifications on the units, many of the program design decisions were made locally by 12 subgrantees. (For the purposes of the Evaluation, Milwaukee was treated as separate grantee, and is not one of the 12 Wisconsin subgrantees.) These subgrantees—Chippewah Falls, Eau Claire, Madison, Manitowoc, Oshkosh, Richland, Rockland, Seboygan, Superior, Wausau, West Allis, and Wisconsin Rapids—selected the units, negotiated the final specifications with the owners, put the specification packages out for bid and picked the contractor, then notified the local health departments to begin household interviews and dust wipe sampling. One of the subgrantees dropped out of the program during the Evaluation. Because of the decentralization of the program, State staff had to increase their monitoring of contractors to ensure that the work was done according to specifications. The Wisconsin Department of Housing was responsible for paying the contractors.

Targeted Areas. The twelve subgrantees were distributed across the state.

Enrollment Methods. Since local housing departments were responsible for selecting units, criteria for recruitment and selection of dwelling units differed from place to place. Some of the methods included: (1) units participating in federally funded rehabilitation projects; (2) housing units having children with elevated blood lead levels; and (3) outreach to owners of housing identified as high risk (i.e., older housing in deteriorated condition).

General Types of Interventions. Types of interventions varied from city to city, depending on the condition of housing and the extent of lead hazards present. The type of treatment also depended on how the units were brought into the program and if the city combined the lead grant with other housing rehabilitation funds. Typical treatments included repair of deteriorated paint, replacement or repair of friction surfaces (e.g., windows, doors, and baseboards), floor (carpet, linoleum, or painted) repair or replacement, and exterior repainting. Although no subgrantee performed any soil remediation, some did collect pre-intervention soil samples.

3.0 STUDY DESIGN AND QUALITY CONTROL METHODS

3.1 DESIGN OF THE EVALUATION

A challenge for the Evaluation designers was to develop a way to judge the cost-effectiveness of treatments without the use of control groups, random selection, or random assignment of treatments. Such research techniques were not compatible with the programmatic intent to have flexible, locally designed treatment strategies. Without these research techniques, the study had to collect additional data to determine whether changes in the principal outcome measures—dust lead loadings and blood lead levels—might be the result of the lead hazard control work or other factors. Because children can be exposed to both lead-based paint in their homes and lead from other sources, the study tried to collect as much information about other sources as feasible. Standard protocols and 23 data collection forms were developed (Appendix A), covering ten major variables of interest (Figure 3-1) in fulfilling the nine objectives of the Evaluation (see Section 1.1).

The study evaluated the environmental intervention (i.e., the scope of work and its costs), as well as two principal outcome measures (i.e., dust lead loadings and blood lead levels). Data about another variable, soil lead levels, were collected at the option of each grantee. Grantees in Alameda County, California, Cleveland, Milwaukee, Minnesota, Rhode Island, Vermont, and Wisconsin obtained soil information from some of the properties that they treated. A summary of environmental sampling procedures for dust, paint, and soil is provided in Figure 3-2. Data about the remaining variables were collected by all grantees so that the possible effects of these variables could be assessed.

In a later project that was separately funded, data on post-intervention exterior dust and soil were collected from selected locations. Chapter 8 describes the design and methods used for this separate project.

Figure 3-1
Ten Factors of Interest in the Evaluation

1. Baseline Program Information - basic characteristics of the dwelling unit and the resident household (e.g., age of dwelling, tenure) at the time of enrollment into the study.
2. Dwelling Condition/Visual Inspection of Exterior/Interior - assessment of the general condition of the dwelling before and after intervention, including visual assessment of treatment integrity.
3. Paint Inspection and Testing - description of the location and condition of all painted building components and measurement of the paint lead levels on those components.
4. Dust Sampling - measurement of dust lead levels on selected floors, interior window sills and window troughs (wells).
5. Soil Sampling [optional] - description of the ground cover and measurement of soil lead levels at the building perimeter and at likely play areas.
6. Environmental Intervention - description of all lead hazard control strategies and treatments.
7. Environmental Intervention Cost - determination of costs associated with treatment of lead hazards.
8. Family Interview - documentation of activities of the resident household that could confound or modify dust and blood lead levels.
9. Occupant Protection/Relocation Questionnaire - documentation of the experience of the household during intervention. Information may identify possible exposure of the resident child to lead hazards at the time of intervention.
10. Blood Lead Testing - measurement of blood lead levels of children between the ages of six months and six years who are enrolled in the study.

Figure 3-2
Summary of Environmental Sampling Protocol

Dust - Dust was collected from 7-9 locations in a dwelling unit during each phase of the Evaluation. Single-surface dust wipe* samples were collected from the:

Floor: (bare or carpeted*)	Interior Entry
	Kitchen
	Child's Play Room (or Living Room)
	Youngest Child's Bedroom (or Smallest Bedroom)
	Next Youngest Child's Bedroom [if present]
Int. Window Sill:	Kitchen
	Youngest Child's Bedroom (or Smallest Bedroom)
Window Trough: (Well)	Child's Play Room (or Living Room)
	Next Youngest Child's Bedroom [if present]

*Grantees had the option of collecting samples on carpet using a prescribed vacuum collection procedure.

Paint - X-ray fluorescence (XRF) paint tests were conducted on all interior and exterior painted component systems prior to intervention. When tests were inconclusive, or components were inaccessible by XRF, up to 10 laboratory paint chip tests per unit were required.

Soil - Soil sampling was conducted at the option of the Grantee. When conducted, composite soil samples were collected from two locations during each phase of the Evaluation:

Perimeter of Building (i.e., foundation or drip line)
Child's Play Area in Yard

3.1.1 Consent and Notification Procedures

As discussed in Section 2.1, grantees determined how best to recruit and enroll property owners and residents who lived in eligible dwellings. Participation in the lead hazard control grant program itself did not require the consent of the family living in the unit(s). However, participation in the Evaluation required the informed consent and voluntary participation of both the property owner and the resident. Each grantee prepared its own written consent form to participate in the Evaluation, outlining reasons for the Evaluation, its risks and benefits and the conditions of participation. Each consent was designed to meet local Institutional Review Board (IRB) requirements. These IRBs, often from universities or medical institutions, reviewed and approved these forms. Grantees were permitted to consider the use of incentives to retain families in the Evaluation.

Grantees were responsible for obtaining informed consent from each participating property owner as a condition of enrollment in the lead hazard control grant program to participate in the Evaluation. Grantees did not deny hazard control services to property owners if resident families did not agree to participate, or subsequently dropped out of the Evaluation. Grantees were also responsible for obtaining, during the initial contact with the family, signed informed consent of the resident household (e.g., parent/legal guardian) to participate in the Evaluation. Children between the ages of 6 months and 6 years at the time of enrollment of the family were eligible to participate. The parents or legal guardians of each participating child were asked to consent to pre- and post-intervention blood lead monitoring and the release of relevant medical information. In addition, grantees were to ask parents/legal guardians to participate in structured interviews and to allow inspectors access to the dwelling for collection of required pre- and post-intervention environmental measurements. Grantees were free to determine how their programs managed families who did not want their children tested.

Grantees were directed to notify participating families of blood lead and environmental lead measurements. They were also directed to notify property owners of environmental lead measurements.

3.1.2 Schedule for Data Collection

As summarized in the data collection schedule (Table 3-1), information was gathered at four times during the Evaluation: prior to intervention (Phase 01), immediately after intervention (Phase 02), and 6 and 12 months post-intervention (Phases 03 and 04). With this information, it was possible to evaluate the costs and effectiveness of the intervention over a one-year period. Because HUD felt that longer periods of follow-up were needed to fully assess the costs and benefits of the different strategies, it provided support to nine grantees to collect information from selected dwelling units at 24- and 36-months post-intervention (i.e., Phases 05 and 06). Grantees who participated in this 24/36-month post-intervention study were Alameda County, Baltimore, Boston, California, Minnesota, Rhode Island, Wisconsin, Milwaukee, and Vermont.

Table 3-1:Data Collection Schedule In Relation To Environmental Intervention

DATA COLLECTED	≤4 MONTHS BEFORE (Phase 01)	≤6 WEEKS BEFORE (Phase 01)	≤3 DAYS AFTER RE-OCCUPANCY (Phase 02)	≤6 WEEKS AFTER	6 MONTHS AFTER (Phase 03)	12, 24, 36 MONTHS AFTER (Phases 04,05, 06)
Baseline Program Information	X					
Dwelling Condition Visual Inspection Exterior/Interior	X		x		x	x
Paint Lead Inspection & Testing Exterior/Interior	X					
Dust Lead Sampling	x[1]	x	x		x	x
Soil Lead Sampling (Optional)	X		x		x	x
Environmental Intervention Description	X		x[3]			
Environmental Intervention Cost	x[2]		x[3]			
Family Interview		x			x	x
Occupant Protection/ Relocation Questionnaire				x[4]	x[4]	
Blood Lead Test/Child		x		x	x	x

[1]Required only if educational information was given to residents before the 6-week dust sampling phase. Pre-intervention dust sampling had to occur before educational information was transmitted to residents to establish true baseline conditions.
[2]Estimate (optional)
[3]Actual intervention and cost as soon as possible after clearance
[4]If Project personnel visited the home to draw the child's blood after the intervention, the Occupant Protection Interview should have been conducted. If not, this questionnaire was included in the 6-month post-intervention visit.

3.1.3 Summary of Evaluation Protocols

Because the quality of the Evaluation was dependent on the grantees reporting information that would be comparable across all sites, the Center and UC developed data collection protocols and forms that were used by all grantees. The Federal Office of Management and Budget approved the data collection forms and protocols in October 1993. All interview forms were translated into Spanish by the Center and the state of California. These forms were available for all grantees to use. Translators were used to conduct interviews with enrollees speaking other languages. The protocols summarized the rationale and procedures for data and sample collection on each of the ten major variables of interest (see Section 3.1), including baseline program information, dwelling unit inspection and lead paint testing, dust sample collection and analysis, soil sample collection, documentation of the type and cost of lead hazard control intervention implemented, post-intervention inspections of treatments, initial and post-intervention household interviews, blood lead sample collection and analysis, and special instructions for multi-unit housing (see Section 3.1). These forms are provided in Appendix A.

3.1.4 Data Management and Storage Procedures

UC developed a customized computer database system to handle the data collection needs. The grantees then worked with the Center and UC to determine how the different agencies and private contractors participating in the Evaluation would collect the data. The database was decentralized, with all grantees entering data into their own computers. Once a month, grantees copied data files onto diskettes and mailed them to the Evaluation's data center at UC, along with hardcopies of forms. At the data center, these files were copied onto diskettes and loaded onto two separate computers. Hardcopy forms were organized and filed using a batch system (i.e., each single set of forms submitted by a grantee was considered a batch). As an additional backup measure, data stored on computer hard drives were periodically saved on magnetic tape. Unless otherwise indicated, data recovered from the original diskettes sent by grantees were subsequently used for statistical analyses. Prior to statistical analyses, data were converted from files stored in an Apple MacIntosh format to a Microsoft Windows Statistical Analysis System (SAS) format. The Center used a computer application ("Specmaster") developed by the Enterprise Foundation to collect a component-specific and treatment-specific scope of work for the lead hazard control activities for each dwelling unit. Like the UC database, the Specmaster™ database was decentralized and could be used by grantees to design their interventions. Monthly, the grantees used a utility application specifically developed for the Evaluation to export the treatment/cost data to a file for submission to the Evaluation data center. The treatment/cost data were reviewed by the Center prior to inclusion in the central data files.

3.2 DATA QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) SUMMARY

Detailed QA/QC results are provided in Appendix B. The Evaluation QA/QC program was established to detect and rectify errors in the collection and management of data. The overall goal was to increase the accuracy and sensitivity of measurements and outcomes by minimizing systematic bias or reducing variability. QA/QC procedures were divided into three broad categories: (1) those related to analytical laboratory bias and field sampling activities; (2) those related to hazard control intervention; and (3) those related to inspection and interview data collected by the grantees.

QC data on dust lead, blood lead, and soil lead samples were obtained by grantees and submitted by facsimile directly to the Evaluation's QC officer at UC. The QC officer transcribed and stored QC data in an Excel format on IBM-type desktop computers. Certain laboratory results were directly supplied by laboratories and were transcribed by data center personnel.

3.2.1 QC Spike Sample Procedures and Results

To aid in assessing the ability of laboratories to accurately and reliably measure lead content, grantees had their participating laboratories analyze QC "spike" samples, i.e., samples prepared with known quantities of lead. QC dust samples were prepared by the Wisconsin State Occupational Health Laboratory (WSOHL); QC soil and dust vacuum spikes by the Hematology and Environmental Laboratories at UC; QC blood samples by the US Centers for Disease Control (CDC) and the WSOHL. The spike submittal schedule is shown in Table 3-2. QC sample materials, containers and labels were identical to those of regular samples of the same matrix, and were included with regular samples when submitted to the laboratories. Laboratories did not know the actual lead content of these QC samples. For dust and soil spikes, results that

Table 3-2: Scheduled Frequency For Submittal of External (Spike) QC Samples

Type of Sample	Recommended Submittal Frequency
Blood	2 per month minimum or 5% of estimated monthly sample volume, whichever was higher
Dust (wipes)	1 per 50 regular samples
Dust (vacuum)	1 per 5 dwelling units
Soil	1 per 50 regular samples

deviated from their true value by more than 20% were considered to be in error. For blood spikes, results that deviated from their true value by more than 3 µg/dL were considered to be in error.

- Dust Wipe Spike Results. Over the entire Evaluation period, all but four of the grantees submitted spikes at a rate equal to or exceeding the 1:50 (2%) rate required by the protocols. However, when looking at compliance on a quarterly basis, only Chicago submitted spikes at the required rate in over 90% of the quarters; three other grantees submitted at the required rate in 70% or more of the quarters, and an additional four in 50% or more of the quarters. The six remaining grantees complied with spike submittal protocols in less than 50% of the quarters, yielding less information available for gauging the performance of the participating analytical laboratories.

  Most laboratories infrequently had dust wipe QC samples with percent recoveries outside the acceptable range. The seven laboratories experiencing systematic problems had their analytical findings closely monitored. The Evaluation QC manager worked with the grantees and the laboratories to bring performance back to protocol requirements. When a laboratory's performance was characterized by excessive variability, all dust lead loadings from that laboratory for the period in question were excluded. A total of 1,996 samples from six laboratories were excluded. This represents 2% of the evaluation field samples collected. In some cases, grantees were advised to stop using problem laboratories and arrange for the use of other laboratories.

  Laboratories sometimes under-estimated the actual lead content of samples, often because a particular laboratory method was unable to fully extract the lead from samples. When the period and magnitude of values being under-reported could be estimated, an adjustment factor was applied to all dust lead loadings reported by the laboratory during the period in question. A total of 2,327 samples from two laboratories were adjusted. This represents 2% of the evaluation field samples collected. For one laboratory, the QC officer was able to identify why the extraction was less than optimal and made suggestions for improving the laboratory method.

- Blood Spike Results. Grantees were asked to submit a minimum of two spiked blood QC samples per month (6 per quarter) or 5% of their estimated monthly volume, whichever is greater. Massachusetts and Vermont submitted spikes at the required rate in over 90% of the quarters; three other grantees submitted at the required rate in 70% or more of the quarters, and an additional five in 50% or more of the quarters. Three grantees complied with spike submittal protocols in less than 50% of the quarters, while one grantee (New Jersey) collected only two blood samples and submitted no spiked blood QC samples.

As with the dust wipe QC samples, occasionally a blood spike sample result was outside the acceptable recovery range. However, only 23 blood samples from two laboratories were excluded due to poor lab performance. This represents less than 1% of all blood lead samples reported. Twenty-five other blood samples were adjusted upward. In one case, the QC officer recommended that a grantee stop sending samples to a poorly performing laboratory and to use another laboratory for blood analyses. Some blood samples were analyzed for lead by laboratories that did not participate in the Evaluation's QC program; these results were used in subsequent analyses only if no other source of information was available.

The QC report in Appendix B offers more details regarding grantee compliance, as well as specific information on data that were considered to be suspect and subsequently excluded from statistical analyses.

3.2.2 QC Blank Sample Procedures and Results

Evaluation protocols required that a "blank" QC wipe sample be prepared and submitted for every 50 field wipe samples collected. All grantees submitted blank samples more frequently, with most submittal rates on the order of 1 blank for every 10 or fewer samples. Blank samples were prepared in the field using the same materials as those used for regular samples. The presence of significant lead on these samples would indicate that lead attributed to a particular surface may in fact be due to cross-contamination from an inspector's glove, a contaminated sample container, or other sources not under experimental control. Measured quantities of lead in ostensibly "blank" samples would also potentially reflect cross-contamination in the laboratory, or laboratory measurement procedures that were in error.

Field blanks were prepared and the results monitored by the grantees. According to HUD Guidelines (HUD 1995), if more than 50 µg/wipe is detected in a field blank, the field samples associated with that blank should be collected again. Practical considerations precluded the re-visiting of tested dwellings to collect additional samples. Because re-sampling was not conducted, we examined the number of contaminated blank wipe media to determine if field sampling results should be disqualified because of presumed contamination.

Eleven thousand eight hundred and eighty nine (11,889) field blank samples were submitted by the various grantees and were analyzed by participating laboratories during periods when their QC performance was acceptable. Overall, high blank values occurred only sporadically (only 58 blanks (0.48%) were above 50 µg/wipe). Slightly less than 1% exceeded 25 µg/wipe. Only 7.1% of blanks exceeded 5 µg/wipe. Because (1) so many blank results were reported to be below the laboratory detection limit, (2) the detection limits used by the participating laboratories were highly variable, and (3) the overall levels encountered on these samples were low, no meaningful average value for the blank results could be derived. While the overall percentage of blank results greater than 50 µg/wipe was 0.48%, only three grantees exceeded that percentage: Massachusetts, Milwaukee, and New York City, with rates of 1.4%, 0.96% and 0.95%, respectively. These results were also considered part of the evaluation of the overall quality of the field sample data and thus did contribute to the exclusions of field wipe data based on overall laboratory performance. They were not used to exclude individual field wipe results associated with individual high blank levels.

These results on field blank samples also indicated that the use of multi-packaged wipe material in large containers by grantees such as those in the Evaluation contributed no contamination problems.

3.2.3 Substitution of Dust Wipe and Blood Sample Results at or below Reporting Limits

Many initial dust wipe sample results were reported to be below the reporting limits of certain laboratories (Table 3-3). Since reporting limits were sometimes as high as 25 µg, and because dust re-accumulation rates (one of the most important measures of intervention outcome) were often below these reporting limits, laboratories were asked to supply the actual machine values for samples with lead content below reporting limits. When machine values could not be obtained, dust lead values were imputed according to the methods delineated in Succop et al., in order to obtain the feasibly lowest results (Succop 2004).

Similar issues arose for blood lead data that were reported to be below reporting limits. Therefore, laboratories analyzing blood samples were asked to supply actual machine values, and in the absence of these machine values, blood lead values were imputed according to Succop et al.

Table 3-3: Initial Dust Wipe Sample Results Reported Below Laboratory "Reporting Limits"

Surface	% Below Reporting Limit[a]	Pre-Intervention	Immediate Post-Intervention	6 Months Post-Intervention	12 Months Post-Intervention
Floor	Average %	29.3%	49.1%	50.7%	52.2%
	Highest %	66.7%	92.7%	95.8%	86.8%
Window Sill	Average %	13.0%	52.7%	36.4%	35.9%
	Highest %	46.4%	95.1%	78.6%	57.7%
Window Trough	Average %	2.4%	44.1%	10.3%	11.1%
	Highest %	15.0%	85.7%	87.5%	21.6%

[a]Average % = percentage as the average across all Grantees; highest % = percentage based on Grantee with the most frequent "below reporting limit" values.
Data as of: August 1997
Data from: Form 19
Data source: QA/QC Summary, October 23, 2000

3.2.4 Quality Control of Inspection and Interview Data

Several different approaches were used to determine the accuracy and reliability of these data at one or more stages of the data review process. These included:

- Visual review of all incoming hardcopy forms;
- Check for valid codes, multiple choice options, dates, and certain calculations;
- Check to be certain that records did not duplicate those already received in earlier data submissions;
- Comparison between first and second key entries to check the accuracy of transcription;
- Forms progress report to help identify forms still needed to have a complete set; and
- Special reports to detect discrepancies and data inconsistencies between two or more forms.

Details concerning these approaches are provided in Appendix B. The method most often used to correct known data errors was a re-submittal request. This request contained sufficient information to identify a particular error, the form on which the error occurred, and the month and year in which the form containing the error was originally submitted. A detailed error message was provided that indicated the nature of the error and the needed correction. Re-submittal requests were compiled for all errors identified within a single batch of forms and were made both after an initial review of a form containing errors and after submittal of unsatisfactory corrections by the grantee. Re-submittal requests were included as part of a monthly mailing to each grantee.

Using these methods, an early overall error rate of more than 25 percent was reduced to less than 1 percent by the end of the data collection process. The Evaluation team concluded that there were no systematic biases in the major study outcome variables based on remaining errors.

3.2.5 Quality Control of Portable XRF Instruments

Before conducting paint inspections on wood substrates, Grantees were instructed to obtain an average of three readings for a National Institute for Standards and Testing (NIST) standard in the range of 0.5 to 1.5 milligrams per square centimeter (mg/cm^2). If they were unable to obtain an acceptable reading after two attempts, they were to defer the paint inspection of the unit until the XRF machine had been serviced or until a new machine was acquired. When tested prior to use, 1.1 percent of XRF instruments failed their pre-inspection calibration tests. This level was considered negligible and XRF data were not excluded on the basis of such violations.

Grantees were also instructed to confirm XRF calibration before the instrument was turned off, i.e., at the conclusion of an inspection or series of inspections. In approximately 1.2 percent of all calibration tests, instruments were found to be out of calibration post-inspection even though they were in calibration pre-inspection. For another 2.2 percent of inspections, instruments that met pre-inspection calibration requirements were not re-tested at the conclusion of an inspection to verify that they remained calibrated during the period of use. This level of compliance with QC requirements was considered acceptable; therefore, no XRF data were excluded.

In addition to calibration checks, grantees were to re-visit 5% of the dwelling units and repeat XRF measurements for a minimum of 10 surfaces. To pass re-inspection, the average of these 10 repeat measurements was to be within 1% of the original average values (e.g., 1 mg/cm^2 if the initial average was less than 10 mg/cm^2). Five of 154 repeat inspections failed to meet this criterion. This level of compliance was considered acceptable; therefore, no data were excluded based on repeat XRF measurements.

3.2.6 Substitution of XRF Results at or above Upper Measurement Level

XRF instruments varied in the upper range at which lead paint concentrations could be measured. Some instruments peaked at 9.9 or 10.0 mg/cm^2 while others could measure higher levels. Data for instruments that had maximum readings of 9.9 or 10.0 were normalized by substituting a calculated value for the maximum reading. Calculated values were determined by estimating the geometric mean and geometric standard deviation for each of the painted components measured by a particular instrument. Tables for right-censored data provided in Cohen, 1961[1] were then used to calculate values, which were then randomly substituted for peak instrument readings and used in subsequent analyses. Of the 333,223 XRF readings taken on interior surfaces, 2.3% are substituted values, while 8% of the 34,240 readings taken on exterior surfaces are substituted values.

3.2.7 Quality Control of Lead Hazard Control Activities and Coding Strategies

Oversight of construction activities was implemented through field audits and a visual review of written specifications for lead hazard control treatments and their associated costs. Field audits were conducted by Evaluation project managers and focused on different aspects of the construction process, including preparation of the scope of work, management of the construction process and completion of construction-related paperwork. Each field audit was followed by a written report provided to the grantee by the person conducting the audit.

Specmaster®, a specification writing and cost-estimating software program, was used by grantees to document the types of lead hazard control treatments implemented. Although designed for uniformity, grantees sometimes selected certain specifications in error or in a non-standard way. The Evaluation team reviewed all Specmaster reports to correct errors, standardize codes (where possible) and identify dwelling units to be excluded from statistical procedures when the recorded specifications did not attain minimal data quality standards. The Evaluation team also compared Specmaster reports with data recorded by grantees on the Strategy Assignment Form (Form 23) to determine if the treatment strategy assignment was appropriate for the scope of work reported in Specmaster. A total of 488 dwelling units required revisions of their strategy codes based on this visual review.

Room identification data recorded on the floor plan/sketch (Form 12) were compared with similar information given on the XRF Paint Inspection and Testing Forms (Forms 14-16) to ensure correspondence and to ensure that each location was consistently assigned to one of the three "region codes" for each housing unit (i.e., interior, exterior, and site). Data on these forms were sometimes ambiguous and occasionally contradictory. Consequently, data from both types of forms were used to establish a region and room/location for treatments as recorded in

[1] Cohen, Jr., A Clifford. Tables for maximum likelihood estimates: singly truncated and singly censored samples. Technometrics, Volume 3, Nov. 1961, pg 535-541.

Specmaster. Regions were subsequently designated as interior, exterior, unknown or in error. Regions designated as "unknown" or "in error" were excluded from certain statistical analyses.

Construction cost data for each specification and for total lead hazard control costs were also reviewed as part of the review of Specmaster data. Region separation by room location was used to categorize the individual specification costs into interior, exterior site work and general requirements. Specification costs were then summed by region, resulting in four summary costs.

3.2.8 Training

The Center and UC carried out a number of activities related to monitoring and assuring data quality. They provided training and re-training to grantee field staff and data managers in data collection, forms completion, data entry, and data review. Periodic site visits, which included direct observation of data collection, were carried out to reinforce training and identify problems. Center and UC staff members were available as needed to answer questions related to the protocols.

3.3 Overview of Statistical Methods Used in the Analysis of Data

Statistical models utilized to evaluate data obtained in this study were:

- Structural Equation Modeling (SEM). This model was fit to the blood lead and dust lead loading data at pre-intervention, 12-months post-intervention, and 36-months post-intervention (dust only) in order to explore the interrelationships among factors potentially influencing these dependent variables. Post-intervention models included variables used to test hypotheses regarding the stability of or change in blood lead and/or dust lead from those observed at pre-intervention. Since the equations for the outcome variables were modeled simultaneously, the SEM approach was used to explore the direct and indirect effects of different factors on all the outcome variables in the causal chain. The factors explored included dust lead loadings at various locations, paint lead levels and condition, intervention strategies, as well as other housing and demographic factors. The SAS program PROC SYSLIN was used to fit the SEMs.
- Repeated Measures Analysis. This was a longitudinal model, applied to the post-intervention blood and dust lead data in the base evaluation (phases 03-04 for blood, phases 02-04 for dust) and the extended Evaluation (phases 03-06 for blood, phases 02-06 for dust) in order to examine predictors of the outcome of interest. This modeling could not be used to separate indirect and direct effects on lead outcomes. Separate models were developed for blood lead and for dust lead loadings at four separate locations (entries, interior floors, window sills and window troughs). Within-phase (i.e., concurrently measured) and pre-intervention lead loadings were tested to determine the significance of their effects on the post-intervention lead loadings. The possibilities of declinations in blood lead or re-accumulation of dust lead were also tested in the simple models for change. Both the repeat measure and simple models for change were fit by the SAS PROC MIXED program.
- Logistic regression and generalized estimating equation (GEE) models. These models were fit to the post-intervention data to identify predictors of clearance failure. The logistic model was used at one phase, for one observation per dwelling. The GEE was also used to investigate whether recontamination of the residences caused greater failure on the various surfaces where dust was collected or whether it caused a lessened decrease or "bottoming

out" of expected declines in post-intervention blood lead levels. GEE models were both longitudinal and cross-sectional and used the SAS procedures PROC LOGIST and PROC GENMOD (with a logit link) to model the clearance failure data.

- Linear regression models. This type of modeling was used in many investigations. One investigation was to determine the impact of several environmental factors, building-related factors, and intervention-related factors on the cost of lead hazard abatement. Using phase 2 dust lead loading data, a linear regression model was also used to identify the predictors of dust lead loadings measured immediately post-intervention. Room-level analyses, in which the impact of the intervention on various structural elements within each room of treated dwellings, were also conducted using linear regression modeling. The majority of the linear regression models employed could also be called "analysis of covariance models" because at least one continuous predictor is included in the model. Simple linear regression models and analysis of variance models were used for a wide range of analyses. The SAS procedure PROC GLM was used for all linear regression modeling.

Details concerning these models are provided in appropriate sections throughout this document and in the Compendium to the Final Report.

3.4 Conventions Used in Summarizing Data

The following set of conventions were used in summarizing data for this report:

- Because of their limited use, results for the following parameters are not used to evaluate treatment effectiveness, although some data may be summarized in the report:
  - Laboratory paint chip sample results (pre-intervention);
  - Interior common area environmental sampling results and treatments;
  - Results for dust samples collected using vacuum sample methods;
  - Grantee-collected soil samples
- Many of the tables and figures present combined data from all grantees, as well as grantee-specific data; however, grantee-specific data are mentioned in the text only when such data indicate a deviation from trends identified based on combined data and only when 20 or more observations are available for the grantee.
- All laboratory data that did not meet Evaluation quality assurance/quality control (QA/QC) requirements were excluded (see Section 3.2.1). QA/QC results are discussed in detail in the Appendix B.
- When environmental sample results are presented by phase of collection, the phase is based on the data recorded on the appropriate forms even if the collection dates may indicate miscoding. When descriptive statistics are presented, no restrictions were placed on sample dates (i.e., samples that were outside the time requirements stated in the protocols were included). For statistical models, eligibility was restricted to data within collection dates described in further detail in this report.
- Except where specifically noted, bare floor lead wipe sample results were not evaluated separately from those for carpets.

PRE-INTERVENTION CHARACTERISTICS OF HOUSING UNITS AND RESIDENT FAMILIES

4.1 INTRODUCTION

Any interpretation of the effectiveness of lead hazard control activities must be conducted with reference to the pre-intervention characteristics of the enrolled dwellings and residents. The HUD Lead Hazard Control Grant Program focused on low- income housing that had lead-based paint hazards. Because of these general enrollment requirements and the specific enrollment criteria that grantees used, the dwellings in the Evaluation and the people who lived in those dwellings differ from the general population. The costs and effectiveness of the lead hazard control activities performed in the Evaluation may have differed had they been applied to a different set of dwellings.

Key pre-intervention characteristics of buildings, dwelling units and households varied greatly by grantee. These variations reflect both regional differences and the differences in the grantees' specific enrollment plans (see Section 2.2). The wide variation in key characteristics may have affected pre-intervention paint lead, dust lead loadings, and soil lead levels and may have contributed to or interfered with the effectiveness of certain interventions.

The pre-intervention housing and family characteristics described in this chapter refer to characteristics present in the 2,682 dwelling units (1,486 buildings) that had dust samples collected immediately post-intervention and had dust lead loading results that were below grantee-specific clearance criteria.[1] The discussion of pre-intervention family characteristics focuses on the 1,548 households and 1,766 children living in dwelling units occupied prior to intervention (1,857 of the 2,682 units).

The 2,682 dwelling units with evidence of "passing clearance" are a subset of the 3,835 dwelling units enrolled and the 2,920 dwellings treated during the Evaluation (Figure 4-1). Although all 2,920 treated dwellings were expected to pass clearance under the requirements of the HUD Lead Hazard Control Grant program, clearance could not be verified for 238 dwellings due to laboratory problems, potentially missing data or discrepancies in interpreting clearance requirements. The 238 dwellings include:

- 92 that failed the initial clearance test, and no further clearance tests were reported to the evaluators;
- 76 that had immediate post-intervention dust lead data that failed laboratory QC standards;
- 31 that did not demonstrate clearance based on the follow-up clearance tests;
- 37 for which all follow-up tests were below standards, but samples were not taken in the required locations; and
- 2 that had clearance dust forms that were missing all results.

[1] Most grantees used the floor clearance value of 200 µg/ft^2 that existed at the start of the Evaluation; however, Cleveland, New Jersey and New York City used 100 µg/ft^2 and Minnesota used 80 µg/ft^2. Clearance criteria for sills and troughs were 500 and 800 µg/ft^2, respectively, for all grantees. A complete discussion of clearance requirements can be found in Chapter 7.

Without verification that the 238 dwellings met the requirements of the Grant program, they were excluded from further detailed evaluation. Data available for the 2,682 dwellings with evidence of "passing" clearance are presented in this chapter and are the focus for the remainder of this report.

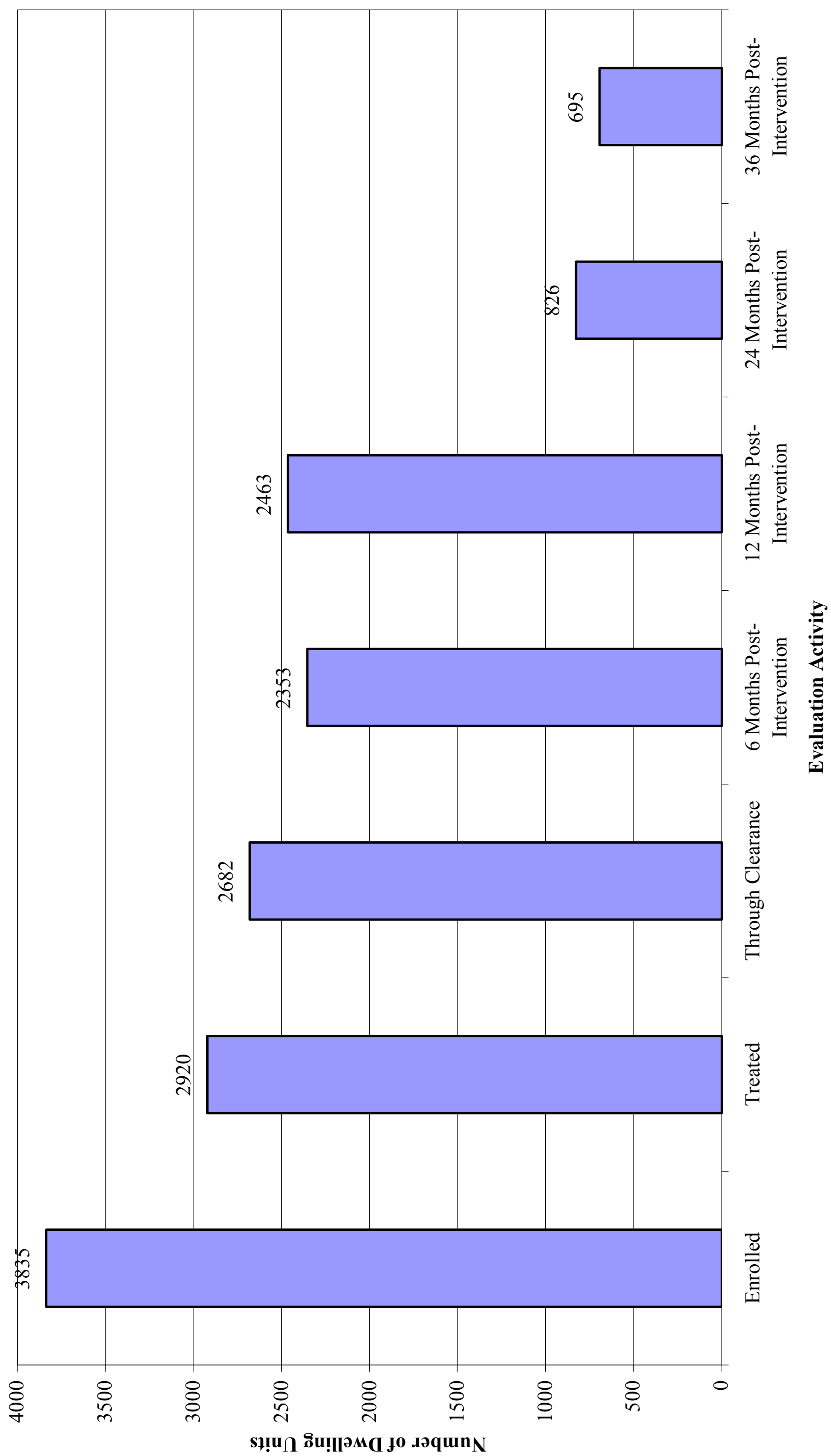
4.2 PRE-INTERVENTION HOUSING CHARACTERISTICS AND CONDITION

A primary feature of the Evaluation was the latitude grantees were given by HUD to design their own programs. As summarized below, local recruitment methods, as well as regional differences in housing stock, yielded a wide variation in the characteristics and condition of Evaluation housing. When reviewing the information presented in this section, it is important to keep in mind that the number of dwellings in the Evaluation varied greatly by Grantee. Grantees with higher numbers of dwellings likely exerted relatively greater influences on several of the variables. For example, as noted in Chapter 2, Baltimore, New York City and Vermont (393 units, 420 units, and 391 units, respectively) each treated and cleared approximately twice the average number of dwellings per grantee (192). In some cases, the relative influence of dwelling-related information from these three grantees may have been greater than the influence of grantees that treated and cleared a smaller number of dwellings.

In the discussion below, relevant 1995 US housing statistics as found in the reference, American Housing Survey for the United States in 1995 (HUD 1997), are used to place Evaluation housing characteristics in context with those of the United States in general. The AHS collects national data every other year, returning to the same homes to gather data, with a national sample covering an average of 55,000 homes. AHS data for 1995 were chosen because most pre-intervention housing data were collected between 1994 and 1996.

At pre-intervention, the majority of units in the Evaluation were pre-1930, occupied rental units located in multi-unit buildings (Table 4-1). Dwellings in the Evaluation tended to be older and have lower occupancy rates and much lower market values than those of the general US housing stock. These differences are likely due to the emphasis of the grant program on low-income housing, the need for grantees to enroll dwelling units of a certain age in order to find lead-based paint, grantee-specific differences in unit selection and regional characteristics of the study areas.

Figure 4-1: Number of Dwelling Units by Evaluation Activity



Data as of: June 1, 2000-restricted to units that passed clearance
Data from: Forms 01, 11, 15, 19, 20
Data Source: UC Table 012

4.2.1 Pre-Intervention Characteristics of Dwellings

Dwelling units in the Evaluation had a greater tendency to be vacant than 1995 US housing (HUD 1997): almost a third of the dwellings were vacant rental units at pre-intervention, while only 11 percent of 1995 US housing fell in this category. Almost half of the dwellings were occupied rental units (1,312 or 49%), while 20 percent were owner-occupied. Baltimore and Vermont tended to have a higher proportion of vacant units (73% and 46%, respectively) than other grantees.

The types of buildings in the Evaluation ranged from single-unit structures (828 (31%) of the 2,682 units) to small, 2-to-4-unit multi-unit buildings (1,069 units (40%)) to larger multi-unit buildings (784 units (29%)) (Table 4-1). This distribution is somewhat the reverse of the national distribution of building types, in which 68 percent were single-family structures and 25 percent were multi-family structures (HUD 1997). Most dwellings had their entry on the first floor of their buildings. Several grantees—Alameda County, Cleveland, Minnesota, and Wisconsin—primarily enrolled single-unit detached structures, while rowhouse was the primary structural type only for Baltimore (Table 4-2). By contrast, 97 percent of the dwelling units in New York City were in large multi-family buildings with many units more than 4 stories above the building entry, reflecting the city's larger and taller style of housing. Boston, Massachusetts, and Rhode Island primarily enrolled "triple-decker" type housing (a common construction style in urban areas of New England) with a majority of units having entries located on the second or third floors. Chicago and Milwaukee primarily enrolled smaller two-family type buildings, or "two-flats," common in those cities.

Unlike building type, there was little variability in the age of buildings in the Evaluation, with 2,270 (84%) units built before 1930. Due to the focus of the study, Evaluation units tended to be much older than the general 1995 US housing stock (HUD 1997), in which only 14 percent of houses were built before 1930. This homogeneity of Evaluation units is not surprising given that lead-based paint was heavily used in residential painting before the 1940s. New Jersey was the only grantee to enroll predominantly post-World War II dwellings, with 93 percent of dwellings built between 1960-69.

Reflecting the fact that two-thirds of the dwellings were located in multi-family buildings, over half (60%) of the dwelling units (1,594) had 1,000 square feet or less living space. Market values for dwellings tended to be low, with 2,058 (78%) reportedly worth $10,000 to $50,000 at pre-intervention, and only 73 (less than 4%) worth more than $100,000. Because dwellings tended to be more deteriorated than the general US housing stock and/or were located in more depressed areas of the country, market values were generally much less than the US at large in 1995, where less than 20 percent were worth $10,000 to $50,000, and 44 percent were worth more than $100,000 (HUD 1997).

TABLE 4-1: Summary of Pre-Intervention Housing Characteristics— All Grantees Combined

Category	**Total Number (Percent) of Evaluation Dwellings within Category**	**Percentage of Dwellings within Category, 1995 American Housing Survey**
Occupancy and Ownership Status:		
Occupied by Owner	545 (20%)	31%
Occupied Rental	1,312 (49%)	58%
Vacant Rental	812 (30%)	11%
Other	13 (1%)	--
Total Dwellings:	2,682 (100%)	100%
Building Type:		
Single Detached	470 (18%)	68%
Rowhouse	358 (13%)	6% (single attached)
2 to 4 units	1069 (40%)	10%
>4 Units	784 (29%)	16%
Total Dwellings[a]:	2,681 (100%)	100%
Construction Period:		
Pre-1910	1,133 (42%)	9% (1919 or earlier)
1910-1919	517 (19%)	
1920-1929	620 (23%)	5%
1930-1939	130 (5%)	6%
1940-1949	160 (6%)	8%
1950-1959	88 (3%)	13%
1960-1969	32 (1%)	15%
Total Dwellings[b]	2,680 (100%)	100%
Living Space, Square Footage:		
<600-1,000	1,594 (60%)	14% (<1,000 ft^2)[e]
>1,000	1,070 (40%)	86% (1,000 or more)
Total Dwellings[c]	2,664 (100%)	100%
Market Value:		
1,000-10,000	210 (8%)	3%[e]
>10,000-50,000	2058 (78%)	18%
>50,000-100,000	292 (11%)	35%
>100,000	73 (3%)	44%
Total Dwellings[d]	2,633 (100%)	100%

[a]One dwelling was excluded due to coding as "other."
[b]Two dwellings were excluded due to coding as post-1969 units.
[c]Eighteen dwellings were excluded 17 due to missing Form 11s, one due to missing data for this variable.
[d]Forty-nine dwellings were excluded because those units were funded by non-HUD agencies.
[e]AHS square footage data for single family detached and mobile homes only. Market values for occupied housing units only.

Data as of: June 1, 2000-restricted to units that passed clearance
Data from: Form 01
Source of data: UC Tables 004, 005, 011, 021, 503

Table 4-2: Summary Of Selected Housing Characteristics—By Grantee

Grantee Name	**Building Type**	**Floor of Bldg. Where Dwelling Entry is located**[a]	**Dwelling Size (ft^2)**	**Occupancy Status**[b]
All Grantees	Single family: 31%	1: 66%	<600-800: 41%	Vacant: 30%
	2-4 units: 40%	2 to 3: 27%	801-1,200: 35%	Occup-Owner: 20%
	>4 units: 29%	4 or more: 7%	>1,200: 24%	Occup-Rental: 49%
Alameda County	Single family: 36%	1: 86%	<600-800: 54%	Vacant: 13%
	2-4 units: 43%	2 to 3: 12%	801-1,200: 31%	Occup-Owner: 26%
	>4 units: 21%	4 or more: 2%	>1,200: 15%	Occup-Rental: 61%
Baltimore	Single family: 89%	1: 96%	<600-800: 16%	Vacant: 73%
	2-4 units: 10%	2 to 3: 4%	801-1,200: 62%	Occup-Owner: 11%
	>4 units: 0.5%	4 or more: 0%	>1,200: 22%	Occup-Rental: 13%
Boston	Single family: 15%	1: 49%	<600-800: 0%	Vacant: 16%
	2-4 units: 85%	2 to 3: 51%	801-1,200: 63%	Occup-Owner: 43%
	>4 units: 0%	4 or more: 0%	>1,200: 37%	Occup-Rental: 41%
California	Single family: 39%	1: 85%	<600-800: 78%	Vacant: 27%
	2-4 units: 14%	2 to 3: 15%	801-1,200: 14%	Occup-Owner: 20%
	>4 units: 47%	4 or more: 0%	>1,200: 8%	Occup-Rental: 53%
Chicago	Single family: 21%	1: 59%	<600-800: 15%	Vacant: 2%
	2-4 units: 62%	2 to 3: 37%	801-1,200: 40%	Occup-Owner: 37%
	>4 units: 17%	4 or more: 4%	>1,200: 45%	Occup-Rental: 61%
Cleveland	Single family: 43%	1: 63%	<600-800: 4%	Vacant: 11%
	2-4 units: 29%	2 to 3: 25%	801-1,200: 49%	Occup-Owner: 31%
	>4 units: 28%	4 or more: 12%	>1,200: 47%	Occup-Rental: 58%
Massachusetts	Single family: 7%	1: 42%	<600-800: 21%	Vacant: 11%
	2-4 units: 80%	2 to 3: 56%	801-1,200: 22%	Occup-Owner: 31%
	>4 units: 13%	4 or more: 2%	>1,200: 57%	Occup-Rental: 58%
Milwaukee	Single family: 29%	1: 81%	<600-800: 42%	Vacant: 8%
	2-4 units: 71%	2 to 3: 19%	801-1,200: 37%	Occup-Owner: 27%
	>4 units: 0.4%	4 or more: 0%	>1,200: 21%	Occup-Rental: 65%
Minnesota	Single family: 39%	1: 73%	<600-800: 24%	Vacant: 11%
	2-4 units: 48%	2 to 3: 25%	801-1,200: 41%	Occup-Owner: 37%
	>4 units: 13%	4 or more: 2%	>1,200: 35%	Occup-Rental: 52%
New Jersey	Single family: 4%	1: 92%	<600-800: 63%	Vacant: 29%
	2-4 units: 4%	2 to 3: 8%	801-1,200: 33%	Occup-Owner: 4%
	>4 units: 92%	4 or more: 0%	>1,200: 4%	Occup-Rental: 67%
New York City	Single family: 0%	1: 22%	<600-800: 96%	Vacant: 34%
	2-4 units: 3%	2 to 3: 46%	801-1,200: 4%	Occup-Owner: 0.2%
	>4 units: 97%	4 or more: 32%	>1,200: 0%	Occup-Rental: 66%
Rhode Island	Single family: 11%	1: 43%	<600-800: 23%	Vacant: 22%
	2-4 units: 76%	2 to 3: 55%	801-1,200: 39%	Occup-Owner: 22%
	>4 units: 13%	4 or more: 2%	>1,200: 38%	Occup-Rental: 56%
Vermont	Single family: 10%	1: 72%	<600-800: 41%	Vacant: 46%
	2-4 units: 54%	2 to 3: 26%	801-1,200: 36%	Occup-Owner: 10%
	>4 units: 36%	4 or more: 2%	>1,200: 23%	Occup-Rental: 44%
Wisconsin	Single family: 48%	1: 83%	<600-800: 29%	Vacant: 17%
	2-4 units: 49%	2 to 3: 11%	801-1,200: 40%	Occup-Owner: 47%
	>4 units: 3%	4 or more: 6%	>1,200: 31%	Occup-Rental: 36%

[a]Number of floors that an enrolled unit's entry is above the entry to the whole building; not equivalent to number of floors within a building.
[b]Baltimore had 3% of units with occupancy status "other;" therefore, total percents for Baltimore and all Grantees do not sum to 100%.
Data as of: June 1, 2000—restricted to units that passed clearance Data from: Form 01 Source of data: UC

Exhibit 4-1 offers a brief overview of twelve "typical" styles of housing that were treated and cleared in the Evaluation. Approximately 60 percent (1,603) of the 2,682 dwellings fit into one of these 12 typical housing styles. For each typical type of housing, the exhibit includes a list of defining characteristics (i.e., construction period, type of exterior, number of bedrooms, and (for multi-unit structures), number of units within a building), as well as a description of the dwelling units contained within the housing. In both the single and multi-unit categories, diverse types of housing were represented. Typical multi-unit buildings included 2-family, triplex and fourplex units, as well as small and large multi-unit buildings with varying exteriors. Typical single-family housing included frame, colonial and ranch style homes, as well as rowhouses.

4.2.2 Pre-Intervention Physical Condition Of Dwellings

As shown in Figure 4-2, 41 percent of dwelling units had visibly obvious and extensive deterioration of interior dwelling component systems (i.e., walls/trim/doors and floors). Forty-one percent of dwelling units had similar deterioration of exterior building component systems (i.e., roofs, siding, windows, porches and foundations). The degree of interior and exterior deterioration differed between grantees. For example, while less than half of the dwelling units had interior deterioration, 70 percent of Baltimore's dwellings and 82 percent of New Jersey's had one or more interior components with deterioration reported.

Conditions of building component systems were assessed by inspectors who received training to rate the component systems according to a single protocol. Some variation between the rating systems of the inspectors existed; however, overall, any variation in rates of building component deterioration between grantees likely reflected actual differences in condition at the time of enrollment.

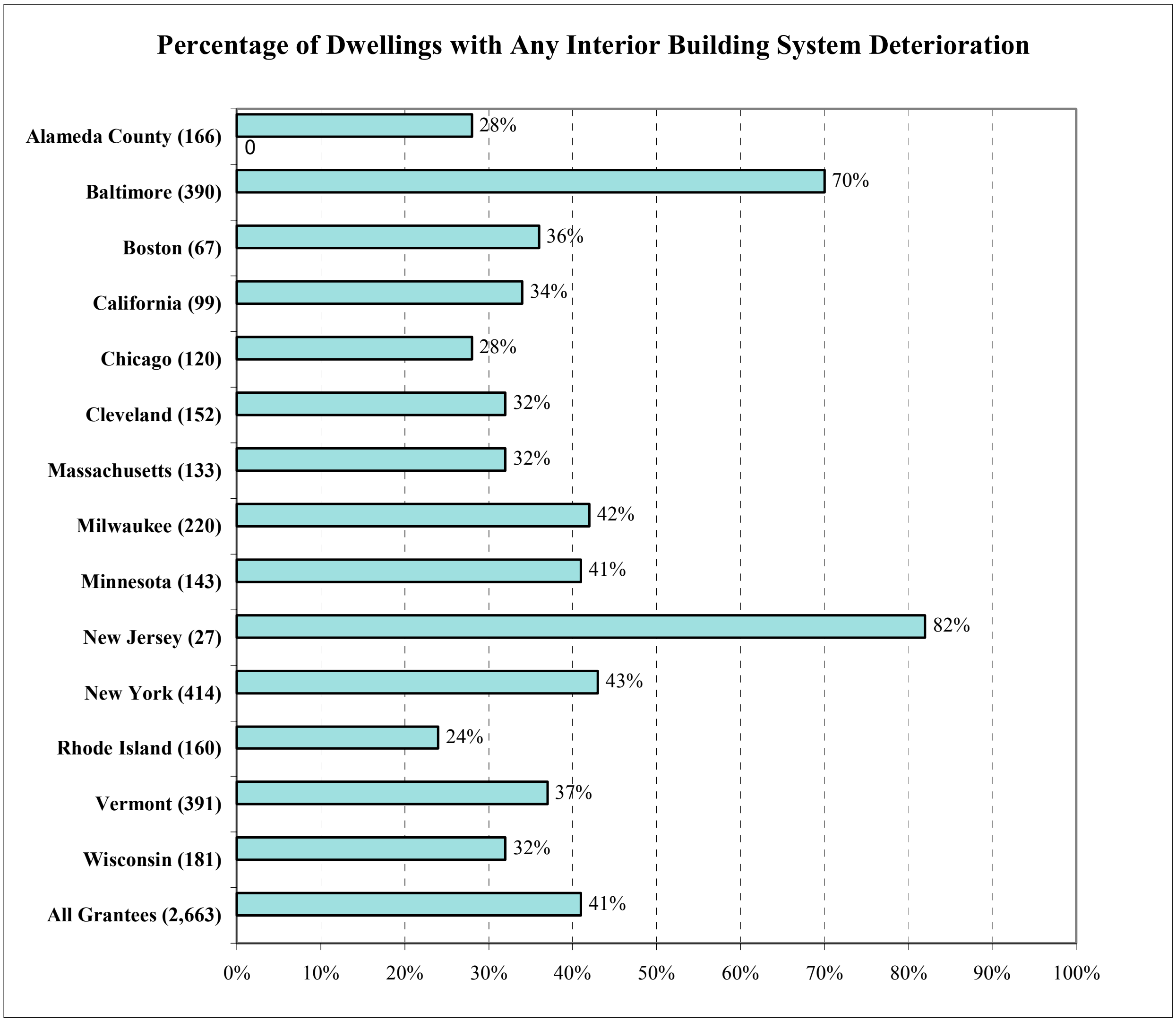
4.3 PRE-INTERVENTION LEAD HAZARDS IN DWELLINGS

4.3.1 Pre-Intervention Condition and Lead Content of Paint

Title X, as well as most states, defines lead-based paint as applied paint that contains 1 mg/cm^2 or more of lead. In the Evaluation, painted components were tested for lead by a certified lead inspector using an X-ray fluorescence (XRF) lead-based paint analyzer. Deteriorated lead-based paint is considered to be a hazard because it can directly contribute to blood lead levels of children who ingest pieces of the paint or indirectly by contributing to the contamination of house dust and soil; therefore, most grantees prioritized deteriorated lead-based paint for treatment. Grantees rated the levels of deterioration by recording the condition (i.e., good, fair, or poor) of each surface that was XRF-tested at pre-intervention[2].

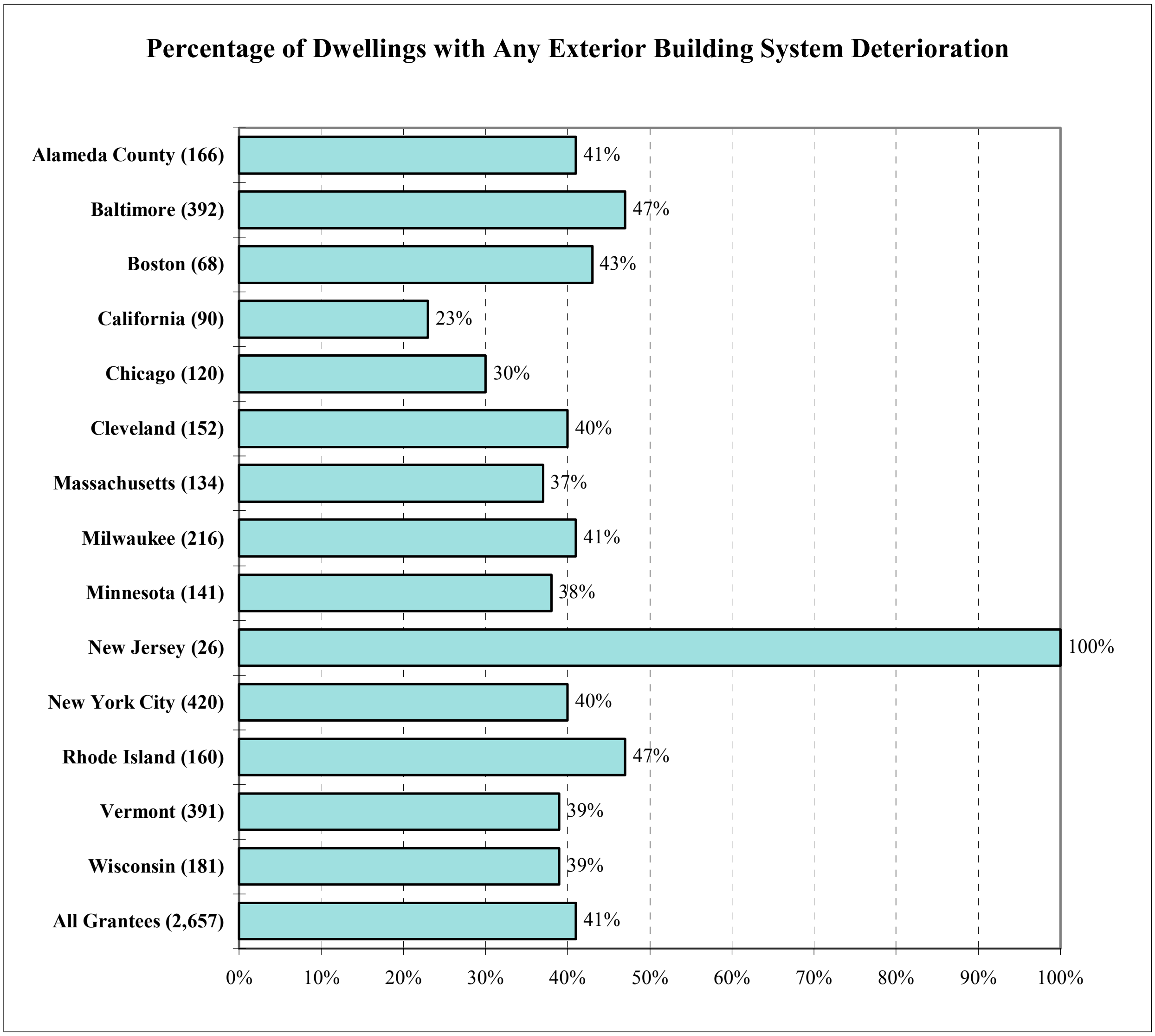
[2] Good (Code=1): <" ft^2 of deteriorated paint on large areas (e.g., walls) and <1% on small areas (e.g., trim); Fair (code=2): ½ to 2 ft^2 of deteriorated paint on large areas or 1% to 10% on small areas; Poor (code=3): >2 ft^2 of deteriorated paint on large areas or >10% on small areas.

Figure 4-2a: Percentage of Inspected Dwelling Units with Reported Building System Deterioration by Grantee Interior



Note: Total number of dwelling units in parentheses
(restricted to those that passed clearance)
Data from: Form 10 (Phase 01) and Form 11 (Phase 01)
Data as of: June 1, 2000
Source of Data: UC Tables 66-E and 67-B

Figure 4-2b: Percentage of Inspected Dwelling Units with Reported Building System Deterioration by Grantee Exterior



Note: Total number of dwelling units in parentheses
(restricted to those that passed clearance)
Data from: Form 10 (Phase 01) and Form 11 (Phase 01)
Data as of: June 1, 2000
Source of Data: UC Tables 66-E and 67-B

In the discussion below, relevant information on the condition and lead content of paint in US housing as found in the reference, The National Survey of Lead and Allergens in Housing (HUD 2001), is used to place measurements obtained during the Evaluation in context with those of the United States in general. The principal lead-related purpose of the NSLAH was to develop a scientific description of the existing lead levels in paint, dust and soil in the nation's housing. A total of 831 occupied homes from all construction-year categories were recruited and completed the survey, with field surveys conducted in 1998-1999.

Interior XRF results are grouped into "doors/trim," "window," and "other" components, primarily because each component system had similar paint lead concentrations. XRF results for all exterior components (except windows) are grouped together because they had similar paint lead levels. The Evaluation team determined the arithmetic mean paint lead level and paint condition for all tested components within each component system at each dwelling. The arithmetic mean paint lead level within each dwelling is approximately normally distributed. The median of mean values for all dwelling units are presented in Table 4-3.

Data provided in Table 4-3 indicate that building component systems with higher lead levels tend to be more deteriorated. This tendency may be due at least in part to the fact that lead paint was used in older buildings. The median of mean lead contents for windows and exterior components were 6.5 and 6.2 mg/cm^2, respectively, and tended to be in fair to poor condition (i.e., median of mean paint condition of 2 and 2.2, respectively). Interior doors/trim had a lower lead content (median of mean=2.7 mg/cm^2) and were in good-to-fair condition (1.3). Other interior components (which include walls, ceilings and floors) had an even lower lead content (1.4 mg/cm^2) and were also in good-to-fair condition (1.4).

The lead content of all exterior surfaces (median of mean=6.2 mg/cm^2) was higher than that of all interior surfaces (median of mean=3.3 mg/cm^2) (Table 4-3). This relationship concurs with the findings of the NSLAH, in which lead content values for the exterior of surveyed units were greater than those for the interior. However, for both the interior and exterior, lead content values for Evaluation units were much higher than those found in the NSLAH, likely because NSLAH surveyed housing of all ages, while the Evaluation targeted older housing.

As shown in Figure 4-3, the lowest lead-based paint levels on both interior and exterior surfaces were found in California (median of mean=1.0 and 3.5 mg/cm^2 for interior and exterior, respectively), New Jersey (0.4 and 1.8 mg/cm^2 for interior and exterior, respectively), and New York City (1.1 and 1.0 mg/cm^2 for interior and exterior, respectively). Buildings in the former two locations were of more recent construction, while buildings in all three locations had predominantly masonry or stucco exteriors. The highest interior and exterior lead-based paint levels were observed in Boston (6.2 and 11.2 mg/cm^2, respectively), Rhode Island (7.0 and 15.4 mg/cm^2, respectively) and Milwaukee (6.6 and 11.2 mg/cm^2, respectively).

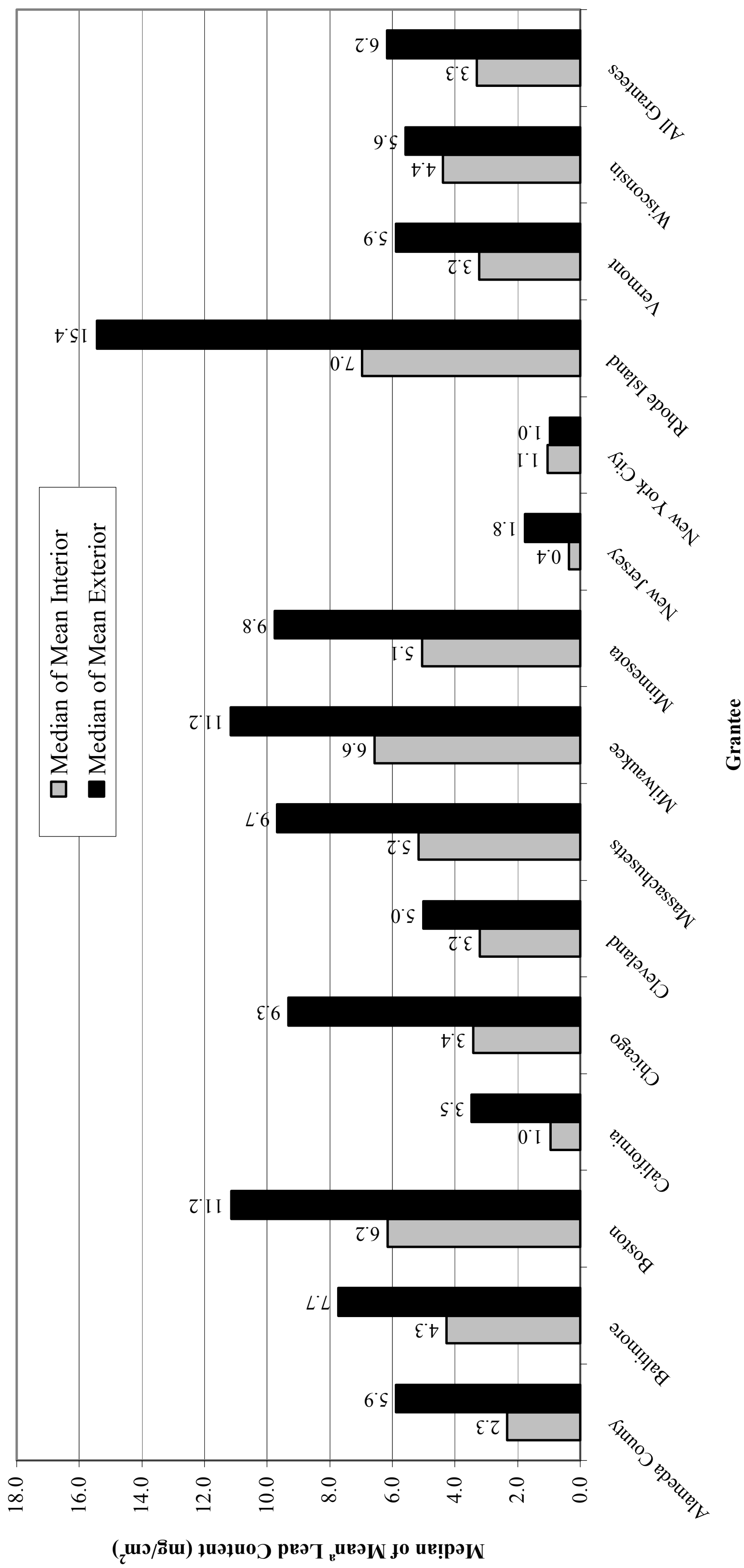
TABLE 4-3: Summary Of Lead Content And Condition Of Interior And Exterior Painted Surfaces At Pre-Intervention

Type of Component	Number of Dwellings [d]	Median of Mean Paint Condition[a,b]	Median of Mean Lead Content (mg/cm^2)[b,c]	NSLAH[e] Arith. Mean Lead Content (mg/cm^2)
All Interior Components	2,627	1.5	3.3	NA
Interior Doors/Trim	2,625	1.3	2.7	0.5-1.1
Interior Window	2,615	2.0	6.5	0.9-2.5
Interior "Other"	2,627	1.4	1.4	0.2-0.4
All Exterior Components	2,609	2.2	6.2	0.9-1.6

[a]Lead paint condition ratings: 1=good (<1/2 ft^2 of deteriorated paint on large areas and <1 ft^2 on small areas); 2=fair (1/2 to 2 ft^2 of deteriorated paint on large areas or 1% to 10% on small areas); 3=poor (>2 ft^2 of deteriorated paint on large areas or >10 ft% on small areas).
[b]Median of mean values were calculated by first calculating the mean of either lead content or paint condition within each dwelling unit for all surfaces tested, then using these dwelling-specific means to calculate the median values across all dwelling units.
[c]Lead paint is defined by HUD and most states to be paint having a lead concentration of 1 mg/cm^2 or more.
[d]55 units excluded due to missing forms. For "interior doors/trim" and "interior window," 2 and 12 additional units, respectively, were excluded due to missing data for variable. For "all exterior components," 73 units were excluded, 51 due to missing forms and 22 because exterior surfaces were not tested.
[e]NSLAH=National Survey of Lead and Allergens in Housing (HUD 2001).

Data as of: June 1, 2000, restricted to units that passed clearance.
Data from: Forms 14, 15, 16
Data source: UC Tables 99, 101 and 527

Figure 4-3: Median of Mean[a] Lead Content (mg/cm^2) of Interior and Exterior Painted Surfaces-by Grantee



[a]Median of mean=using dwelling-specific means to calculate median values across all dwellings
Data as of: June 1, 2000-restricted to units that passed clearance
Data from: Forms 01, 14, 15, 16
Data Source: UC Tables 099, 101

As expected, for both interior and exterior surfaces, higher geometric mean lead content values were found in older dwelling units. Paint with the highest lead content was found in units constructed before 1910, and paint with the lowest lead content was found in units constructed after 1949 (Figure 4-4).

4.3.2 Pre-Intervention Interior Dust Lead Loadings

In this report, dust lead results are reported as "loadings," expressed as the mass (in micrograms, µg) of lead per square foot of surface area (µg/ft^2). Dust lead loadings from the playroom, kitchen, and bedrooms were considered together because sample results in these locations generally were not distinct from one another. Entry floors, however, were grouped separately from interior floor data collected from other locations after statistical evaluation indicated that entry floor dust lead loadings were consistently higher than those from other floor sample locations. Because the entry is in the path leading from the exterior to the interior of the dwelling, it is logical to keep results for this location separate. Although wipe samples collected from carpets tended to result in lower loadings than those collected from bare floors, carpet wipe samples were grouped with bare floor wipe samples because collection and analytical methods, as well as clearance standards, were the same. This grouping also resulted in a more representative illustration of pre-intervention dust lead loadings in units having both carpets and bare floors.

Pre-intervention dust lead loading measurements followed the expected trend, with the highest loading values detected in window troughs, followed by window sills, then entry floors, and finally interior floors (Figure 4-5). Geometric mean dust lead loadings, shown in Table 4-4, were quite similar to median dust lead loadings for all surfaces, indicating that within-dwelling loadings are log-normally distributed (Figure 4-5). For all sample locations, pre-intervention dust lead loadings tended to be higher in vacant dwellings than in occupied dwellings; this finding was most dramatic for floors, whose median loadings on entry and interior floors in vacant dwellings (151 µg/ft^2 and 139 µg/ft^2, respectively) were six to eight times larger than those in occupied dwellings (20 and 16 µg/ft^2, respectively). Dust lead loadings on window sills and window troughs also tended to be greater in vacant than in occupied dwellings; however, the difference was less dramatic than for floors. These results may reflect the impact of routine cleaning common to occupied dwellings, or it may be due to differences in characteristics of vacant and occupied dwellings, or some combination of the two. Occupancy status will be further considered later in this report when evaluating the impact of lead hazard reduction on post-intervention dust lead loadings.

The NSLAH (Jacobs 2002) reported median dust lead loadings in occupied homes (0.9 µg/ft^2 for floors, 8.3 µg/ft^2 for sills, and 89.1 µg/ft^2 for troughs) that were much lower than Evaluation results from these locations in occupied units (16 µg/ft^2, 237 µg/ft^2 and 4,486 µg/ft^2, respectively). These differences are likely due to the fact that NSLAH dust wipe samples were collected from dwellings built in all age categories, while the Evaluation collected wipe samples primarily from pre-1930 housing.

Interestingly, pre-intervention dust lead loading values on floors were lower than expected. Indeed, the pre-intervention median dust lead loadings for interior floors, entry floors and sills in occupied units (Figure 4-5) were less than the dust lead standards for risk assessment recommended by EPA in 1995: 100 µg/ft^2 for floors and 500 µg/ft^2 for sills (EPA 1995a). (EPA has since lowered the floor standard to 40 µg/m^2.) The pre-intervention median for troughs in occupied units (4,486 µg/ft^2), however, was well above the Evaluation clearance standard of 800 µg/ft^2.

Pre-intervention dust lead loadings differed among grantees (Table 4-4). In Baltimore, Boston, New York City and Rhode Island, geometric mean interior floor dust lead loadings in both vacant and occupied units tended to be higher than those for all grantees together. On the other hand, Minnesota, New Jersey, Alameda County and California tended to have lower interior floor dust lead loadings. For entry floors, geometric mean dust lead loadings in vacant and occupied units tended to be higher in Baltimore, Boston, Vermont and Rhode Island, while those in Minnesota, New Jersey and Massachusetts tended to be lower.

For window sills, higher geometric mean dust lead loadings were found in both occupied and vacant units in Milwaukee, Baltimore, Rhode Island and Boston, while those in New Jersey, Alameda County, Minnesota and Vermont tended to be lower than all grantees together. Milwaukee, Wisconsin and Rhode Island tended to have higher window trough geometric mean dust lead loadings in both vacant and occupied units, while Chicago, Alameda County, California and New Jersey tended to have some of the lowest dust lead loading values for troughs.

4.3.3 Pre-Intervention Soil Lead Levels

As discussed in Section 2.2, seven grantees—Alameda County, California, Cleveland, Milwaukee, Minnesota, Rhode Island, Vermont, and Wisconsin—submitted soil lead data from enough premises to be included in this report. Two soil samples were generally collected from each property: a sample from the building perimeter/dripline (i.e., next to the foundation of the building) and a sample from a child's play area (or likely play area). Soil samples were collected from both bare and covered soil.

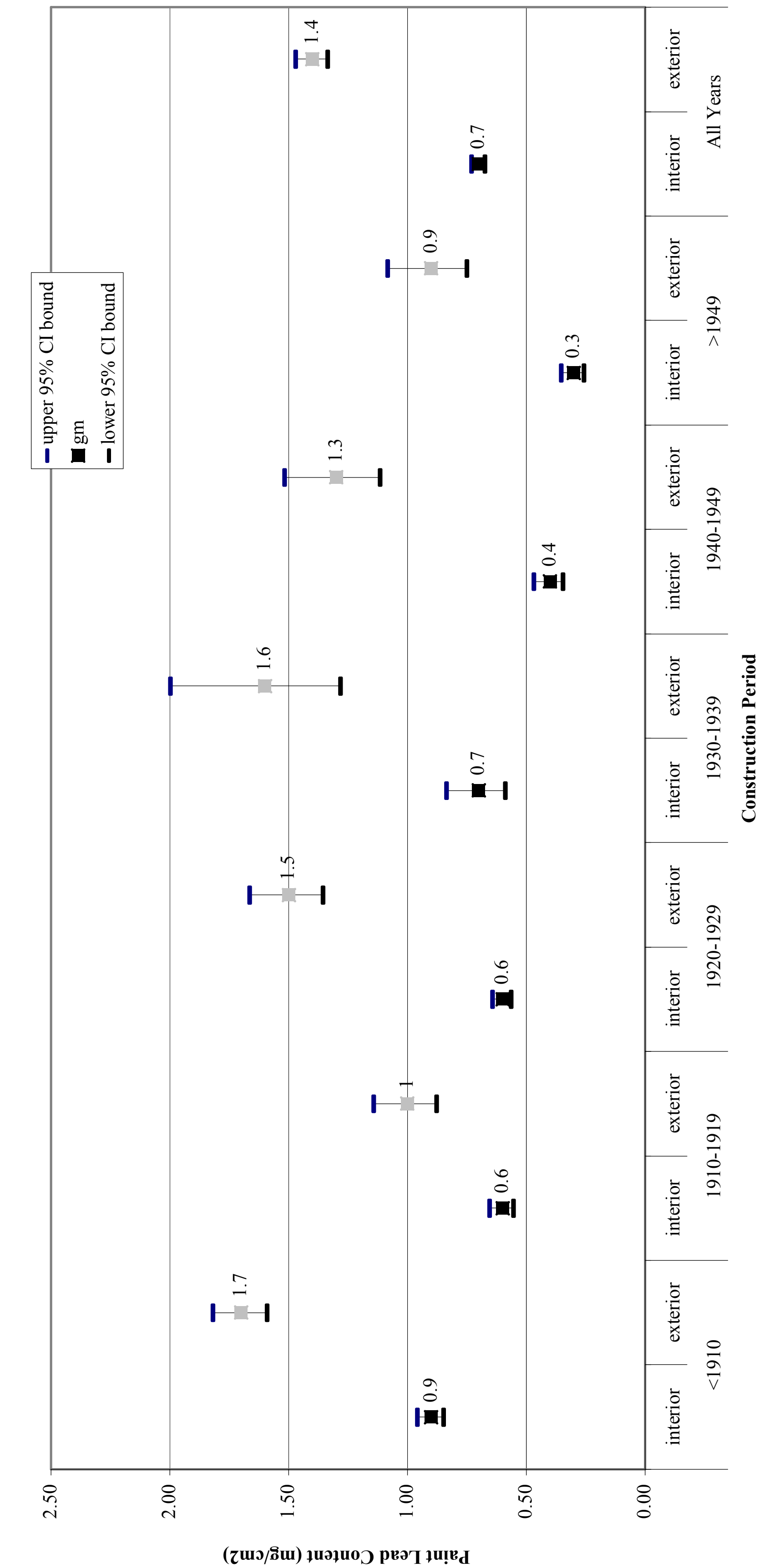
On average, regardless of the amount of soil cover, samples collected from building perimeters had higher lead concentrations than those collected from play areas, perhaps due to the deposition of lead particles from weathered exterior paint onto perimeter soil. Overall, the geometric mean perimeter and play area soil concentrations were 1,104 ppm and 504 ppm, respectively (Figure 4-6). The two geometric mean dripline bare soil sample results reported in the NSLAH (HUD 2001) were 44.5 and 49 ppm, much lower than levels in Evaluation perimeter samples. The two NSLAH geometric mean soil results reported for mid-yard bare soil samples were 28.1 and 29.9 ppm, much less than the Evaluation's play area geometric mean.

Soil lead concentrations tended to be higher at the building perimeter when soil cover was limited (from half bare to all bare) than when the soil had no bare areas or only small areas bare. A relationship between soil lead concentrations and the amount of soil cover was not apparent from the samples taken at play areas (Figure 4-6).

4.3.4 Discussion

The highest prevalence with lead paint was found on exterior surfaces and interior windows, with about half of the units tested having lead-based paint in fair or poor condition. Building component systems with higher lead levels also tended to be more deteriorated and were found in older dwelling units. This tendency may be due at least in part to the fact that lead paint was used in older buildings.

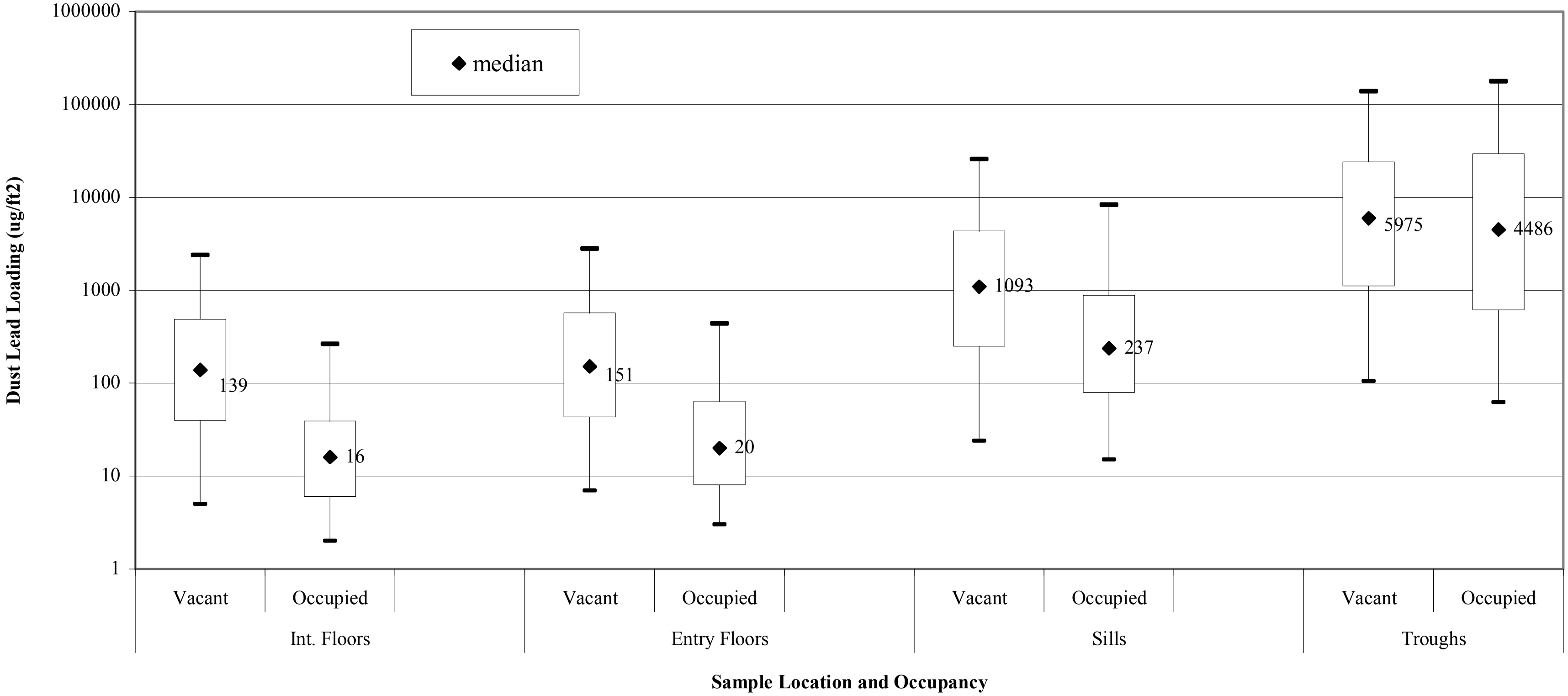
Figure 4-4: Geometric Mean Paint Lead Content (mg/cm2) and 95% Confidence Interval for the Geometric Mean--by Building Construction Period



Data as of: June 1, 2000-restricted to units that passed clearance
Data from: Forms 14, 15, 16
Data source: UC Tables 099, 101, 529-I07, 532-E03

Figure 4-5: Overall Dust Lead Loading Results (ug/ft2) (Logarithmic Scale)

(Based on dwelling unit arithmetic mean of all wipes for a specified surface type. Data presented are 5th, 25th, median, 75th and 95th percentiles)



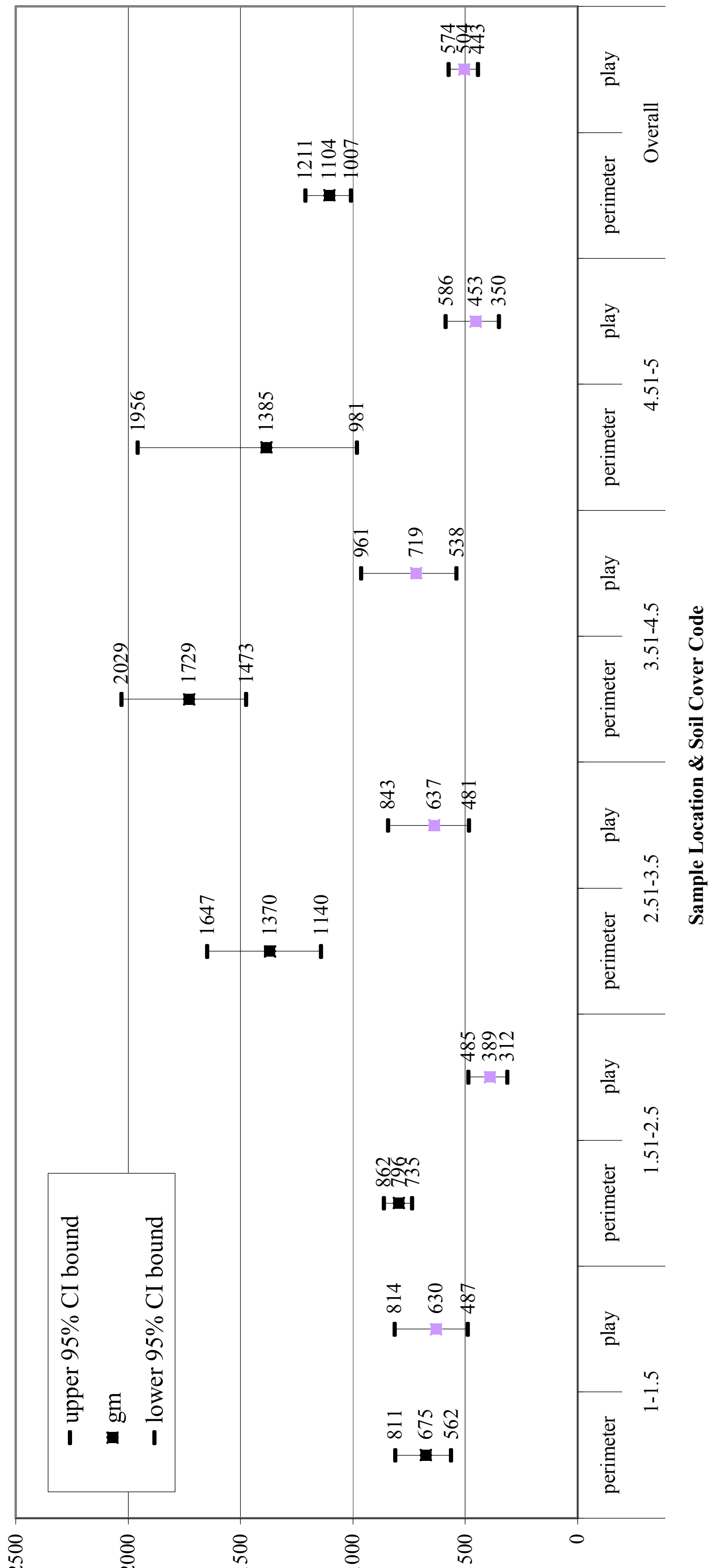
Data as of: June 1, 2000-restricted to units that passed clearance
Data from: Forms 01, 19
Data source: UC Tables 27A, 27B, 33A, 37A, 37B, 538A, 538B

TABLE 4-4: Pre-Intervention Geometric Mean Dust Lead Loading (ug/ft^2)[a] by Type, Occupancy, and Grantee

Grantee		Dust Lead Loading Results (ug/ft^2)							
		Interior Floors[b]		Entry Floors[b]		Window Sills		Window Troughs	
		Vacant	Occup.	Vacant	Occup.	Vacant	Occup.	Vacant	Occup.
Alameda County	GM (GSD)	32 (7)	6 (4)	133 (3)	17 (5)	181 (6)	116 (5)	614 (4)	846 (7)
	# DUs	18	139	12	78	18	139	10	79
Baltimore	GM (GSD)	246 (4)	48 (5)	233 (5)	30 (6)	2,480 (4)	854 (8)	3,783 (7)	1,444 (9)
	# DUs	288	92	267	88	286	91	282	90
Boston	GM (GSD)	165 (4)	26 (5)	152 (8)	33 (4)	1,242 (5)	358 (6)	22,731 (5)	6,193 (10)
	# DUs	11	57	11	57	11	56	13	56
California	GM (GSD)	41 (6)	12 (4)	61 (5)	14 (4)	686 (5)	319 (5)	995 (4)	774 (6)
	# DUs	25	64	25	64	26	57	13	33
Chicago	GM (GSD)	38 (6)	28 (5)	40 (4)	20 (4)	278 (2)	302 (6)	303 (8)	834 (15)
	# DUs	3	117	3	111	3	113	2	101
Cleveland	GM (GSD)	44 (8)	16 (6)	50 (6)	29 (6)	173 (9)	387 (7)	631 (9)	3,084 (17)
	# DUs	16	126	16	126	16	125	14	114
Mass.[c]	GM (GSD)	51 (6)	18 (4)	51 (7)	16 (5)	645 (5)	302 (7)	12,032 (5)	5,452 (12)
	# DUs	15	119	15	117	15	119	14	112
Milw.	GM (GSD)	85 (7)	15 (3)	110 (5)	30 (5)	2,646 (11)	437 (6)	45,524 (7)	20,962 (11)
	# DUs	16	198	15	197	67	197	14	194
Minnesota	GM (GSD)	21 (11)	14 (4)	20 (8)	18 (5)	141 (7)	359 (6)	1,145 (35)	11,077 (8)
	# DUs	14	127	14	127	13	123	13	116
New Jersey	GM (GSD)	37 (8)	3 (2)	56 (14)	2 (2)	137 (6)	14 (3)	--	25 (1)
	# DUs	8	18	8	18	8	18	--	2
New York City	GM (GSD)	208 (7)	21 (4)	190 (11)	23 (4)	779 (6)	155 (4)	1,967 (9)	669 (4)
	# DUs	103	225	100	223	99	223	86	204
Rhode Island	GM (GSD)	129 (4)	24 (4)	214 (5)	31 (5)	1,396 (6)	598 (6)	12,661 (7)	13,753 (8)
	# DUs	35	124	35	122	32	124	32	117
Vermont	GM (GSD)	64 (7)	26 (5)	91 (7)	43 (6)	275 (12)	206 (8)	10,610 (7)	7,472 (7)
	# DUs	130	174	130	174	118	167	116	153
Wisc.[c]	GM (GSD)	129 (10)	12 (5)	149 (11)	15 (5)	1,339 (6)	204 (5)	40,054 (4)	7,504 (8)
	# DUs	29	151	29	148	29	148	28	139
All Grantees	GM (GSD)	132 (6)	17 (5)	147 (7)	23 (5)	1,001 (8)	278 (6)	4,849 (9)	4,049 (12)
	# DUs	711	1,731	680	1,650	687	1,700	635	1,510

[a]Lab data out of QC excluded, vacuum samples excluded; no restrictions on sample date. Each data point used to calculate geometric mean is the dwelling unit arithmetic mean of all wipes for a specified surface type for all rooms listed on Form 19, page 1.
[b]For floors, samples less than 6 inches on one side excluded.
[c]Post-education samples collected close to intervention were used when available for Massachusetts and Wisconsin.
Data as of June 1,2000—restricted to units that passed clearance Data from: Forms 01, 19 Source of data: UC Tables 027-A, 027-B, 33-A, 33-B, 37-A, 37-B, 538-A, 538-B.

Figure 4-6: Geometric Mean and 95% Confidence Intervals for Pre-Intervention Soil Lead Concentration (ppm) by Average Soil Cover & Area Sampled



Soil Cover Code: 1=no bare soil; 2=small amount bare; 3=half bare; 4=mostly bare; 5=all bare.
Data as of: June 1, 2000-restricted to units that passed clearance
Data from: Form 21
Data source: UC Table 508

The highest dust lead loadings were found on window troughs, then sills, followed by entry floors and interior floors (which had lower pre-intervention loadings than originally expected). Occupancy status influenced dust lead, especially floor dust lead, with larger loadings observed in vacant dwellings. The findings of multivariate statistical modeling of the effects of pre-intervention variables on dust lead loadings are presented in Chapter 8.

Pre-intervention dust lead loadings measured in the Evaluation were generally greater than those reported in the NSLAH (Jacobs 2002), likely due to the sizeable presence of younger housing in the NSLAH versus predominantly pre-1930 housing in the Evaluation. Soil from building perimeter areas had higher lead concentrations than those collected from play areas. Soil from perimeter areas also had higher lead concentrations when soil cover was limited. All of these exposure factors potentially influence the magnitude of lead hazards in a dwelling unit and may contribute to children's lead-related exposure.

4.4 Pre-Intervention Characteristics of Enrolled Families

Information presented in this section is based primarily on initial interviews conducted prior to the start of the lead hazard control intervention. All households in enrolled dwellings were eligible for participation in the Evaluation. Using procedures approved by their Institutional Review Boards, the grantees were required to enroll the household by obtaining informed consent to participate from an adult household member prior to conducting an interview. In some dwellings, multiple households were present and each household was enrolled. A household member could refuse to participate without loss of benefits from the HUD Lead Hazard Control Grant Program.

The number of households and the number of children enrolled in the Evaluation varied greatly by grantee. While Baltimore, New York City and Vermont treated the most dwellings, over one-third of each of these grantees' dwellings was vacant prior to intervention. The number of young children in the enrolled households also varied by grantee: enrolled households in Minnesota, Baltimore, Chicago and Massachusetts averaged 1.5 or more children under 6 years of age per household, while households in New York and New Jersey averaged less than 0.5 children per household.

As a result of the varying occupancy rates, recruitment levels and household sizes, the rankings of grantees by the number of households or children enrolled per grantee differed from the rankings by number of dwellings treated per grantee. The number of households enrolled in the Evaluation from New York City and Milwaukee (221 and 194, respectively) was nearly double the average number of households enrolled per grantee (110). The number of children enrolled in the Evaluation from Milwaukee and Minnesota (263 and 212, respectively) was substantially larger than the average number of children enrolled per grantee (126). These grantees with higher numbers of enrolled households and children likely exerted relatively greater influences on the overall findings of several of the variables discussed in this section.

In the discussion below, relevant statistics for the US population in general are used to place demographic information for enrolled families in context. These statistics were obtained from using 1995 data from the American Housing Survey (see description in Section 4.2) and US Census data for July 1, 1995.

Pre-intervention family characteristics generally show an enrolled population that had a lower level of education, lower income, and higher percentage of non-white individuals than the general US population (Census 1996, HUD 1997). This finding is not surprising given the grant program focus on low-income housing and the focus of the Evaluation on populations most in need of lead hazard reduction, i.e., those generally living in older, depressed inner city areas. This suggests that the program was effective in targeting resources to units where the risk was the greatest.

4.4.1 Characteristics of Adults

The amount of formal education completed by adults may be associated with dust lead loadings and blood lead levels (Lanphear 1996a). Education levels for principal[3] females and males were very similar. Overall, approximately one-third each of principal males and females completed less than 12 years of schooling, one-third had graduated from high school, and one-third had more than 12 years of schooling (Table 4-5). This differs from the 1995 national education distribution, where a higher percentage of individuals (47%) stayed in school past high school, and only 20 percent of people have less than 12 years of education.

Poverty has been associated with high blood lead levels in children (Pirkle 1998). Overall, the median income of households enrolled in the Evaluation at pre-intervention was $13,000 per year, far less than the 1995 national household median of $31,416 (Table 4-6) (HUD 1997). Median income for households in Baltimore, California, and Cleveland tended to be lower, in the vicinity of $9,000 per year. Median income for households in Boston and Wisconsin tended to be higher, at approximately $21,000 per year.

4.4.2 Characteristics of Children

Separate information was collected about each enrolled child between the ages of six months and six years in a household. Data were collected to document the characteristics of children in the Evaluation and help identify conditions that might affect the children's blood lead levels.

4.4.2.1 Gender, Age and Racial/Ethnic Group Distribution. At pre-intervention, enrolled children were evenly distributed across gender groups (52% male, 48% female), and evenly distributed across age groups, with a median age at the time of enrollment being between 36 and 48 months (Table 4-6). Not surprisingly, given that the target child population was supposed to be 6 months to 5 years of age, only 3 percent of the enrolled children were 6 years or older, and only 7 percent were less than 1 year old. Age distributions for individual grantees were generally similar, although some grantees such as Boston, California, and Rhode Island had a relatively higher proportion of children 48 months or older and fewer that were less than 24 months old.

Several different racial/ethnic groups were represented in the enrolled children: Black (47%), White (23%), Hispanic (17%), Asian or Pacific (8%) (Table 4-5). Another four percent of the enrolled children were reported as "Other." Compared with 1995 US Census data, the Evaluation had higher percentages of racial/ethnic groups that were not White (Table 4-5)

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[3] Interview information was obtained from a variety of adults, including parents, legal guardians, or primary adult caregivers for households with children, and other men and women for households without children. Information from these various adults was combined in order to summarize data and identify trends; therefore, for this report, these adults were grouped under the terms "principal males" and "principal females."

(Census 1996). Certain grantees widely differed from this overall distribution, reflecting regional differences in racial/ethnic distributions and the targeting by grantees of areas having a particular racial/ethnic makeup. For instance, as shown in Table 4-6, more than 90 percent of children enrolled in Baltimore and Cleveland were Black, while more than 90 percent of those in Vermont were White. Sixty percent (60%) of enrolled children in California were Hispanic.

4.4.2.2 Length of Residence for Children. Length of residence for children is an important issue because in many instances, previously unexposed children must live in a residence having low-level leaded dust for several months for the effects of exposure to lead hazards in that residence to be fully reflected in the blood. A wide distribution in length of residence was observed for enrolled children at pre-intervention, with approximately one-third residing at the address of the enrolled dwelling less than 12 months, one third 12 to less than 24 months, and one-third 24 months or more (Table 4-6). Overall, 15 percent of enrolled children had lived in their homes for 6 months or less. Boston, New York City and Wisconsin had slightly higher percentages of long-term child residents, with 50 percent or more of their enrolled children living in the residence for 24 to more than 48 months. Half of Minnesota's enrolled children had lived in their residence for less than 12 months (Table 4-6).

4.4.2.3 Previous Blood Lead Testing History. Although universal screening for blood lead was recommended by the CDC in 1991, such testing was typically focused in areas that were expected to pose high risks to young children. Pre-intervention Evaluation data corroborate this tendency: as discussed in Section 2.2, most grantees tended to enroll children from neighborhoods expected to have lead hazard concerns, and 77 percent of the enrolled children had had a blood lead test prior to any testing done as part of the Evaluation. Only in California were fewer than 50 percent of enrolled children previously tested, while 95 percent of those in Boston had been tested previously.

Although 40 percent of previously tested children reportedly had been previously lead-poisoned, grantee-specific reports of lead poisoning were highly variable (Figure 4-7), possibly depending on whether grantees used lead-poisoned children as a major criterion for enrolling households and dwelling units in the Evaluation. For example, over 50 percent of previously tested children enrolled by Baltimore, Chicago, Cleveland and Minnesota (which specifically enrolled units with lead-poisoned children) were reported to be previously lead poisoned, while less than 15 percent of previously tested children enrolled by Boston, California and New York City had such reports.

4.5 PRE-INTERVENTION BLOOD LEAD LEVELS

The information provided in this section is useful in determining the differences in the impact of lead hazard control interventions on the blood lead levels of children who were lead poisoned prior to the intervention compared with those who were not previously lead poisoned. The influence of factors such as season, child's age, race, and sex on pre-intervention blood lead levels are discussed in order to help ensure that interventions are not unjustifiably credited or penalized for blood lead changes that would have been expected due to such influences.

TABLE 4-5: Comparison of Pre-Intervention Family Characteristics with General US Population—All Grantees Combined

Category	**Total Number (Percent) of Individuals within Category, National Evaluation**		**Percentage of Individuals within Category, US Population (Gender/Race: Children <6years old)**
Gender of Children:			
Female	854 (48%)		49% [1]
Male	912 (52%)		51% [1]
Total Number of Children:	1,766 (100%)		--
Racial/Ethnic Group of Children:			
Black	833 (47%)		15% [1]
White	405 (23%)		65% [1]
Hispanic	304 (17%)		16% [1]
Asian or Pacific	142 (8%)		4% [1]
Other	75 (4%)		1% [1]
Total Number of Children[a]:	1,759 (100%)		--
Years of Schooling:	**Principal Males**	**Principal Females**	**Males & Females Combined**
Less than 12 years	270 (35%)	527 (36%)	19% [2]
12 years	266 (34%)	507 (35%)	34% [2]
More than 12 years	234 (31%)	433 (29%)	47% [2]
Total Number of Households[b]	770 (100%)	1,467 (100%)	--

[a]Number of children excluded due to missing data for specified variable: age, 3; racial/ethnic group, 6; length of residence, 1.
[b]Number of households excluded due to non-responses: years of schooling for females, 81; for males, 778.

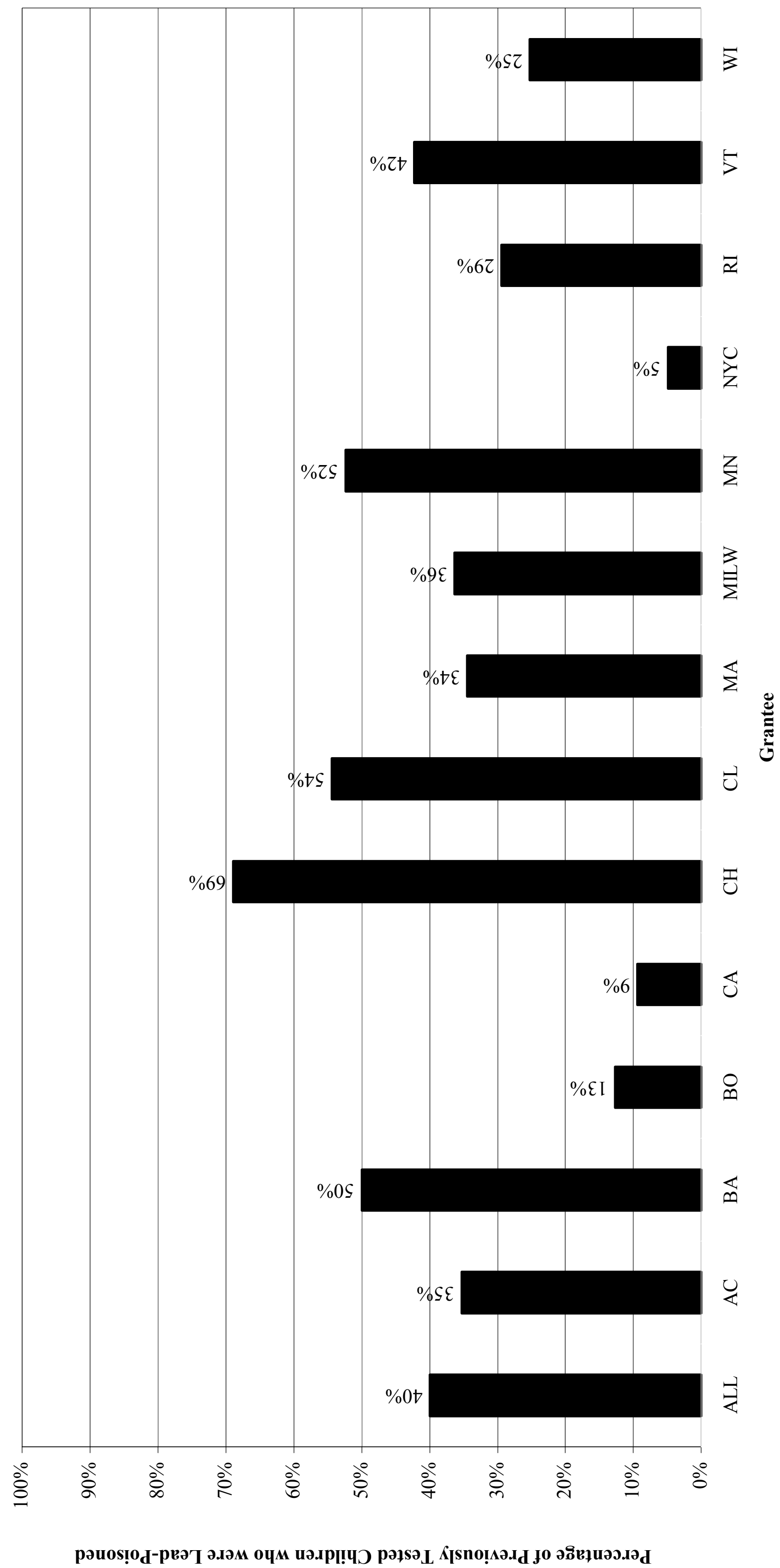
Data as of June 1, 2000-restricted to units that passed clearance
Data from: Forms 04, 05
Source of Data: UC Tables 073, 151, 153, 070, 071, 072, [1]1995 Population Estimates (Census 1996), [2] 1995 American Housing Survey (HUD 1997)

TABLE 4-6: Summary Of Selected Household Characteristics[a]—By Grantee

Grantee Name	Length of Residence of Children	Age of Children	Racial/Ethnic Group of Children[b]	Household Median Annual Income
All Grantees	0-<12 months: 33% 12-<24 months: 28% 24 ->48 months: 39%	0-<24 months: 25% 24-<48 months: 37% 48 months or more: 38%	Black: 47% White: 23% Hispanic: 17%	$13,000
Alameda County	0-<12 months: 26% 12-<24 months: 29% 24 ->48 months: 45%	0-<24 months: 27% 24-<48 months: 33% 48 months or more: 40%	Hispanic: 36% Black: 26% White: 26%	$12,600
Baltimore	0-<12 months: 35% 12-<24 months: 22% 24 ->48 months: 43%	0-<24 months: 24% 24-<48 months: 40% 48 months or more: 36%	Black: 96%	$9,400
Boston	0-<12 months: 15% 12-<24 months: 32% 24 ->48 months: 53%	0-<24 months: 20% 24-<48 months: 31% 48 months or more: 49%	Black: 56% Other: 22%	$22,000
California	0-<12 months: 35% 12-<24 months: 24% 24 ->48 months: 41%	0-<24 months: 21% 24-<48 months: 32% 48 months or more: 48%	Hispanic: 60% Asian/Pacific: 21%	$9,900
Chicago	0-<12 months: 33% 12-<24 months: 26% 24 ->48 months: 41%	0-<24 months: 23% 24-<48 months: 44% 48 months or more: 33%	Black: 69% Hispanic: 28%	$10,500
Cleveland	0-<12 months: 38% 12-<24 months: 32% 24 ->48 months: 30%	0-<24 months: 29% 24-<48 months: 31% 48 months or more: 40%	Black: 90%	$9,600
Massachusetts	0-<12 months: 37% 12-<24 months: 30% 24 ->48 months: 33%	0-<24 months: 24% 24-<48 months: 44% 48 months or more: 32%	Hispanic: 42% White: 25% Black: 18%	$14,000
Milwaukee	0-<12 months: 44% 12-<24 months: 25% 24 ->48 months: 31%	0-<24 months: 24% 24-<48 months: 39% 48 months or more: 37%	Black: 71%	$12,000
Minnesota	0-<12 months: 50% 12-<24 months: 27% 24 ->48 months: 23%	0-<24 months: 26% 24-<48 months: 37% 48 months or more: 37%	Black: 44% White: 27% Asian/Pacific: 16%	$14,000
New Jersey	0-<12 months: 0% 12-<24 months: 0% 24 ->48 months: 100%	0-<24 months: 0% 24-<48 months: 50% 48 months or more: 50%	Hispanic: 100%	$16,100
New York City	0-<12 months: 15% 12-<24 months: 28% 24 ->48 months: 57%	0-<24 months: 22% 24-<48 months: 43% 48 months or more: 35%	Black: 62% Hispanic: 38%	$16,000
Rhode Island	0-<12 months: 27% 12-<24 months: 37% 24 ->48 months: 36%	0-<24 months: 24% 24-<48 months: 29% 48 months or more: 47%	White: 55% Hispanic: 16%	$12,900
Vermont	0-<12 months: 28% 12-<24 months: 31% 24 ->48 months: 41%	0-<24 months: 30% 24-<48 months: 30% 48 months or more: 40%	White: 90%	$13,100
Wisconsin	0-<12 months: 15% 12-<24 months: 35% 24 ->48 months: 50%	0-<24 months: 21% 24-<48 months: 38% 48 months or more: 41%	White: 65% Asian/Pacific: 27%	$20,600

[a]Children living in units that passed clearance and had interview data available.
[b]Categories included in column if they were in at least the top 70% of the grantee's children. For all grantees, 8% of children were Asian/Pacific and 4% were reported in "other" racial/ethnic groups.
Data as of: June 1, 2000; Data from: Forms 04, 05; Data source: UC Tables 10A, 070, 071, 072, 073

Figure 4-7: Blood Lead Poisoning History of Children Tested Prior to Enrollment in Evaluation



NJ Excluded due to too few children with data for this variable
Data as of: June 1, 2000-restricted to units that passed clearance
Data from: Form 05
Data source: UC Tables 124, 125

Because grantees used different methods to recruit households and dwelling units into the Evaluation, grantee-specific differences in blood lead levels of enrolled children may be expected and are highlighted as appropriate.

This section focuses on the 1,274 children who had blood lead test results available at pre-intervention, from testing conducted just prior to or after enrollment in the Evaluation. Blood lead levels are generally discussed in terms of the following "breakpoints" (CDC 1991):

- <10 µg/dL: Level at which CDC recommended reassessment or re-screening in one year, but no additional action unless exposure sources change.
- At or exceeding 20 µg/dL: At levels between 20 and 44 µg/dL, CDC recommended environmental investigation, clinical management, and lead hazard control intervention.[4]

At pre-intervention, over half of the tested children (54%) had blood lead levels less than 10 µg/dL, with a median blood lead level of 9 µg/dL for all tested children at pre-intervention (Figure 4-8). Pre-intervention blood lead levels varied considerably among grantees, with four grantees enrolling a higher-than-average percentage of children who had blood lead levels below 10 µg/dL: Alameda County (85% of its tested children, median=5 µg/dL); California (89%, median=4 µg/dL); New York City (96%, median=5 µg/dL); and Wisconsin (82%, median=6 µg/dL).

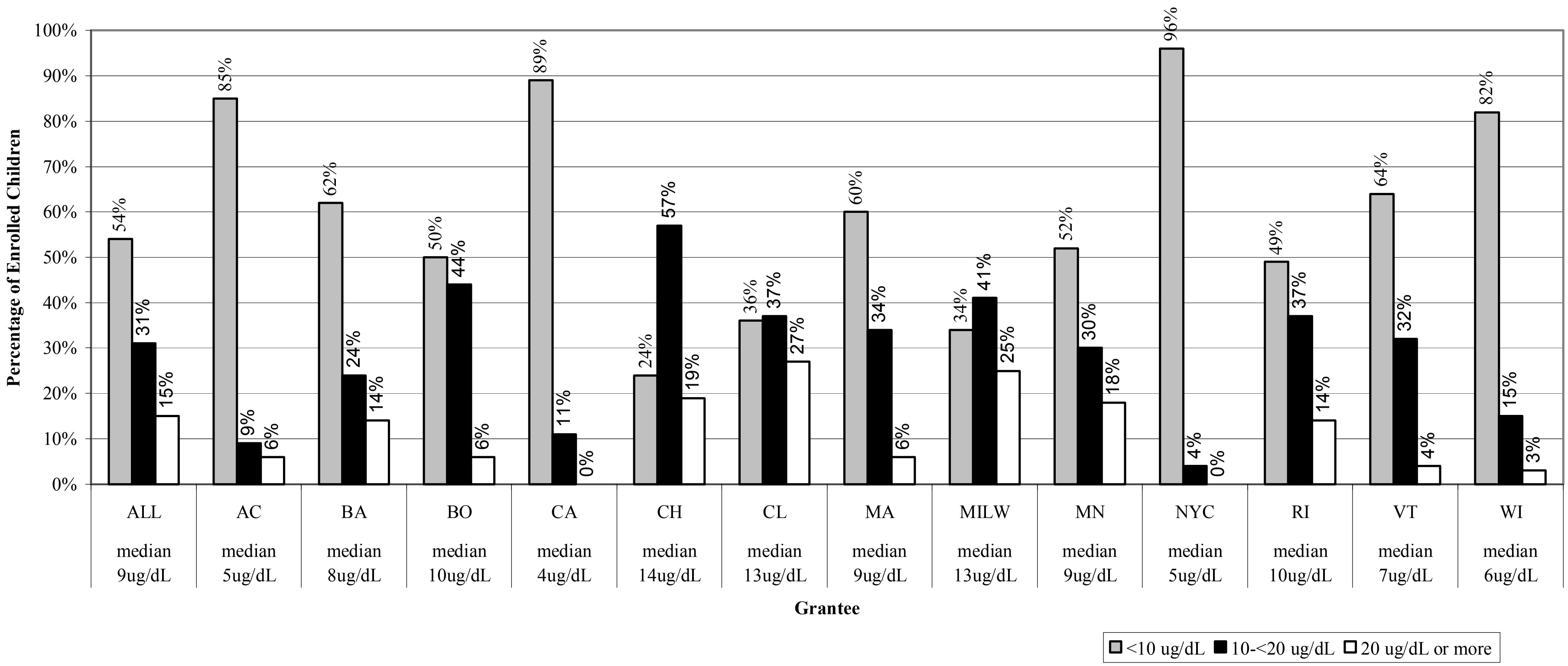
Overall, 15 percent of the tested children had blood lead levels between 20 and 44 µg/dL. Cleveland (27%, median=13 µg/dL) and Milwaukee (25%, median=13 µg/dL) had an even higher percentage of tested children with blood lead levels in this range (Figure 4-8).

4.5.1 Comparison of Evaluation Blood Lead Levels with NHANES III

The third National Health and Nutrition Examination Survey (NHANES III) Phase 2 is a nationally representative survey of the civilian, non-institutionalized U.S. population from 1991 through 1994.. Blood lead level results for NHANES III are not directly comparable to those from the Evaluation since NHANES III Phase 2 provided data collected somewhat earlier (1991 through 1994) than the pre-intervention dates for the Evaluation, which were collected from approximately 1994 to 1997. In addition, in the reporting of blood lead levels from NHANES III, children aged 1 to 5 years were considered as a group, while the Evaluation generally grouped children between 6 months to 6 years of age. With these caveats in mind, NHANES III reported a mean blood lead level of 2.7 µg/dL for children 1 to 5 years of age, much lower than the geometric mean blood lead level of 9 µg/dL reported for children enrolled in the Evaluation. In addition, while 46 percent of Evaluation children had pre-intervention blood lead levels of 10 µg/dL or greater, less than five percent of the US child population had blood lead levels in this range. This is an expected result since grantees generally targeted neighborhoods or communities where lead hazards were of concern, whereas the NHANES III was representative of the entire United States population.

[4] If confirmed levels were between 15 and 19 µg/dL, CDC (1991) also recommended these actions be taken if sufficient resources were available.

Figure 4-8: Percentage of Enrolled Children Within Each Specified Range of Pre-Intervention Blood Lead Levels



Data as of: June 1, 2000-restricted to units that passed clearance
Data from: Form (09 or 05) (04 or 01 for age)
Data Source: UC Table 024
NOTE: NJ excluded because only 1 child had data.

4.5.2 Influence of Various Factors on Pre-Intervention Blood Lead Levels

As expected, blood lead levels tended to vary with the child's age. Pre-intervention blood lead levels appeared to increase as children approached 24 to 36 months of age and then began to decline in older children. Children 6 to 12 months of age had the lowest geometric mean blood lead level (5.3 µg/dL). The 24- to 36-month age group had the highest geometric mean blood lead level (10.0 µg/dL) (Figure 4-9). As expected, pre-intervention blood lead levels appeared to increase as children approached 24 to 36 months of age and then began to decline in older children. This overall trend is generally comparable with NHANES III, which reported that the geometric mean blood lead level in 1 to 2 year olds (3.1 µg/dL) was higher than that of 3 to 5 year olds (2.5 µg/dL) (Pirkle 1998).

Children that were reported to be in the Black and "Other" racial/ethnic groups had higher geometric mean blood lead levels (10.9 and 10.1 µg/dL, respectively) than those in the Hispanic, Asian, or White racial/ethnic groups (7.3, 7.3 and 7.0 µg/dL, respectively) (Figure 4-10). Again, although NHANES III generally reported much lower blood lead levels, the overall racial trend held, with Black non-Hispanic individuals having a larger geometric mean blood lead level (2.8 µg/dL) than that of White non-Hispanic individuals (2.2 µg/dL) (Pirkle 1998).

The geometric mean blood lead level for males was the same as that for females (8.9 µg/dL). This trend is different from NHANES III data, which reported a higher geometric mean blood lead level for males (2.8 µg/dL) than for females (1.9 µg/dL) (Pirkle 1998).

Pre-intervention blood lead levels tended to vary by season, with higher blood lead levels generally present during the summer and fall months and lower levels in the winter (Figure 4-11). This is the same trend observed previous EPA study of children in Milwaukee, which observed that blood lead levels in the summer were about 40 percent higher than those in the winter (EPA 1996a). For the Evaluation, the magnitude of the difference appeared to be approximately 2 µg/dL from peak to trough. During the months of April, June and July, the blood lead levels were lower than expected. These differences may be due in part to variations in when grantees tested children. For example, in July, over one-fifth of the blood lead results were reported from Wisconsin, a grantee that had lower blood lead levels across all seasons.

Children who lived in older dwelling units had higher geometric mean blood lead levels, with concentrations tending to decrease as building age decreased. Blood lead levels in children living in dwelling units constructed in the decades before 1920 (geometric means ranging from 8.1 to 8.5 µg/dL) were higher than those for children living in units constructed in the decades after 1940 (geometric means ranging from 4.8 to 5.1 µg/dL). This trend is similar to that observed in NHANES III, which found that people living in homes built before 1946 had a slightly higher geometric mean blood lead level (2.6 µg/dL) than those living in homes built between 1946 and 1973 (2.3 µg/dL) (Pirkle 1998).

Figure 4-9: Pre-Intervention Blood Lead Levels (ug/dL) by Age of Child

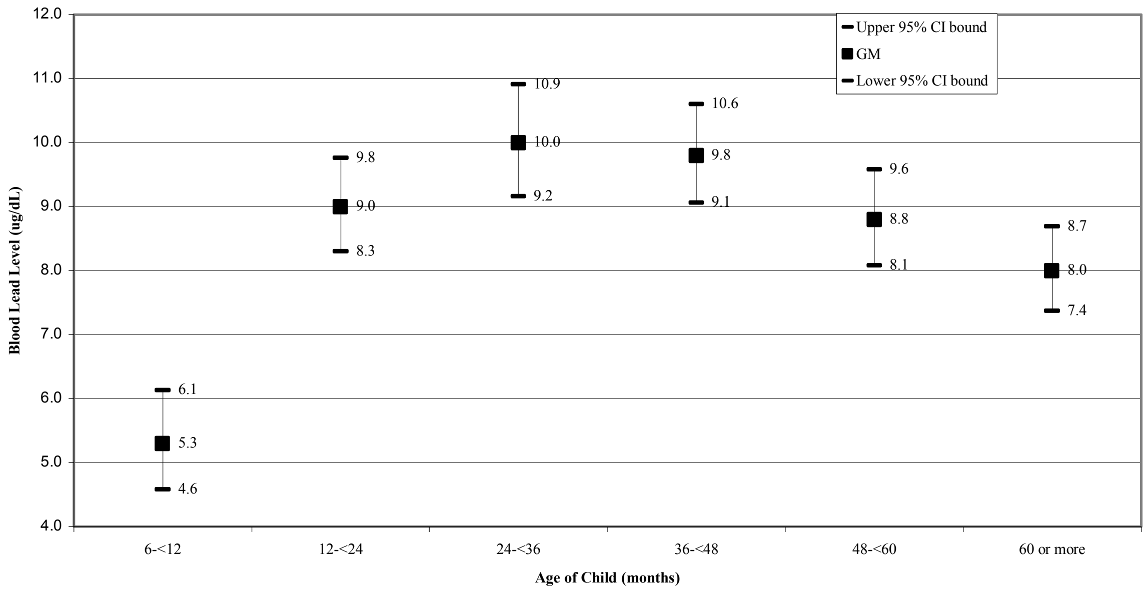


Figure 4-10: Pre-Intervention Blood Lead Levels by Racial/Ethnic Group and Gender

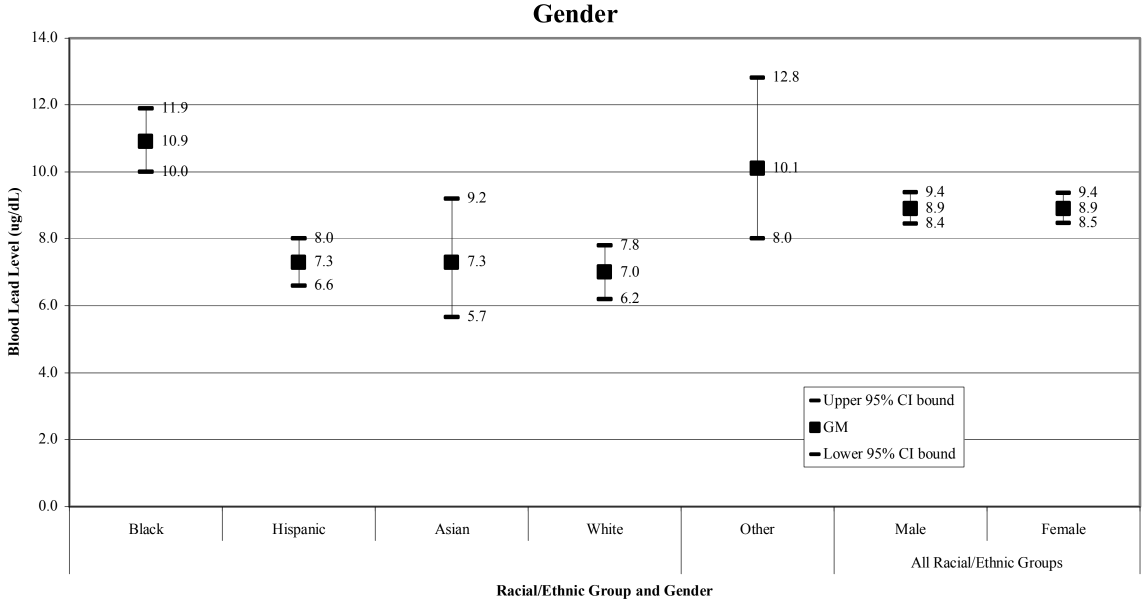
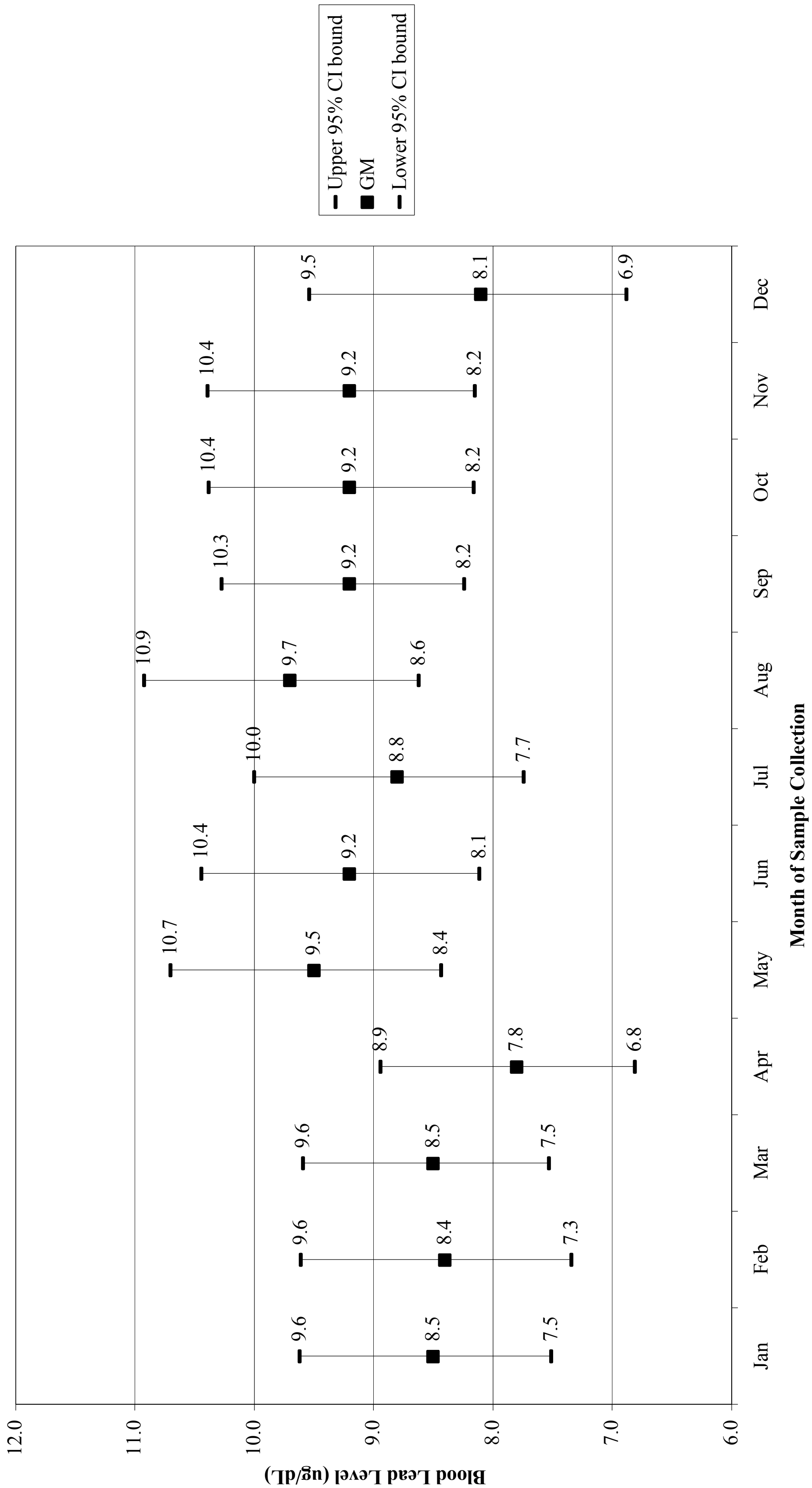


Figure 4-11: Pre-Intervention Blood Lead Levels (ug/dL) by Month of Sample Collection



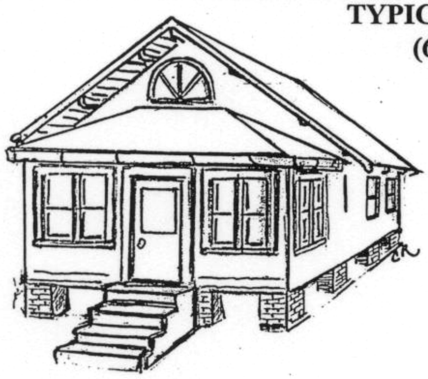
4.5.3 Discussion

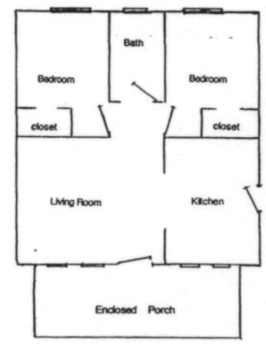
Grantee-specific reports of lead poisoning occurring prior to enrollment in the Evaluation were highly variable, possibly due to variation in the use of this factor as an enrollment criterion. Over half of enrolled children had blood lead levels less than 10 µg/dL at pre-intervention, 31 percent had levels between 10 and 19 µg/dL, and 15 percent had blood lead levels of 20 µg/dL or greater. These levels were generally much higher than those observed for a similar age group of children in the NHANES III survey.

Blood lead levels varied with age, peaking in the 24 to <36-month age group. Blacks and "Other" racial/ethnic groups had higher blood lead levels than Hispanics, Asians, or Whites. No gender-related differences in blood lead levels were noted. Seasonal influences were apparent, with higher levels in the summer and lower levels in the winter. Higher blood lead levels were observed in older dwelling units. The findings of multivariate statistical modeling of the effects of pre-intervention variables on blood lead levels are presented in Chapter 9.

EXHIBIT 4-1
EXAMPLES OF COMMONLY TREATED HOUSING

TYPICAL SINGLE RANCH (68 DWELLINGS)

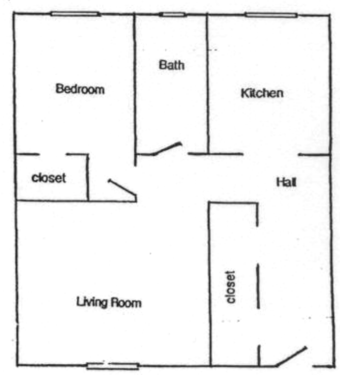




Defining Characteristics
- Single detached
- Pre-1930
- Any exterior
- 1 floor in house
- 2-3 bedrooms

Dwelling Unit Description
- 990 sq. ft. living space (quartile range 760-1,200)
- $61,200 value (quartile range $50,000-$126,000)
- 50% located in Alameda County; 16% in California; 9% in Minnesota; and 9% in Wisconsin.

TYPICAL LARGE MULTIFAMILY 240 DWELLINGS



Defining Characteristics
- >=20 units
- Pre-1930
- Masonry or stucco exterior
- > 3 floors in building
- 1-3 bedrooms

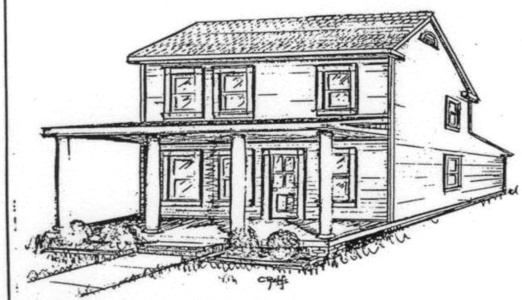
Dwelling Unit Description
- 550 sq. ft. living space (quartile range 450-650)
- $38,300 value (quartile range $36,000-$46,600)
- 89% located in New York; and 11% in Cleveland.

Note: Median sq. ft. living space and value reported.
Data From: Form 01, Form 10, Form 12
Data as of: June 1, 2000; restricted to units that passed clearance
Source of Data: NCLSH tables C9-C10

Typical Dwelling Unit: A dwelling unit in the appropriate building type that satisfies the defining characteristics.

EXHIBIT 4-1 (Cont'd)
EXAMPLES OF COMMONLY TREATED HOUSING

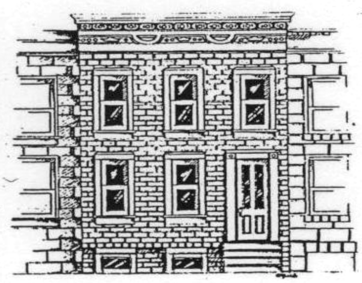
TYPICAL SINGLE FAMILY FRAME/COLONIAL (128 DWELLINGS)

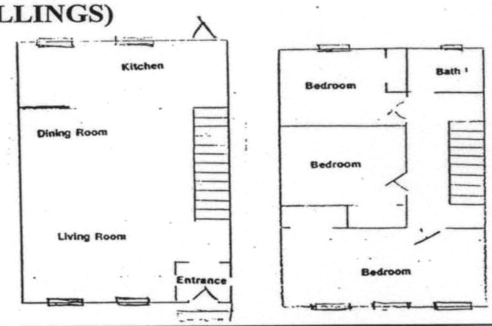


Defining Characteristics
- Single detached
- Pre-1930
- Non-masonry and non-stucco exterior
- 2 floors in house
- 2-3 bedrooms

Dwelling Unit Description
- 1,300 sq. ft. living space per unit (quartile range 1,200-1,500)
- $42,000 value (quartile range $23,200-$57,200)
- 19% located in Minnesota; 23% in Wisconsin; 17% inVermont; and 16% in Cleveland.

TYPICAL ROWHOUSE (297 DWELLINGS)





Defining Characteristics
- Rowhouse
- Pre-1950
- Masonry or stucco exterior
- 2 floors in building
- Basement
- 2 or 3 bedrooms

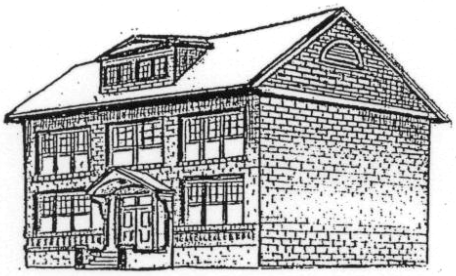
Dwelling Unit Description
- 1,040 sq. ft. living space (quartile range 900-1,150)
- $12,100 value (quartile range $9,650-$19,400)
- 96% located in Baltimore; and 4% in California.

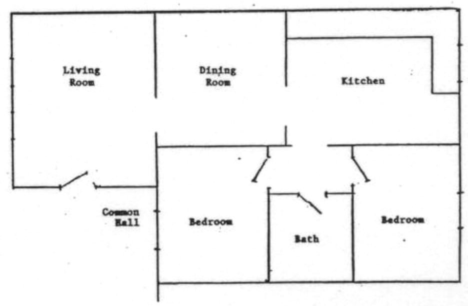
Note: Median sq. ft. living space and value reported.
Data From: Form 01, Form 10, Form 12
Data as of: June 1, 2000; restricted to units that passed clearance
Source of Data: NCLSH tables C9-C10

Typical Dwelling Unit: A dwelling unit in the appropriate building type that satisfies the defining characteristics.

EXHIBIT 4-1 (Cont'd)
EXAMPLES OF COMMONLY TREATED HOUSING

TYPICAL FOUR-PLEX
(136 DWELLINGS)

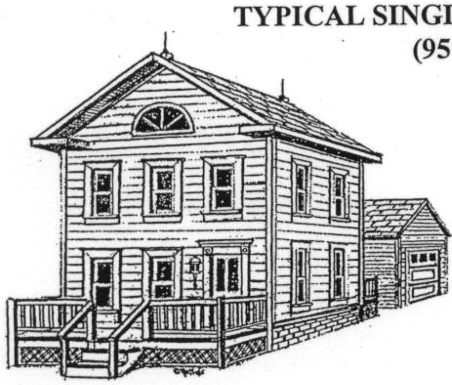


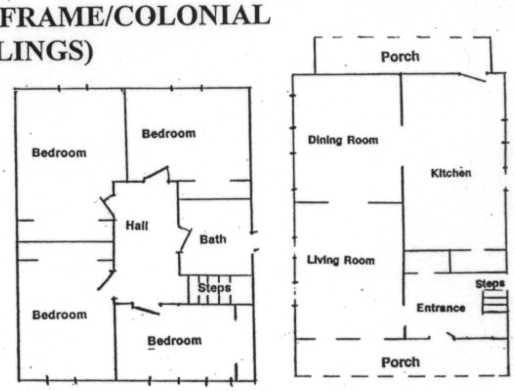


Defining Characteristics
- Four-plex
- Pre-1950
- Any exterior
- 2-3 floors in building
- 2-3 bedrooms

Dwelling Unit Description
- 1,000 sq. ft. living space (quartile range 800-1,200)
- $16,000 value (quartile range $15,000-$26,600)
- 57% located in Vermont; 13% in Minnesota; and 14% in Milwaukee.

TYPICAL SINGLE BIG-FRAME/COLONIAL
(95 DWELLINGS)





Defining Characteristics
- Single detached
- Pre-1930
- Non-masonry and non-stucco exterior
- 2 floors in house
- 4-5 bedrooms

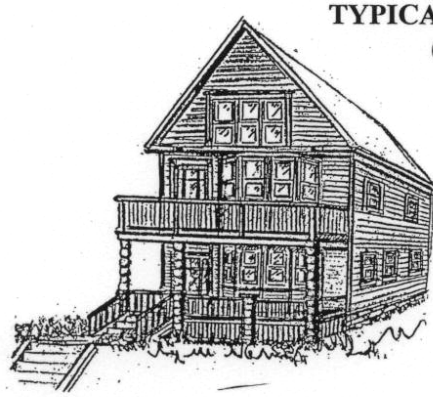
Dwelling Unit Description
- 1,540 sq. ft. living space (quartile range 1,300-2,000)
- 36,100 value (quartile range $23,800-$69,000)
- 25% located in Milwaukee; 20% in Wisconsin; 13% in Vermont ; and 16% in Cleveland.

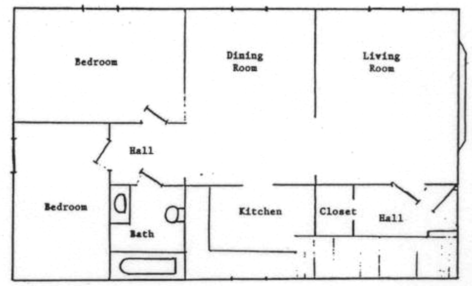
Note: Median sq. ft. living space and value reported.
Data From: Form 01, Form 10, Form 12
Data as of: June 1, 2000; restricted to units that passed clearance
Source of Data: NCLSH tables C9-C10

Typical Dwelling Unit: A dwelling unit in the appropriate building type that satisfies the defining characteristics.

EXHIBIT 4-1 (Cont'd)
EXAMPLES OF COMMONLY TREATED HOUSING

TYPICAL TWO FAMILY FRAME (274 DWELLINGS)

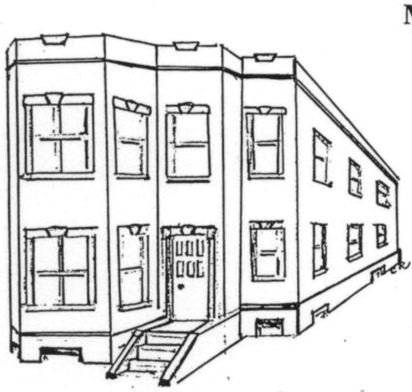


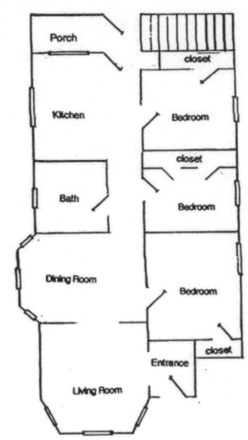


Defining Characteristics
- Two flats or duplex
- Pre-1930
- Non-masonry and non-stucco exterior
- 2 or 3 floors in building
- 2-3 bedrooms

Dwelling Unit Description
- 1,000 sq. ft. living space (quartile range 800-1,200)
- $22,000 value (quartile range $11,500-$35,000)
- 34% located in Milwaukee; 13% in Vermont; 13% in Wisconsin; and 13% in Cleveland.

TYPICAL TWO FAMILY MASONRY/STUCCO (50 DWELLINGS)





Defining Characteristics
- Two flats or duplex
- Pre-1930
- Masonry or stucco exterior
- 2 floors in building
- 2-4 bedrooms

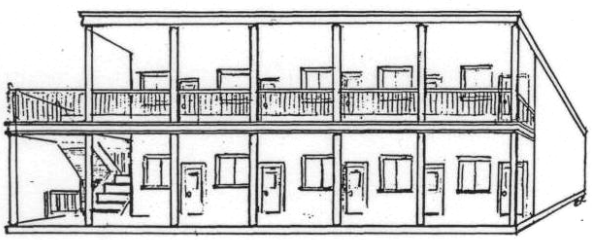
Dwelling Unit Description
- 1,200 sq. ft. living space (quartile range 1,000-1,400)
- $35,000 value (quartile range $22,400-$40,000)
- 62% located in Chicago; and 12% in Minnesota.

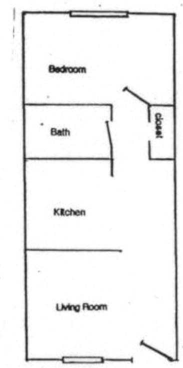
Note: Median sq. ft. living space and value reported.
Data From: Form 01, Form 10, Form 12
Data as of: June 1, 2000; restricted to units that passed clearance

Typical Dwelling Unit: A dwelling unit in the appropriate building type that satisfies the defining characteristics.

EXHIBIT 4-1 (Cont'd)
EXAMPLES OF COMMONLY TREATED HOUSING

TYPICAL SMALL MULTI FAMILY MODERN (49 DWELLINGS)

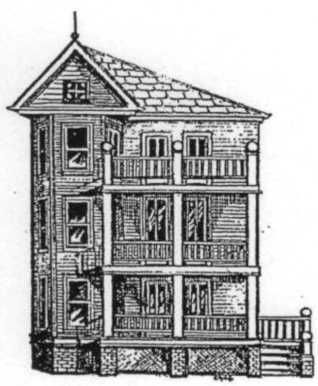


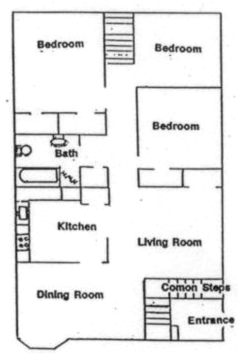


Defining Characteristics
- 5-12 Units
- 1920-1959
- Masonry or stucco exterior
- 1 or 2 floors in building
- 0-1 bedrooms

Dwelling Unit Description
- 425 sq. ft. living space (quartile range 290-600)
- $25,000 value (quartile range $25,000-$25,000)
- 78% located in California; and 12% located in Minnesota.

TRIPLEX (139 DWELLINGS)





Defining Characteristics
- Triplex
- Pre-1930
- Non-masonry and non-stucco exterior
- 3 floors in building
- 2-3 bedrooms per unit

Dwelling Unit Description
- 1,100 sq. ft. living space (quartile range 800-1,380)
- $32,000 value (quartile range $22,800-$40,000)
- 36% located in Rhode Island; 25% in Massachusetts; and 16% in Boston.

Note: Median sq. ft. living space and value reported.
Data From: Form 01, Form 10, Form 12
Data as of: June 1, 2000; restricted to units that passed clearance
Source of Data: NCLSH tables C9-C10

Typical Dwelling Unit: A dwelling unit in the appropriate building type that satisfies the defining characteristics.

5.0 DESCRIPTION OF INTERVENTIONS

5.1 DESCRIPTION OF THE INTERVENTION DATA COLLECTION PLAN/DEFINITION OF TERMS

A main attribute of the HUD LHC Grant Program has been the flexibility that grantees are given to select the lead treatments for any particular dwelling. The grantees have had the freedom to treat all areas of the property or to treat only some locations (interior, exterior, and/or soil). The grantees can also decide on the intensity of the treatments. Possible treatment intensities have ranged from specialized cleaning to full abatement of all lead-based paint. Especially in the initial rounds of the grants, HUD encouraged grantees to experiment with different levels of lead hazard control activities.

Grantees were allowed to experiment because there is no apparent single state-of-the-art intervention to control lead-based paint hazards. For example, some programs believed that windows containing lead-based paint must be replaced to protect the health of residents. Other programs contended that by using lower level/lower cost treatments, more residents could be served, while still protecting their health. In some cases, grantees even decided to leave some limited or negligible lead-based paint hazards untreated, believing that these limited hazards did not endanger the resident's health.

The Evaluation collected information about the lead interventions on two levels: a general characterization of the intensity of the intervention for each dwelling unit and a detailed list of all lead hazard control treatments. Because readers may be interested in different levels of detail, the report examines the costs and effectiveness of interventions at both levels. At the dwelling unit level, comparisons can be made between low-intensity interventions (e.g., cleaning and spot painting) and more intensive interventions (e.g., partial or full abatement). At the individual treatment level, comparisons can be made between low-level treatments to a component (e.g., paint stabilization of a window) and more intensive treatments to that component (e.g., window replacement).

5.1.1 Dwelling Unit Interventions

The system to characterize the intensity of the lead interventions at the dwelling unit level was originally developed in the early 1990s by URC, Inc. a consultant for a Baltimore nonprofit housing developer. The developer used this system to develop a strategic plan to address the lead-based paint hazards in its varying stock of housing. The Evaluation designers used the same consultant to create a system to categorize the lead interventions of the grantees. Although the categorization system was, in essence, unique to the Evaluation, it can be related to the classes of lead hazard control activities, such as interim controls and abatement, discussed in the HUD Guidelines.

The different levels of lead interventions are called *strategies,* from their roots as elements of a strategic plan. Grantees reported the strategies that were applied to each dwelling unit using a three-part "strategy code": one strategy for each region of the dwelling (i.e., dwelling interior, building exterior, and site/soil). Higher strategy levels reflect more intensive interventions. A list of the strategy codes used in the Evaluation is found in Table 5-1.

Table 5-1: Strategy Code Definitions

Strategy		Definition
Interior	01	No Action
	02	Cleaning, Spot Paint Stabilization Only
	03	Level 02 plus Complete Paint Stabilization, Floor Treatments
	04	Level 03 plus Window Treatments
	05	Level 04 plus Window Replacement, Wall Enclosure/Encapsulation
	06	All Lead-Based Paint Enclosed, Encapsulated, or Removed (Meets Public Housing Abatement Standards)
	07	All Lead-Based Paint Removed
Exterior	00	No Action
	01	Spot or Partial Paint Stabilization
	02	Complete Paint Stabilization, Porch Treatments
	03	Level 02 plus Porch/Trim Enclosure, Stabilization or Encapsulation
	04	All Lead-Based Paint Enclosed, Encapsulated, or Removed
	05	All Lead-Based Paint Removed
Site	0	No Action
	1	Cover Soil with Temporary Cover (Mulch, Stone)
	2	Level 01 plus Seed, Install Barriers (Bushes, Fencing)
	3	Level 02 plus Partial Soil Removal, Plant Sod
	4	Complete Soil Removal or Enclosure with Asphalt, Concrete

Glossary of Treatments

Encapsulation - The application of a covering or coating that acts as a barrier between lead-based paint and the environment, the durability of which relies on adhesion and which has an expected life of at least 20 years.

Enclosure - The application of rigid, durable construction materials that are mechanically fastened to the substrate to act as a barrier between lead-based paint and the environment.

Paint Stabilization - The process of repainting surfaces coated with lead-based paint, which includes the proper removal of deteriorated paint and priming.

Paint Removal - The complete removal of lead-based paint by wet scraping, chemical stripping, or contained abrasives.

Removal/Replacement - The removal/replacement of a building component that was coated with lead-based paint.

Window Treatments - The process of eliminating lead-containing surfaces on windows that are subject to friction or impact through the removal of paint or enclosure of certain window components.

Strategies in the Evaluation are defined by the treatments applied to the dwelling rather than by the condition of the dwelling after treatment is completed. For example, when the primary treatment to two different dwelling units was complete paint stabilization, both dwellings would be classified with the same strategy. It did not matter in the strategy assignment that one dwelling might have had its windows replaced prior to enrollment, while the second dwelling retained its lead-painted windows.

By defining the lead intervention by what was done, the objectives of the study could be met without placing an additional data collection burden on the grantees. The effect of intervention strategies on environmental and biological lead levels was examined by comparing pre- and post-intervention conditions of the dwellings. Pre-existing conditions, such as the previously replaced windows, should already be accounted for by the pre-intervention data. Had the strategies been defined by outcomes, grantees would have needed to conduct a complete inventory of the lead-based paint and lead-based paint hazards after the intervention to verify the reported outcomes. Such an inventory was not considered feasible.

In addition to characterizing lead hazard control work using intervention strategies, the Evaluation team collected detailed information about individual lead hazard control treatments. Grantees were asked to provide a list of construction *specifications* that described every lead hazard control treatment that was conducted at a dwelling unit.

5.1.1.1 Reporting Lead Hazard Control Strategies. It must be emphasized that neither HUD nor the Evaluation team dictated the lead hazard control treatments to be used by the grantees. The grantees selected treatments and then fit the work to the Evaluation strategy definitions. Thus, the strategy definitions presented on Table 5-1 are examples of the predominant treatments within each strategy category. The strategy definitions do not specify exactly what was done to each dwelling. While the Evaluation team tried to standardize the definitions of strategies, in a small percentage of the cases, similarly treated dwellings may have been assigned different interior strategies. In some homes, mixtures of treatments were done that did not neatly fit into one strategy. For example, New York City conducted work in some dwellings where walls and ceilings were enclosed, trim was replaced, and windows were only minimally treated because most had already been replaced. Without window replacement, these units did not fall into Interior Strategy 05, but these treatments were much more intensive than paint stabilization so Interior Strategy 03 was too low. These units were thus classified as Interior Strategy 04 even though they did not receive traditional window treatments such as jamb liners.

Grantees were responsible for identifying the strategies performed at each dwelling. A potential drawback of having grantees designate the intervention strategies was that each grantee might have had a slightly different interpretation of the strategy definitions. In an attempt to avoid this problem (poor inter-rater reliability), the consultant who developed the strategy system was retained to compare each set of strategy codes with the scope of the specifications for each dwelling. Strategy codes that deviated significantly from the scope of the specifications were returned to the grantee for revision. This review not only corrected inappropriately coded strategies but also helped to standardize the reporting of future strategy codes.[1]

[1] At the end of the study, the Evaluation team developed a computer program to compare reported interior strategies with the specifications for the interior treatments. Based on this review, it was determined that 15 percent of the interior strategies should be reclassified to better reflect the level of lead hazard control. The reclassified interior strategies are used in this report.

5.1.1.2 Concurrent Work. The flexibility that was given to grantees when determining what would be done to each dwelling went beyond decisions about how to treat lead hazards and included decisions about the complete scope of the construction project. The HUD Office of Lead Hazard Control (presently known as the Office of Healthy Homes and Lead Hazard Control) encouraged the integration of lead hazard control activities with general housing rehabilitation activities when the combination of such activities made economic and programmatic sense. While HUD LHC Grant Program funds could not be used to carry out major rehabilitation activities, grantees could combine the grant funds with other federal, state or local funds to complete a comprehensive project. Residents would benefit from a comprehensive project when a dwelling unit had other housing code and safety hazards that could not be addressed with HUD LHC Grant Program funds. Taxpayers also benefit from the potential cost efficiencies of rehabilitating low-income housing and controlling lead hazards simultaneously.

Comprehensive projects may have offered benefits to residents and the general public, but they added a complication for the Evaluation team. The distinction between a lead hazard control activity and a basic construction activity was not always clear. Consider a building exterior that was coated with intact lead-based paint. A grantee may not have considered treating intact lead-based paint as a priority for lead hazard control, but the grantee could have decided to apply exterior siding using another funding source. While the siding would be applied primarily for reasons such as reduced maintenance costs or improved energy efficiency, it could also be expected to have long-term lead hazard control benefits.

The Evaluation team found it impossible to define rigid rules to distinguish between lead work and non-lead work. Instead, grantees were given guidance to generally classify work on lead-based paint *hazards* as a lead hazard control activity and to use their own judgment in other situations, such as the example above. Non-lead work activities that occurred between the collection of the initial pre-intervention environmental samples and the immediate post-intervention samples (clearance) were to be reported. Non-lead work was given the term *concurrent* work. Grantees determined what work was concurrent work, calculated the cost of these activities and then classified the extent of the concurrent work based on these costs. Concurrent work costs were classified as $5,000 or less; $5,001 to $15,000; $15,001 to $25,000; and more than $25,000.

5.1.2 Individual Lead Hazard Control Treatments

For a lead program that is considering (or reconsidering) its strategic plan, the effectiveness of different strategies on housing in different conditions is likely to be of critical importance. This level of analysis, however, does not provide the level of detail needed for a specification writer, contractor or property owner to decide how to treat a particular building component. In order for the Evaluation team to examine the effectiveness of different treatments at the building component level, grantees were told to report all lead hazard control treatments that they performed in each enrolled dwelling unit.

To help facilitate the reporting of this information, grantees were given a copy of Specmaster®, a specification-writing and cost-estimating software program developed by The Enterprise Foundation to assist nonprofit developers of lower-income housing design and estimate the costs of their projects and then solicit bids (Enterprise 1994). Some grantees used Specmaster® in this manner to streamline the specification writing and contractor selection process. In addition, Specmaster® offered the grantees the ability to report treatments in a uniform manner so that they could be compared across all grantees. Grantees were expected to confirm that all treatments were completed as written prior to submitting the specifications for a particular dwelling unit.

Specmaster® contains a master database of detailed write-ups for more than 2,000 housing rehabilitation specifications. Periodically during the Evaluation, the master database was revised when grantees requested changes based on special local conditions. Over 400 specifications related to lead hazard control were included in the final database. An example of a Specmaster® specification is titled: Trim – Replace 1" x 3". The specification included a detailed (39-word) description of the method of properly removing the old trim, disposing of it and installing the new trim. The specification also included a recommended unit of measure for determining the amount of work performed, in this case, linear feet.

The use of Specmaster® served an important function in standardizing the descriptions of component treatments and limiting the number of unique potential treatments. However, with over 400 lead specifications, the final number of different specifications used proved unworkable for evaluation purposes. Before analyses began, the Evaluation team reviewed the specifications and collapsed them into a more manageable number of categories. These categories are called *equivalent treatment categories*.

Equivalent treatment categories were developed separately for cost analyses and effectiveness analyses. For example, for cost analyses, Trim – Replace 1" x 3" was combined with seven other trim replacement specifications to be examined as Trim - Modern Molding. For effectiveness analyses, Trim – Replace 1" x 3" was combined with 46 other trim replacement specifications to be examined as Trim – Remove/Replace Component. The criteria for combining treatments for cost analyses were more restrictive because the Evaluation team believed that certain attributes would matter for cost (i.e., historic trim v. modern trim), but they would not impact leaded dust generation that could modify effectiveness outcomes.

5.2 Description of the Lead Hazard Interventions at the Dwelling Unit Level

A total of 2,920 dwelling units were treated as part of the Evaluation. Grantees submitted complete and accurate construction data (i.e., a strategy report form and a Specmaster® report for the dwelling interior and exterior) and evidence of clearance for 2,615 (90%) of these dwellings. The 2,615 dwellings were contained in 1,440 buildings.

5.2.1 Lead Hazard Control Strategies

Grantees used a variety of lead hazard control strategies: 2,583 dwellings (99%) had interior work, 1,827 dwellings (70%) had treatments done to the exterior of the building, and 343 (13%) had soil work (Table 5-2). The most common combination of strategies was Interior Strategy 05 along with treatments to the exterior and no soil treatment (1,062 dwellings (41%)). Interior Strategy 05 is defined as the abatement of lead-based paint from windows in the dwelling, primarily by window replacement, and the treatment of other lead-based paint hazards in the dwelling. Although the intensity of the treatments to the other building components is not part of the strategy definition, grantees tended to stabilize the paint on identified hazards. However, interior strategy 05 did not preclude other components from being treated with more intensive treatments.

Table 5-2: Frequency of Dwelling Units Treated by Interior Strategy and Whether Exterior and/or Soil Work was Conducted

Interior Strategy	Treatment to Building Exterior		No Treatment to Building Exterior	
	Soil Treatment	No Soil Treatment	Soil Treatment	No Soil Treatment
01 – None	16	13	2	1
02 - Spot Painting/Cleaning	39	49	3	125
03 – Complete Painting	25	130	2	179
04 – Complete Painting plus Additional Window Treatments	30	241	13	137
05 – Partial Abatement of Lead including Window Abatement	171	1,062	39	160
06/07 – Full Abatement of Lead	3	48	0	127
Total Dwellings 2,615	**284**	**1,543**	**59**	**729**

Data from: Form 23, Question 2
Data as of: June 1, 2000
Source of Data: UC Table 517

Another 241 (9%) of the dwellings had treatments to the exterior and no soil treatments, but were treated with Interior Strategy 04. Interior Strategy 04 is defined as an intervention of the dwelling that includes window treatments that are more intensive than paint stabilization, but less intensive than the removal or replacement of the lead-based paint, along with the treatment of other lead-based paint hazards in the dwelling.

While these two combinations of strategies made up half of the dwellings, a diversity of strategies existed that allowed the effectiveness of a number of different treatments to be compared. At least 20 dwellings were treated within the strategy combinations that included Interior Strategies 02-05 and either exterior and site treatments, exterior treatments without site treatments, or no exterior/site treatments (Table 5-2). However, some combinations were rarely used, so the ability to measure effects was limited for treatment combinations such as interior strategies with just soil treatments; full interior lead abatement with exterior/soil treatments; and all combinations with no interior work.

5.2.1.1 Interior Strategies. The most common interior strategy was Interior Strategy 05, the partial abatement of lead, including window replacement (1,432 dwellings (55%)) (Table 5-3). Other frequently used interior strategies included Interior Strategies 02 through 04. These strategy levels represent interventions ranging from minimal spot painting and cleaning of lead-contaminated dust (Interior Strategy 02) to painting with window friction controls (Interior Strategy 04). Only 178 dwellings (7%) underwent full abatement of the interior (Interior Strategies 06 & 07). Even fewer dwellings (32 dwellings (1%)) had no interior work conducted (Interior Strategy 01).

While a variety of interior strategies were used in the Evaluation, grantees tended to select one or two dominant strategies (Table 5-3). Grantees often developed one or two intervention designs that they repeated throughout the project. Ten grantees used a single interior strategy in 60 percent or more of their dwellings. The remaining four grantees had over half of their dwelling units treated by one of two strategies. Ten grantees (Baltimore, Boston, California, Chicago, Cleveland, Massachusetts, Minnesota, Rhode Island, Vermont, and Wisconsin) used Interior Strategy 04 and 05 in their dwellings.

Milwaukee, Alameda County, and New York conducted a more diverse selection of interior interventions. These grantees had less than three quarters of their dwellings treated by their two most frequently used strategies. These three grantees plus Vermont and Minnesota were the only grantees to have at least 20 dwellings in at least three of the six interior strategy categories.

In some cases, strategies were concentrated at a few grantee sites or a single site. For example, Alameda County contributed 25 (78%) of the 32 dwellings to which no interior work was conducted (Interior Strategy 01). Similarly, New York contributed 127 (71%) of the 178 dwellings where full abatement (Interior Strategy 06-07)[2] was conducted. Concentrations of units from a few grantees were also apparent for Interior Strategies 02 through 04 (Table 5-4).

As explained in Section 5.1.1, interior strategies were assigned by the grantees based on how well they fell into the strategy definitions presented in Table 5-1. Within a strategy, there was some variability of the treatments selected. For the grantees that conducted at least five percent of their interventions within Interior Strategies 02 through 05, Tables 5-4 and 5-5 present the principal interior treatments that each grantee conducted.

[2] During the process of writing this report, New York City provided further information about their Interior Strategy 06 treatments. In most if not all dwellings where this strategy was conducted, the lead-based paint had been completely removed. This information suggests that these dwellings might better have been coded as being treated with Interior Strategy 07. For most analyses in this report, the full abatement strategies (06-07) are merged so this new information has little impact on the findings in later chapters.

Table 5-3: Number and Percentage of Dwelling Units in which a Specific Interior Intervention Strategy was Undertaken

Grantee	Interior Intervention Strategy							
	01	02	03	04	05	06	07	Total Dwellings with Strategy Reported
Alameda County	25 *15.3%*	55 *33.7%*	26 *16.0%*	14 *8.6%*	35 *21.5%*	3 *1.8%*	5 *3.1%*	163 *100%*
Baltimore	0 *0.0%*	1 *0.3%*	12 *3.1%*	5 *1.3%*	362 *94.3%*	0 *0.0%*	4 *1.0%*	384 *100%*
Boston	0 *0.0%*	1 *1.5%*	1 *1.5%*	7 *10.3%*	49 *72.1%*	10 *14.7%*	0 *0.0%*	68 *100%*
California	0 *0.0%*	3 *2.9%*	17 *16.5%*	3 *2.9%*	80 *77.7%*	0 *0.0%*	0 *0.0%*	103 *100%*
Chicago	0 *0.0%*	1 *0.8%*	6 *5.0%*	12 *10.0%*	101 *84.2%*	0 *0.0%*	0 *0.0%*	120 *100%*
Cleveland	0 *0.0%*	9 *7.5%*	5 *4.2%*	31 *25.8%*	75 *62.5%*	0 *0.0%*	0 *0.0%*	120 *100%*
Massachusetts	0 *0.0%*	5 *3.8%*	7 *5.3%*	17 *12.8%*	104 *78.2%*	0 *0.0%*	0 *0.0%*	133 *100%*
Milwaukee	0 *0.0%*	56 *25.2%*	54 *24.3%*	94 *42.3%*	18 *8.1%*	0 *0.0%*	0 *0.0%*	222 *100%*
Minnesota	3 *2.1%*	21 *14.7%*	9 *6.3%*	72 *50.3%*	38 *26.6%*	0 *0.0%*	0 *0.0%*	143 *100%*
New Jersey	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	1 *4.0%*	0 *0.0%*	24 *96.0%*	25 *100%*
New York City	0 *0.0%*	0 *0.0%*	168 *40.0%*	79 *18.8%*	46 *11.0%*	127 *30.2%*	0 *0.0%*	420 *100%*
Rhode Island	0 *0.0%*	1 *0.6%*	11 *6.9%*	8 *5.0%*	137 *86.2%*	2 *1.3%*	0 *0.0%*	159 *100%*
Vermont	1 *0.3%*	58 *14.8%*	12 *3.1%*	74 *18.9%*	246 *62.9%*	0 *0.0%*	0 *0.0%*	391 *100%*
Wisconsin	3 *1.8%*	5 *3.0%*	8 *4.9%*	5 *3.0%*	140 *85.4%*	0 *0.0%*	3 *1.8%*	164 *100%*
All Grantees:	32 *1.2%*	216 *8.3%*	336 *12.8%*	421 *16.1%*	1432 *54.8%*	142 *5.4%*	36 *1.4%*	2615 *100%*

Note 1: Table includes dwelling units in single and multifamily buildings. It does not include work conducted on common areas (e.g., hallways) of multifamily buildings.

Note 2: Interior Strategy Codes: 01=No Action, 02=Cleaning/Spot Painting, 03=02 + Full Painting, 04=03 + Window Treatment, 05=04 + Windows, 06=05 + Public Housing Standard, 07=Lead Free. See Table 4.1 for detailed strategy definitions.

Data from: Form 23, Question 02
Data as of: June 1, 2000
Source of Data: UC Table 176

For Interior Strategy 02, the treatments ranged from cleaning only in Minnesota to a mixture of treatments including spot stabilization and replacement of a few small leaded components in Alameda County. For Interior Strategy 03, the treatments were generally limited to paint stabilization, but the intensities ranged from New York City where over 60 percent of the rooms treated had walls, doors, trim and windows repainted (and some trim replaced) to Alameda County where less than 40 percent of rooms had windows stabilized and less than 20 percent of rooms had doors, trim and walls stabilized.

Table 5-4: Description of Lead Hazard Control Treatments for Dwellings Undergoing Interior Strategy 02 through 04 by Grantee

Interior Strategy	Grantee	Number of Dwellings	% of Dwellings by Strategy	Treatment Description
02	Vermont	58	27%	Spot paint stabilization, window trough caps, and cleaning
	Milwaukee	56	26%	Cleaning only or cleaning with aluminum window wraps/caps on window sill and troughs
	Alameda Co.	55	25%	Treatments ranged from clean-only to spot stabilization with replacement of a few small leaded components
	Minnesota	21	10%	Clean-Only
	Others[1]	26	12%	
03	New York City	168	50%	Paint stabilization of most components except floors; replacement of trim.
	Milwaukee	54	16%	Paint stabilization of most windows and some walls, doors and trim; and window sill caps.
	Alameda Co.	26	8%	Paint stabilization of some components and minor window repair.
	California	17	5%	Paint stabilization of most windows and some walls, doors and trim.
	Others[2]	71	21%	

[1] Other Grantees conducting Interior Strategy 02: Baltimore (1 Dwelling), Boston (1), California (3), Chicago (1), Cleveland (9), Massachusetts (5), Rhode Island (1), Wisconsin (5)
[2] Other Grantees conducting Interior Strategy 03: Baltimore (12), Boston (1), Chicago (6), Cleveland (5), Massachusetts (7), Minnesota (9), Rhode Island (11), Vermont (12), Wisconsin (8)

Data from: Form 23, Question 2 and Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table

Table 5-4 (continued): Description of Lead Hazard Control Treatments for Dwellings Undergoing Interior Strategy 02 through 04 by Grantee

Interior Strategy	Grantee	Number of Dwellings	% of Dwellings by Strategy	Treatment Definition
04	Milwaukee	94	22%	Jamb liners installed in most windows; some window sill caps; paint stabilization of walls, doors, trim and other window components
	New York City	79	19%	Enclosure of most walls/ceiling; replacement of most trim; refinishing of most floors; paint stabilization of doors; minimal window work
	Vermont	74	18%	Paint removal and reinstallation of sashes or sash replacement on most windows; window trough caps; paint stabilization of doors and trim and some walls; paint removal on some door sills, jambs and window sills.
	Minnesota	72	17%	Sash replacement on most windows with some trough caps; paint stabilization of trim and some other components
	Cleveland	31	7%	Paint removal from window sills/troughs and some sashes; paint stabilization of other window components, walls, doors and trim; enclosure of some floors
	Others[3]	71	17%	

[3] Other Grantees conducting Interior Strategy 04: Alameda County (14), Baltimore (5), Boston (7), California (3), Chicago (12), Massachusetts (17), Rhode Island (8), Wisconsin (5)

Data from: Form 23, Question 2 and Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table

Table 5-5: Description of Lead Hazard Control Treatments for Dwellings Undergoing Interior Strategy 05 by Grantee

Interior Strategy	Grantee	Number of Dwellings	% of Dwellings by Strategy	Treatment Description
05	Baltimore	362	25%	Replacement of most windows; paint stabilization of most trim and doors and some walls; replacement of some doors and enclosure of some floors
	Vermont	246	17%	Replacement or off-site stripping of most windows and/or installation of trough caps; replacement of some doors and trim; paint removal from some trim; enclosure of some floors and walls; paint stabilization of doors and trim and some walls.
	Wisconsin	140	10%	Replacement of most windows and some doors; paint stabilization of some trim, doors and other components.
	Rhode Island	137	10%	Replacement of most windows and doors and some trim; paint removal from some trim; paint stabilization of most walls, trim and doors and some floors; enclosure of some walls.
	Massachusetts	104	7%	Replacement of most windows and some trim; paint removal from trim, windows and doors; paint stabilization of some walls, doors, and trim; installation of trough caps
	Chicago	101	7%	Replacement of most windows and some trim and doors; enclosure of walls; paint stabilization of some walls and trim
	California	80	6%	Replacement of most windows and some trim and doors; encapsulation or paint stabilization of walls and other trim; enclosure of some floors
	Cleveland	75	5%	Replacement of most windows and/or installation of trough caps; very limited replacement or stabilization of other components
	Others*	187	13%	

*Others include: Alameda County (35), Boston (49), Milwaukee (18), Minnesota (38), New Jersey (1), and New York City (46)

Data from: Form 23, Question 2 and Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table

Interior Strategy 04 had the greatest variety of treatments among the five grantees that most frequently conducted this strategy. Window treatments included jamb liners (Milwaukee); sash replacement (Minnesota/Vermont); paint removal from sashes (Vermont/Cleveland) and stripping or capping of window sills and/or troughs for all four grantees. For these four grantees, additional treatments generally included paint stabilization of doors, trim and walls with some floor enclosure in Cleveland and some paint removal on door components in Vermont. In New York City, windows were generally *not* treated as part of their Interior Strategy 04, but the other treatments were so intensive that the interventions were placed in this strategy. Work in New York included enclosure of most walls/ceilings, replacement of most trim, refinishing of most floors and paint stabilization of doors.

Grantees that conducted Interior Strategy 05 generally replaced all or most windows in the dwellings. In Vermont, some of the windows were abated with off-site paint removal. A variety of additional treatments were conducted in these dwellings, ranging from limited replacement of doors (<10% of rooms) and some paint stabilization in Cleveland and Wisconsin to mixtures of door and trim replacement, wall or floor enclosure, and paint removal, encapsulation or stabilization at the other grantee sites.

5.2.1.2 <u>Exterior Strategies</u>

Exterior Strategies by Dwelling

Seventy percent of the dwellings (1,843) in the Evaluation were in buildings where the exterior was treated (Table 5-6). Almost two-thirds of these 1,843 dwellings had lower level exterior strategies, such as partial or full paint stabilization, while the remaining dwellings had partial or full exterior lead abatement. The most common exterior strategy consisted of full paint stabilization (Exterior Strategy 02) and was conducted at 36 percent of all dwellings (51% of treated dwellings). Other levels of exterior work included partial abatement (Exterior Strategy 03 -13% of all), partial painting (Exterior Strategy 01-10%) and full abatement (Exterior Strategy 04-05 -1%).

Eleven of the 14 grantees used a single exterior strategy (including Exterior Strategy 00 – No Treatment) in at least 48% of their dwellings (Table 5-6). However, for most grantees, the preference of an exterior strategy was not as strong as for an interior strategy. Only three grantees selected one exterior strategy for over three-quarters of their dwellings: New York City (Exterior Strategy 00), New Jersey (05), and Baltimore (02). Eight grantees had at least five percent of their dwellings classified in each of four categories of exterior strategies. As with interior strategy selections, Alameda County, Milwaukee, Minnesota and Vermont tended to select a variety of exterior strategies. Eighty-three percent of the dwellings without exterior work were contributed by four grantees (New York, Vermont, Minnesota, and Cleveland), with 53 percent contributed by New York City alone.

Table 5-6: Number and Percentage of Dwelling Units on which a Specific Exterior Intervention was Undertaken

Grantee	Exterior Intervention Strategy						
	00	01	02	03	04	05	Total Dwellings with Strategy Reported
Alameda County	7 *4.3%*	28 *17.2%*	96 *58.9%*	23 *14.1%*	9 *5.5%*	0 *0.0%*	163 *100.0%*
Baltimore	6 *1.6%*	72 *18.8%*	304 *79.2%*	0 *0.0%*	0 *0.0%*	2 *0.5%*	384 *100.0%*
Boston	1 *1.5%*	9 *13.2%*	17 *25.0%*	38 *55.9%*	3 *4.4%*	0 *0.0%*	68 *100.0%*
California	0 *0.0%*	2 *1.9%*	19 *18.4%*	23 *22.3%*	59 *57.3%*	0 *0.0%*	103 *100.0%*
Chicago	50 *41.7%*	32 *26.7%*	13 *10.8%*	13 *10.8%*	12 *10.0%*	0 *0.0%*	120 *100.0%*
Cleveland	58 *48.3%*	0 *0.0%*	11 *9.2%*	4 *3.3%*	47 *39.2%*	0 *0.0%*	120 *100.0%*
Massachusetts	0 *0.0%*	12 *9.0%*	66 *49.6%*	48 *36.1%*	7 *5.3%*	0 *0.0%*	133 *100.0%*
Milwaukee	54 *24.4%*	41 *18.6%*	74 *33.5%*	21 *9.5%*	30 *13.6%*	1 *0.5%*	221 *100.0%*
Minnesota	85 *59.4%*	16 *11.2%*	15 *10.5%*	17 *11.9%*	10 *7.0%*	0 *0.0%*	143 *100.0%*
New Jersey	0 *0.0%*	0 *0.0%*	0 *0.0%*	1 *4.0%*	0 *0.0%*	24 *96.0%*	25 *100.0%*
New York City	420 *100.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	420 *100.0%*
Rhode Island	0 *0.0%*	9 *5.7%*	85 *53.5%*	37 *23.3%*	28 *17.6%*	0 *0.0%*	159 *100.0%*
Vermont	98 *25.1%*	12 *3.1%*	208 *53.2%*	42 *10.7%*	31 *7.9%*	0 *0.0%*	391 *100.0%*
Wisconsin	8 *14.3%*	16 *9.5%*	19 *28.6%*	82 *33.3%*	34 *14.3%*	5 *0.0%*	164 *100.0%*
All Grantees:	787 *30.1%*	249 *9.5%*	927 *35.5%*	349 *13.4%*	270 *10.3%*	32 *1.2%*	2614 *100.0%*

Note 1: One dwelling unit was excluded from this table due to miscoding.
Note 2: Exterior Strategy Codes: 00=No Action, 01=Partial Paint Stabilization, 02=Complete Paint Stabilization, Porch Treatments, 03=02 + Porch/Trim Enclosure and Stabilization, 04=All Lead Paint Enclosed or Removed, 05=All Lead Paint Removed.
See Table 5-1 for more complete strategy definitions.
Data from: Form 23, Question 02
Data as of: June 1, 2000
Source of Data: UC Table 177-A

Exterior Strategies by Building

In 82 percent of the buildings in the analysis, the exterior was treated (Table 5-7). Grantees selected exterior strategies based on the general guidance provided by Table 5-1, yet as with interior strategy selection, certain treatments were conducted that went beyond the strategy definitions. While Exterior Strategy 01 was principally limited to paint stabilization, between 10 and 20 percent of the buildings had some paint removed, components enclosed or components replaced. Exterior Strategy 02 had rates of component enclosure and replacement similar to those of Exterior Strategy 01, but the percentage of buildings with paint removal more than doubled (from 15 to 32 percent).

Table 5-7: Use of Exterior Treatments by Exterior Strategy

Exterior Strategy	Number of Buildings	% of Treated Buildings	Treatment Description (by building)
01	201	17%	84% had stabilization 17% had replacement 15% had paint removal 12% had enclosure
02	613	52%	96% had stabilization 32% had paint removal 19% had replacement 12% had enclosure
03	216	18%	72% had stabilization 66% had enclosure 35% had replacement 29% had paint removal 6% had encapsulation
04	140	12%	71% had enclosure 59% had stabilization 54% had replacement 15% had encapsulation 7% had paint removal
Total Treated Buildings	1,177*		

*Includes 7 Buildings treated with Exterior Strategy 05 (Full Abatement)

Data from: Form 23, Question 2 and Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table

For the buildings treated with Exterior Strategy 03, paint stabilization remained the leading treatment, as it was used at 72 percent of the buildings. However, the application of enclosure and replacement increased substantially from the lower level exterior strategies. For Exterior Strategy 04, the full abatement strategy, the leading exterior treatment was enclosure (71% of buildings) and a majority of the buildings (54%) had some component replacement. Another 15 percent of these buildings included encapsulation and seven percent included paint removal. While Exterior Strategy 04 was intended to include only full abatement strategies, 59 percent of the buildings were treated with some paint stabilization. This may represent repainting after replacement, enclosure or paint removal; the repainting of surfaces with a paint lead level below 1 mg/cm^2; or the misclassification of some dwelling units.

5.2.1.3 Site Strategies

Site Strategies by Dwelling

Only 13 percent of the dwellings in the Evaluation had site lead hazard control work conducted (Table 5-8). Site lead hazard control work included treatments to reduce a child's exposure to lead in soil, such as the installation of barriers/fencing or grass/ground cover and treatments that permanently abated the hazard, such as soil removal or capping of the ground with concrete/asphalt. Of the dwellings that had site treatments, 264 dwellings (77%) had limited, temporary treatments such as mulching (Site Strategy 01 and 02), while the remaining 79 dwellings (23%) had partial or full abatement of the soil (Site Strategy 03 and 04).

The distribution of site strategies across grantees was far from balanced (Table 5-8). Six of the 14 grantees never treated the site: Baltimore, Boston, Massachusetts, Milwaukee, New Jersey and New York City. Four other grantees (California, Chicago, Vermont, and Wisconsin) treated the site at less than 8 percent of their dwellings. Of the remaining four grantees, only Alameda County, Cleveland and Rhode Island treated the soil at more than half of their dwellings. Five grantees, the three above plus Vermont, and Minnesota, treated 97 percent of the 348 dwellings with site treatments. Alameda County and Rhode Island alone contributed 61 percent of the dwellings with site treatments in the Evaluation. Of the 79 dwellings with full or partial abatement of soil (Site Strategy 03 and 04), 64 (81%) were treated by Alameda County or Rhode Island. Cleveland, along with Rhode Island and Alameda County, dominated the lower level site strategies; 77 percent of these strategies were completed by the three grantees.

Table 5-8: Number and Percentage of Dwelling Units at which a Specific Site Intervention Strategy was Undertaken

Grantee	Site Strategy					
	00	01	02	03	04	Total Dwellings with Strategy Reported
Alameda County	68 *41.7%*	32 *19.6%*	13 *8.0%*	23 *14.1%*	27 *16.6%*	163 *100.0%*
Baltimore	384 *100.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	384 *100.0%*
Boston	68 *100.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	68 *100.0%*
California	97 *94.2%*	6 *5.8%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	103 *100.0%*
Chicago	119 *99.2%*	1 *0.8%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	120 *100.0%*
Cleveland	55 *45.8%*	1 *0.8%*	60 *50.0%*	4 *3.3%*	0 *0.0%*	120 *100.0%*
Massachusetts	133 *100.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	133 *100.0%*
Milwaukee	221 *100.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	221 *100.0%*
Minnesota	111 *83.5%*	21 *11.3%*	8 *2.6%*	1 *0.9%*	2 *1.7%*	143 *100.0%*
New Jersey	25 *100.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	25 *100.0%*
New York City	420 *100.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	420 *100.0%*
Rhode Island	46 *28.9%*	44 *27.7%*	55 *34.6%*	12 *7.5%*	2 *1.3%*	159 *100.0%*
Vermont	362 *92.6%*	15 *3.8%*	6 *1.5%*	8 *2.0%*	0 *0.0%*	391 *100.0%*
Wisconsin	162 *98.8%*	0 *0.0%*	2 *1.2%*	0 *0.0%*	0 *0.0%*	164 *100.0%*
All Grantees:	2271 *86.9%*	120 *4.6%*	144 *5.5%*	48 *1.8%*	31 *1.2%*	2614 *100.0%*

Note 1: One dwelling unit was excluded from this table due to miscoding

Note 2: Site Strategy Codes: 00=No Action, 01=Cover Soil, 02=01+ Seed and Install Barriers, 03=02 + Partial Soil Removal and Plant Sod, 04=Complete Soil Removal or Enclosure with Concrete.

See Table 5-1 for more complete strategy definitions.

Data from: Form 23, Question 02

Data as of: June 1, 2000

Source of Data: UC Table 178-A

Site Strategies by Building

A total of 154 of the 1,440 buildings (11%) in this analysis had site treatments conducted (Table 5-9). Site Strategies 1 and 2 were similar; both were dominated by temporary ground cover (mulch, grass, or other plantings). Of the buildings treated with Site Strategies 1 or 2, 93 percent had temporary ground covers applied and less than nine percent had soil removed or permanently enclosed. The distinction between two lower level site strategies was largely determined by the amount of surface area treated, although a clear distinction between the two strategies did not exist.

Site Strategies 3 and 4 were also similar strategies, with permanent enclosure of soil conducted at a majority of the buildings. Soil removal was conducted at 17 percent of the buildings classified as Site Strategy 3 or 4. While Site Strategy 4 had a higher percentage of buildings with permanent enclosure than Site Strategy 3, it was not apparent that Site Strategy 4 truly represented full abatement of soil, since ground cover was installed on at least a portion of the soil at 81 percent of the buildings. These higher level site strategies may better be defined as partial to substantial abatement of the soil.

Table 5-9: Use of Site Treatments by Site Strategy by Building

Site Strategy	Number of Buildings	% of Treated Buildings	Treatment Description (by building)
1	63	41%	89% had mulch/seed/sod/plant 8% had soil removal 6% had enclosure 3% had structure removal
2	56	36%	98% had mulch/seed/sod/plant 10% had enclosure 7% had soil removal 4% had structure removal
3	21	14%	81% had mulch/seed/sod/plant 52% had enclosure 19% had soil removal 10% had structure removal
4	14	9%	93% had enclosure 81% had mulch/seed/sod/plant 14% had soil removal
Total Treated Buildings	154		

Data from: Form 23, Question 2 and Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table

5.2.2 Concurrent Work

In addition to the observations about the lead hazard control strategies, the Evaluation made observations about the presence or absence of additional construction work at each of the dwellings and the extent of that work. As defined previously, this related construction work, conducted immediately before, during, or immediately after the lead hazard control work, is referred to as concurrent work. While considered “non-lead work”, the concurrent work may have influenced the effectiveness of the lead hazard control work in some dwelling units either directly (e.g., siding covering stabilized lead-based paint) or indirectly (e.g., storm windows that reduce the effect of climate on painted window components).

Forty-five percent of the dwelling units had concurrent work conducted (Table 5-10). Every grantee had concurrent work done in at least some of their dwelling units. The frequency of concurrent work ranged from one percent in Chicago to 100 percent in New Jersey, with a median of 22 percent. Six grantees completed concurrent work in at least half of their dwelling units: Baltimore, California, New Jersey, New York City, Vermont, and Wisconsin.

In the dwelling units where concurrent work was conducted, the value of concurrent work varied considerably: 46 percent of dwellings had concurrent work costs less than $5,000, 27 percent had concurrent work costs between $5,000 and $25,000, and 27 percent had concurrent work costs over $25,000. Baltimore and California contributed almost 70 percent of the dwelling units with concurrent work valued at less than or equal to $5,000, while Vermont and New York City contributed over 60 percent of the dwelling units with concurrent work valued between $5,000 and $25,000. New York City and Vermont also were the largest contributors (90%) of the dwelling units with concurrent work valued over $25,000. These findings reflect the different types of concurrent work conducted. In general, Baltimore property owners conducted pre-intervention housing code work and/or post-intervention painting, while California’s program conducted weatherization activities in conjunction with the lead hazard control work. In Vermont and New York City, lead hazard control work was often performed in conjunction with moderate or substantial housing rehabilitation work completed by the local housing program.

Concurrent work was associated with increasing levels of interior work (Table 5-11). Grantees that selected lower level interior strategies (Interior Strategies 02-03) rarely conducted concurrent work (8% of dwellings), while grantees that selected abatement strategies (Interior Strategies 06-07) almost always conducted concurrent work (94% of dwellings). Dwellings treated with Interior Strategies 04-05 were fairly evenly split between having concurrent work conducted (49% of dwellings) or not.

Table 5-10: Number and Percentage of Dwelling Units Having Undergone Concurrent Non-Lead Work by the Cost of the Concurrent Work

Grantee	Cost of Concurrent Work						
	None	$1 to < $1,000	$1,000 to < $5,000	$5,000 to < $15,000	$15,000 to < $25,000	$25,000 or more	Total Dwellings with Intervention Reported
Alameda County	132 *83.0%*	5 *3.1%*	13 *8.2%*	2 *1.3%*	2 *1.3%*	5 *3.1%*	159 *100.0%*
Baltimore	61 *15.9%*	148 *38.5%*	164 *42.7%*	1 *0.3%*	5 *1.3%*	5 *1.3%*	384 *100.0%*
Boston	55 *80.9%*	10 *14.7%*	2 *2.9%*	1 *1.5%*	0 *0.0%*	0 *0.0%*	68 *100.0%*
California	32 *31.4%*	4 *3.9%*	62 *60.8%*	4 *3.9%*	0 *0.0%*	0 *0.0%*	102 *100.0%*
Chicago	118 *99.2%*	0 *0.0%*	1 *0.8%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	119 *100.0%*
Cleveland	100 *83.3%*	10 *8.3%*	7 *5.8%*	0 *0.0%*	0 *0.0%*	3 *2.5%*	120 *100.0%*
Massachusetts	108 *81.8%*	7 *5.3%*	10 *7.6%*	7 *5.3%*	0 *0.0%*	0 *0.0%*	132 *100.0%*
Milwaukee	165 *75.0%*	10 *4.5%*	16 *7.3%*	13 *5.9%*	11 *5.0%*	5 *2.3%*	220 *100.0%*
Minnesota	133 *93.7%*	0 *0.0%*	3 *2.1%*	3 *2.1%*	0 *0.0%*	3 *2.1%*	142 *100.0%*
New Jersey	0 *0.0%*	0 *0.0%*	0 *0.0%*	0 *0.0%*	25 *100.0%*	0 *0.0%*	25 *100.0%*
New York City	169 *40.2%*	0 *0.0%*	0 *0.0%*	42 *10.0%*	40 *9.5%*	169 *40.2%*	420 *100.0%*
Rhode Island	135 *84.9%*	11 *6.9%*	9 *5.7%*	4 *2.5%*	0 *0.0%*	0 *0.0%*	159 *100.0%*
Vermont	150 *38.4%*	0 *0.0%*	2 *0.5%*	33 *8.4%*	86 *22.0%*	120 *30.7%*	391 *100.0%*
Wisconsin	55 *33.7%*	27 *16.6%*	26 *16.0%*	38 *23.3%*	7 *4.3%*	10 *6.1%*	163 *100.0%*
All Grantees:	1413 *54.3%*	232 *8.9%*	315 *12.1%*	148 *5.7%*	176 *6.8%*	320 *12.3%*	2604 *100.0%*

Note: 11 Dwellings were excluded from this table because concurrent work was reported without an associated cost
(7 dwellings) or no concurrent work was reported, but a concurrent work cost was reported
(4 dwellings)

Data from: Form 23, Question 6 & 7
Data as of: June 1, 2000
Source of Data: NCLSH Table

Table 5-11: Number and Percentage of Dwelling Units with Concurrent Work by Interior Strategy

Interior Strategy	Concurrent Work Completed	Total Dwellings
02	12 *5.6%*	216
03	32 *9.6%*	332
04	191 *45.6%*	419
05	720 *50.4%*	1,428
06	132 *93.0%*	142
07	36 *100%*	36
Total	1,123 *43.6%*	2,573

Note 1: 11 Dwellings were excluded from this table because concurrent work was reported without an associated cost (7 dwellings), or no concurrent work was reported but a concurrent work cost was reported (4 dwellings).
Note 2: 31 Dwellings were excluded from this table because no interior work was conducted.
Note 3: Interior Strategy Codes: 01=No Action
02=Cleaning/Spot Painting
03=Full Painting
04=Window Treatments
05=Window Abatement
06=Full Abatement
07=Lead Free
See Table 5-1 for detailed strategy definitions
Data from: Form 23, Question 9
Data as of: June 1, 2000
Source of Data: NCLSH Table

5.2.3 Summary of Strategy Selection and Interventions

The descriptions of interventions presented in this chapter offer a picture of the treatments undertaken. Grantees tended to select interior strategies that were below full abatement but included significant window treatments, ranging from jamb liner installation or sash replacement to off-site stripping of window components or full window replacement. While some grantees such as Boston and Massachusetts had their strategies largely dictated by state law, most grantees had the freedom to choose from the full range of lead hazard control options. Most grantees decided that treatments beyond paint stabilization but less than full abatement met their needs, after taking into account factors such as local housing conditions, presence of a lead-poisoned child, and financial constraints.

Grantees generally chose to treat building exteriors using a range of strategies. When exterior treatments were not selected, a principal reason was the lack of exterior lead-based paint hazards. Over half of the dwellings that had no exterior treatments were in New York City, where the buildings were masonry with little or no exterior paint. Because of cost, some grantees deliberately selected buildings without exterior lead hazards. At most properties, grantees chose not to treat the site. Decisions were often based on programmatic decisions not to include soil as part of the grantee's lead hazard control plans and were not made based on the existence or absence of lead-contaminated soil, since most grantees chose not to test the soil. Just three grantees, Alameda County, Cleveland, and Rhode Island chose to treat soil at a majority of their properties.

Lead hazard control activities were often accompanied by concurrent work. The types of work varied by grantee, with some grantees such as Baltimore requiring additional work from property owners, while other programs incorporated the lead hazard control work with other activities such as weatherization or substantial housing rehabilitation. The use of concurrent work tended to correspond with higher intensities of interior treatments.

The descriptions in this chapter also offer an understanding of the analytic opportunities and limitations produced by the selection of treatments in this Evaluation. Never before have studies of lead hazard control had the opportunity to analyze the effectiveness of such a diversity of treatments. In addition, the diversity of pre-intervention building conditions, the variety of housing types and locales, and differences in grantee programs (see Section 2.2) offer opportunities for considering the effects of treatments under many different conditions.

Yet at the same time, this Evaluation's central feature, the freedom provided to grantees when they selected their lead hazard control strategies, created some limitations for the analyses of treatment effectiveness. The Evaluation team did not have the authority to direct grantees to use certain strategies, so in some cases the quantity of dwellings treated with certain strategies was limited. For example, an examination of the post-intervention effects of creating dwellings free of lead-based paint was not possible because of the small number of dwellings treated with this strategy that had complete post-intervention data available.

The flexibility afforded the grantees meant that strategies were not randomly or evenly distributed across the enrolled dwellings. As will be explained in more detail in Sections 8.0 and 9.0, the clustering of intervention strategies among a few grantees and a limited variety of housing types and housing conditions posed challenges in data analysis and in the interpretation of findings. One challenge posed by the clustering of strategies was that while the Evaluation was national in scope, some findings are based on the work of just a few grantee sites and may be less generalizable. For example, the results from Alameda County and Rhode Island will have a large influence on the conclusions that can be drawn about the effectiveness of site work because they contributed 60 percent of the site treatment data. The non-random application of strategies also created a situation where strategies were often correlated with other factors such as baseline building condition (i.e., buildings in worse condition received higher level strategies). This intercorrelation of strategy with other factors presented a challenge to the Evaluation team's ability to determine which factors were influencing treatment effectiveness and the magnitude of the effects.

While the Evaluation team did their best to organize the lead hazard control activities into a limited number of strategies and treatment categories, the findings demonstrate quite clearly that the specific interventions within a strategy do vary from grantee-to-grantee. A limitation of this study is that the "short-hand" definitions of strategy that are used throughout this report may not fully reflect the diversity of treatments within each strategy. Furthermore, the outcomes associated with any particular strategy offer important information about the strategy in general, but cannot provide conclusive data about any specific treatment approach taken by just one or two grantees. For example, the outcomes related to Interior Strategy 04 should not be used to draw conclusions about the utility of jamb liners since they were used in just a portion of the dwellings treated with this strategy.

5.3 DESCRIPTION OF INDIVIDUAL LEAD HAZARD CONTROL TREATMENTS

Of the 2,920 dwelling units treated in the study, 2,615 dwellings in 1,440 buildings had acceptable specifications submitted and had evidence of passing clearance. A total of 23,580 rooms were identified within these dwellings.

5.3.1 Interior Treatments

The most common treatments that were reported (other than cleaning[3]) were window replacement and paint stabilization of trim, doors and walls/ceilings (Table 5-12). Each of these treatments was reported in at least 22 percent of the rooms. Window replacement was the most popular treatment having been conducted in 40 percent of the rooms. In 15 percent of the rooms, some form of friction/impact/moisture control was applied to the windows; nine percent of the rooms had both replacement and friction controls. Enclosure was the preferred treatment on floors and stairways (10% of rooms).

When developing the equivalent treatment categories, the term stabilization of paint was used to identify all reported uses of a paint or sealant. As presented on Table 5-1, paint stabilization is generally defined as "the process of repainting surfaces coated with lead-based paint, which includes the proper removal of deteriorated paint and priming." However, the evaluation team found that grantees used specifications for pure paint stabilization and other repainting interchangeably. In some cases, paint was applied to intact painted surfaces and sealant was applied to non-leaded surfaces. Because it was observed that the specifications were more commonly used for the purpose of treating deteriorated paint, the decision was made to consider all painting and sealing as "paint stabilization."

[3] Cleaning was assumed to be completed in all treated rooms

Table 5-12: Interior Component System Treatments (By Room)

		Number and Percentage of Rooms with a Specific Class of Treatment						
Component Systems	Total Rooms	Misc. Treatments	Paint Stabilization	Encapsulation	Paint Removal	Window Rework	Enclosure	Component Replacement/ Removal
Wall/Ceiling	23,580	13 <1%	5,065 22%	246 1%	46 <1%		2,252 10%	105 <1%
Floor/Stairs	23,580	53 <1%	954 4%	3 <1%	607 3%		2,301 10%	92 <1%
Doors	23,580	63 <1%	5,600 24%	34 <1%	400 2%			2,389 10%
Trim	23,580	25 <1%	7,826 33%	301 1%	2,629 11%		190 1%	3,479 15%
Windows	23,580	33 <1%	2,137 9%	16 <1%	724 3%	3,444 15%		9,511 40%

Data from: Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table C6

Beyond the commonly used treatments, grantees selected a broad variety of treatments to meet their needs. Even when treatments were selected less frequently on a percentage basis, there are still enough instances to allow further investigation of effectiveness. For example, paint was stabilized on windows in 9 percent of the rooms, encompassing 2,137 rooms, sufficient to analyze the effect of this treatment.

Encapsulation was infrequently used in the Evaluation. Encapsulation was used on 301 of the trim systems (1%), 246 of the wall/ceiling systems (1%), and less than 20 of the floor/stair and window systems. Grantees were more than 20 times more likely to use paint than encapsulants on wall/ceilings and more than 25 times more likely to use paint on trim.

Table 5-13 presents the 25 most commonly used interior equivalent treatment categories used for effectiveness analyses. The table includes eight individual window treatments and four individual treatments in each of following treatment categories: wall/ceilings, floor/stairs, doors and trim.

Table 5-13: Top 25 Most Frequently Used Individual Interior Lead Hazard Control Treatments

Rank	Treatment	Number of Times Used*
1	Trim – Stabilize Paint	10,025
2	Window – Replace	9,002
3	Wall/Ceiling – Stabilize Paint	7,949
4	Door – Stabilize Paint	6,198
5	Trim – Replace/Remove	4,619
6	Trim – Remove Paint	3,798
7	Wall/Ceiling – Enclose	3,149
8	Window – Wrap Sill/Trough	2,721
9	Door – Replace	2,543
10	Floor/Stair – Enclose (wood/vinyl)	2,382
11	Window – Stabilize Paint	2,323
12	Floor/Stair – Stabilize Paint	1,245
13	Window – Remove Component	1,171
14	Window – Replace Sash Only	883
15	Window – Install Jamb Liner	814
16	Window – Remove Paint	788
17	Window – Repair	673
18	Floor/Stair – Refinish	612
19	Door – Remove Paint	496
20	Door – Remove Component	475
21	Trim – Encapsulate	358
22	Wall/Ceiling – Patch	307
23	Wall/Ceiling – Encapsulate	262
24	Floor/Stair – Dispose of Carpet	219
25	Floor/Stair – Enclose (carpet)	213

*Number of Times Used is based on the number of instances when a specification was reported. Specifications were generally reported once per room but an individual treatment could be used more than once in a room. For example, if two separate window specifications were used to report sash paint stabilization and sill paint stabilization in a room, two Window-Stabilize treatments would be counted for that room. However, if a single specification were used to report the replacement of 3 windows in a room, then a single Window-Replace treatment would be counted for that room. A total of 23,580 rooms were considered for this analysis.

Data from: Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table C2

5.3.2 Exterior/Site Treatments

Paint stabilization was by far the most common treatment on building exteriors, used on the cladding and trim of 69 percent of the 1,440 buildings (Table 5-14a). Other frequently used treatments on building exteriors were: component enclosure (24%), paint removal (21 %), and component replacement/disposal (20 %).

On exterior stairways and porch decking, the most common treatment was replacement/disposal, which was conducted at 137 buildings (10%). Enclosure and paint stabilization were used on stairs and decks at five percent of the buildings.

The most common soil treatment was the installation of a soil covering, including mulch, seed or sod (Table 5-14b). Soil covering was installed at 147 buildings (10%). A small subset of buildings had more intensive soil remediation conducted: two buildings with both permanent enclosure and soil removal, 32 buildings with partial or full permanent enclosure only, and 13 buildings with partial or full soil removal only. The relatively small number of buildings with higher intensity soil treatments precludes comparison of soil treatments. At 18 buildings (1%), an outbuilding was removed.

Table 5-15 presents the 11 most commonly used exterior/site equivalent treatment categories used for effectiveness analyses. The table includes six individual treatments to exterior cladding or trim, three individual treatments to exterior stairs or decking, and two individual treatments to soil.

Table 5-14a: Exterior Component System Treatments (By Building)

		Number and Percentage of Buildings with a Specific Class of Treatment					
Component Systems	Total Buildings	Misc. Treatments	Paint Stabilization	Encapsulation	Paint Removal	Rework /Replacement	Enclosure
Exterior Cladding/Trim	1,440	36 3%	997 69%	40 3%	298 21%	305 21%	341 24%
Stairs/Decking	1,440	6 <1%	71 5%	0 0%	8 1%	137 10%	77 5%

Table 5-14b: Site Treatments (By Building)

		Number and Percentage of Buildings with a Specific Class of Treatment				
Component Systems	Total Buildings	Misc. Treatments	Remove Structure	Mulch/Seed /Sod/Plant	Remove Soil	Permanent Enclosure
Site	1,440	13 1%	18 1%	147 10%	15 1%	34 2%

Data from: Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table C6

Table 5-15: Top Most Frequently Used Individual Exterior Lead Hazard Control Treatments

Rank	Treatment	Number of Times Used*
1	Exterior - Stabilize Paint	2,082
2	Exterior - Remove Paint	707
3	Exterior - Enclose	654
4	Exterior - Replace	497
5	Exterior Stair/Decking - Replace	133
6	Exterior Stair/Decking - Stabilize	102
7	Soil - Seed	86
8 (tie)	Exterior - Encapsulate	85
8 (tie)	Exterior Stair/Decking - Enclose	85
10 (tie)	Exterior - Dispose Component	59
10 (tie)	Soil - Mulch	59

**Number of Times Used* is based on the number of instances when a specification was reported. Specifications were generally reported once per location (building) but an individual treatment could be used more than once at a building. For example, if two separate exterior specifications were used to report siding paint stabilization and fascia paint stabilization at a building, two Exterior-Stabilize treatments would be counted for that building. However, if a single specification were used to report the stabilization of 2 porches at a building, then a single Exterior-Stabilize treatment would be counted for that building. A total of 1,440 buildings were considered for this analysis.

Data from: Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Table C3

5.3.3 Summary of Individual Treatments

As with intervention strategies, grantees selected a wide variety of individual lead hazard control treatments. The variety of treatments provided the Evaluation team with an opportunity to explore the effects of the different treatments. Many types of building components were treated with a sufficient variety of treatment categories (e.g., stabilization, paint removal, replacement) so that comparisons of effectiveness could be undertaken. Among the analyses presented later in this report are comparisons of the cost of individual treatments (Section 6.0), the longevity of the treatments (Section 8.6) and the effectiveness of window treatments and paint removal treatments as measured by longitudinal dust lead levels (Section 8.7). Additional comparisons between floor, trim and door treatments were originally part of the analysis plan, but as explained in Section 8.7, the Evaluation team was unable to confidently separate the effects on dust lead levels of the treatments to these components.

6.0 COSTS OF LEAD HAZARD CONTROL ACTIVITIES

6.1 BACKGROUND

When the Evaluation was being designed, there were very few sources of empirically based estimates of lead hazard control costs. For example, lead abatement cost estimates developed during the HUD Lead-Based Paint Abatement Demonstration in 1991 (HUD 1991) were based on applying costs of labor, materials and overhead/profit provided by contractors to the study's findings of time and material requirements for certain treatments. Other reports of lead hazard control costs were often anecdotal, based on unscientific surveys of contractors and property owners in limited geographic areas. In 1999, HUD relied on cost estimates based on interviews with contractors and state officials, as well as data from this Evaluation, to identify lead hazard reduction costs for its *Economic Analysis of the Final Rule on Lead-Based Paint* (HUD 1999).

Given the number of requests for information about costs that the Evaluation team has received, the limited availability of lead hazard control cost data cannot be for a lack of demand. The paucity of empirical cost data is more likely due to the many issues involved in reporting costs. The costs of lead hazard control may vary greatly depending on factors such as the size of the dwelling, the extent of the hazards, the number of dwellings in the project, the scope of the treatments and regional cost differences. A more basic question which must be addressed is what lead hazard control activities (e.g., lead hazard evaluation, hazard reduction, relocation, clearance, general oversight) should be included when reporting costs. When reporting construction costs, the costs that will be attributable to lead hazard control must be defined. For example, for some constituents, such as property owners, the most informative value is likely to be the amount that a lead abatement contractor will charge. For other constituents, such as state legislatures, a more useful value may be the incremental costs of treating lead hazards, subtracting the costs of routine maintenance and painting and standard rehabilitation activities.

6.1.1 Evaluation Costs

One of the principal objectives of the Evaluation was to describe the costs of applying the various intervention strategies to dwelling units that received interventions under a HUD LHC Grant. The Evaluation offered an opportunity to report empirically based lead hazard control costs because of the detailed information about housing conditions, treatments, and costs that were collected. However, the researchers faced challenges in determining how best to report the costs. Decisions about what to report were sometimes based on data collection limitations and in other cases based on analytical decisions. This section discusses the process used to collect cost data in the Evaluation while the methodology portions of Sections 6.2 and 6.4 describe analytical decisions made when considering the costs. An understanding of how costs were determined is critical to interpreting the results, especially when comparing costs to those reported by other programs.

6.1.2 Methodology

A central concern of HUD when designing the Evaluation was "to evaluate the cost and efficacy of lead-based paint hazard control efforts conducted under the HUD program" (NCLSH 1994). Given this focus, data collection forms were designed to report information about the costs of lead hazard reduction. The costs of other lead hazard control activities including the costs of environmental testing, medical surveillance of children, family relocation or program oversight were not collected as part of the Evaluation. This study was not designed to measure the per-unit costs of managing a Lead-Based Paint Hazard Control Grant or any similar governmental program. The costs presented are strictly related to the costs that an organization or individual could expect to pay for lead hazard control, including worksite preparation, lead treatments, clean-up, and hazard disposal, as well as profit and overhead (if applicable).

For each dwelling unit, grantees reported the cost of lead hazard control work, the total cost of the intervention (lead hazard control work plus concurrent work) and the cost for each treatment specification for the dwelling. Grantees usually obtained these costs from the contractor invoices. For single-unit homes, the costs included the cost of interior, exterior and site work. For multi-unit buildings, costs were reported on a form for each separate dwelling unit that was treated and a separate form was prepared for the common areas. The dwelling unit forms for multi-unit buildings included only the costs for treating the interior of the dwellings, while the common area forms included costs for interior common areas, exteriors and site work. (It should be noted that the costs of interior treatments to common areas in multi-unit buildings have not been examined. In general, common hallway treatments, costs and their effects are not part of this report.)

During the first months of the data collection process, questions arose about when costs should be allocated to lead hazard control work versus concurrent work. Among the allocation systems that the Evaluation team considered:

1) Allocate costs by source of funding (e.g., work paid for by the HUD LHC Grant Program = lead work);
2) Allocate costs by surface treated (e.g., work conducted on a leaded surface = lead work);
3) Allocate costs by intent (e.g., treatments conducted to control lead hazards = lead work);
4) Allocate costs by incremental lead costs (e.g., special worksite preparation, worker protection, and clean-up = lead work, while regular painting activities = non-lead work).

After discussing the issue with Grantees at a meeting in February 1995, oral guidance was provided to all grantees that cost allocation should be conducted based on intent. All work that could have been legitimately paid for by the HUD LHC Grant was eligible to be considered lead work. All work conducted on lead-based paint hazards as well as to lead-based paint was eligible to be lead work. Work conducted in order for other lead treatments to be effective (roof repair, plumbing leak repair, minor structural repairs) was also considered lead work. In general, grantees were encouraged to report treatments as lead work when those treatments were eligible costs under the grant program.

The purpose of this allocation system was to identify the full cost per unit for lead-based paint hazard reduction activities that a property owner might expect to pay while discounting any extra work that may have been conducted. This extra work included major structural work conducted as part of substantial rehabilitation projects, HVAC or electrical work that would not be eligible for lead grant funding. The extra work also included treatments that could arguably have improved the effectiveness of the lead work, but in the opinion of the spec writer, were conducted for other reasons such as energy efficiency. These treatments included storm window and siding installation and cosmetic painting. While the use of *intent* to allocate costs resulted in some variation in cost reporting from grantee to grantee and from spec writer to spec writer, the system appeared to reasonably reflect the full cost per unit of lead-based paint hazard control.

One obvious limitation of this approach was that it was not possible to empirically estimate the incremental costs of lead hazard control. Grantees were not required to report the cost of treatments they would have incurred had lead abatement contractors and lead-safe work practices not been used. Any estimate of the incremental costs based solely on these data would be speculative.

The dollar amounts reported by the grantee were expected to be the actual dollar amounts paid by the program for the treatments. As such, the costs included the labor and materials for the project as well as any overhead and profits that were charged. Eighty-eight percent of the dwelling units were treated by for-profit contractors and generally all of these factors were included in their reported costs. (In a few cases, grantees paid for some contractor expenses such as worker training and liability insurance.) In a limited number of dwellings, grantees hired non-profit contractors (5%), property owners (5%), or used their own staff (2%) to complete the treatments. In these cases, the reported costs did not include a profit factor and in the case of the public employees may not fully account for the overhead expenses. The possible impact of this variation will be discussed with the results.

To report the costs of individual lead hazard control treatments, grantees estimated those costs using their personal knowledge of construction pricing and in some cases values reported by the contractor. Grantees were required to develop estimates for specifications that when totaled would be within 20 percent (or $200, if that was larger) of the total lead hazard control costs for the dwelling as reported on Form 23. Dwellings where this level of precision of estimation could not be achieved were excluded from the analysis of individual lead hazard control treatment costs. Fifteen percent of treated dwellings and 26 percent of treated common areas from all grantees except New York City were excluded because reported costs did not meet these criteria.

6.2 DWELLING UNIT LEVEL COST ESTIMATES

The cost of lead hazard control varied substantially from dwelling to dwelling. The variation was influenced by many factors including the scope of the treatments and the size of the dwelling. Although sufficient study data are available to generate a single "national" average cost for lead hazard control in the Evaluation, such a result would have little practical value to anyone planning to fund or conduct lead hazard control work. Agencies would most likely find it more useful to have average costs presented for the type and size of dwelling that they plan to treat and for the intensity of the treatments they plan to implement.

6.2.1 Methodology

A central data analysis issue was how to organize and subdivide the cost data to have practical benefit. After consideration of a number of different organizational methods, it was determined that costs would be subdivided by the "geography" (interior, exterior, site) of the property treated as well as by strategy. This report presents the dwelling unit costs of interior treatments, exterior treatments and site/soil treatments by the intensity of the interventions**.**

A cost separation procedure to categorize the specifications into the three "geographies" of the property was applied to eligible dwellings. In order to be considered for the cost separation procedure, the dwelling had to have:

1. construction forms available with data representing both interior and exterior/site treatments. For multi-unit buildings, these include data for the dwelling unit and the common areas;
2. all data on strategies accepted by the Evaluation team (based on a visual comparison of the strategies and the specifications conducted); and
3. total costs for the specifications meet the criteria of being within 20% or $200 (whichever is larger) of the total lead hazard control costs reported on Form 23 (Appendix A).

In brief[1], the cost separation procedure used the sketch and paint inspection report information to identify interior and exterior locations at each dwelling. Specifications in interior locations were considered interior treatments. Specifications in exterior locations were separated into site treatments and exterior building treatments, using the specification descriptions.

Specifications that did not apply to an individual treatment, but defined general requirements for the whole intervention were classified as general requirements. Because some grantees reported separate costs for the general requirements and others had already included these costs for each specification, a determination was made that general requirement costs needed to be incorporated into the cost of treatments at all dwellings to make the costs comparable. General requirement costs, when assigned an individual cost value, were proportionately distributed across the three "geographies".

For example, in a building where $5,000 was spent on interior treatments, $2,000 was spent on exterior treatments, $1,000 was spent on site treatments, and $2,000 was spent on general requirement costs, the general requirement costs would be allocated across the three "geographies" of the property. With $8,000 in treatment costs, 62.5% (5000/8000) of the $2000 general requirements costs would be allocated to interior treatments, 25% (2000/8000) to exterior treatments, and 12.5% (1000/8000) to soil/site treatments. For this building, the allocated costs would be calculated as $6,250 for interiors, $2,500 for exteriors, and $1,250 for site.

While specification costs from SpecMaster® were used to allocate costs to the three "geographies" at each property, the Evaluation team determined from field observations and discussions with spec writers that the total specification costs were not the most accurate value for total lead hazard control costs. The lead hazard control costs reported on Form 23 were judged to be a more accurate accounting of the lead hazard reduction costs because they were generally based on contractor invoices. Therefore, when the total of the specification costs was not the same as the total lead hazard control cost reported on Form 23, the total allocated costs were adjusted to equal the Form 23 lead hazard control costs. In the example above where the total specification costs for the building were $10,000, if the Form 23 lead hazard control costs were reported as $11,000, then each of the allocated costs would be adjusted upward by 10 percent. The adjusted values were the final costs used in this report.

The lead hazard control costs for each "geography" of the property are presented by the strategy level (intensity of treatment) applied to that "geography". For example, for interior treatment costs, the costs are presented for each interior strategy ranging from Interior Strategy 02

[1] A full description of the procedure is available with the data documentation for this study.

(cleaning and spot painting) to Interior Strategy 07 (full removal of all lead-based paint). The strategies are described in more detail in Section 5.2.1.

A variety of descriptive statistics are presented here. Both the arithmetic mean and the median cost of lead hazard interventions are reported by "geography". Because the lead hazard control cost data had a skewed distribution, the median cost is a better measure of the cost to treat an individual "average" dwelling. On the other hand, the arithmetic mean value provides a better measure of the average costs a program might encounter if it were treating numerous dwellings. To illustrate the wide variation in costs reported, the 5th and 95th percentiles of costs by "geography" are described in the text. When comparisons between strategies are made, the more commonly used measure of statistical variability is presented, the interquartile range (i.e., 25th and 75th percentiles). The costs were not adjusted for any factors including regional cost differences or inflation.

6.2.2 Interior Treatment Costs

A total of 2,332 dwelling units that met the three cost separation criteria had interior interventions conducted. The mean cost of interior work was $6,140 while the median cost was $5,960 (Table 6-1). The 5th and the 95th percentile costs were $410 and $11,690, respectively.

The broad range of interior lead hazard control costs can be largely explained by the wide variety of the treatment intensities represented by these costs. As expected, treatment costs tended to increase with the increase in treatment intensity. The median cost for interior work when cleaning and possibly some spot painting were conducted (Interior Strategy 02) was $430. As the level of intensity of the interior strategies increased, from full paint stabilization (Interior Strategy 03) through partial (04) and full window abatement (05) to full abatement (06), the median costs were $4,930, $6,120, $6,800, and $9,570, respectively.

Only Interior Strategy 07, full removal of lead-based paint, deviated from the trend of increasing cost with increasing treatment intensity. The median cost for the full removal of lead-based paint was $4,110. While this finding is counterintuitive, the results make sense when considered in the context of a lead hazard control program where grantees had control over the intensity of treatments that they applied. Grantees rarely set out to fully remove all lead-based paint from a dwelling, but when opportunities arose to achieve full removal that were not cost prohibitive, this strategy was selected. Often, there was only a limited amount of lead-based paint present in the dwelling so full removal was more moderately priced.

Although subdividing the interior costs by strategies reduced the variation, a fairly wide distribution of costs still exists within each strategy. The interquartile ranges overlapped for most of the most of the strategies (Figure 6-1). The coefficient of variation[2] was 44 percent or higher for all interior strategies except Strategy 06 (Table 6-1). For interior costs, the cost factors that might explain this variation were examined through statistical analysis. The methods of this analysis and discussion of the findings are presented in Section 6.3.

[2] The coefficient of variation (CV) is a measure of dispersion, which is calculated by dividing the standard deviation of a sample by its arithmetic mean. A higher CV indicates the results are more variable.

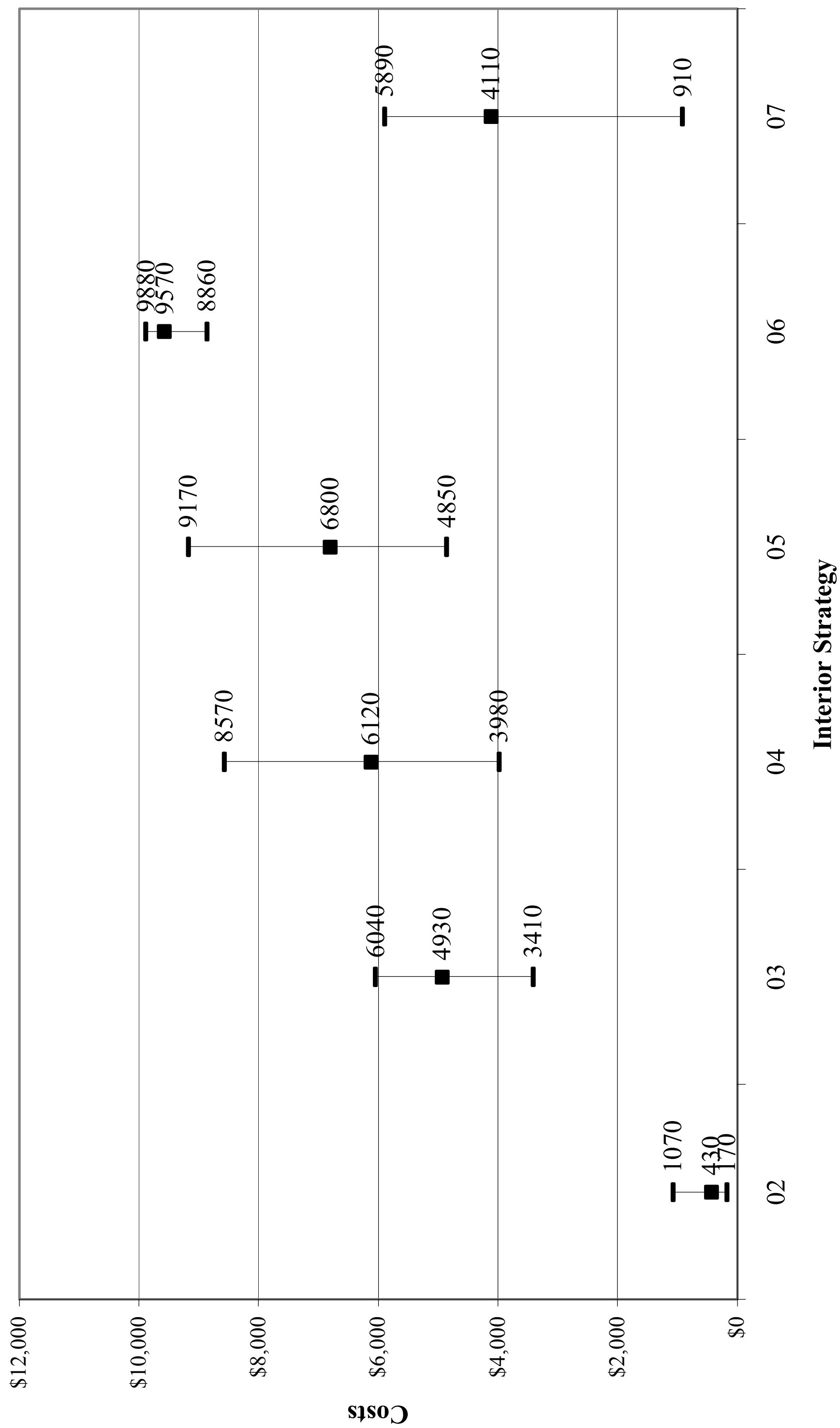
Table 6-1: Intervention Costs by "Geography" and Strategy

Strategy[1]		**Number of Dwelling Units Or Buildings**	**Lead Hazard Control Costs by "Geography"**				
			Mean	Coeff. Of Variation	5th %tile	Median	95th %tile
Interior	02	238 Dwellings	$730	108%	$60	$430	$2,200
	03	328 Dwellings	$4,730	44%	$1,170	$4,930	$7,960
	04	368 Dwellings	$6,370	52%	$1,880	$6,120	$11,740
	05	1,219 Dwellings	$7,150	46%	$2,740	$6,800	$12,680
	06	145 Dwellings	$9,510	16%	$8,290	$9,570	$9,950
	07	34 Dwellings	$4,410	83%	$880	$4,110	$10,570
	02-07	2,332 Dwellings	$6,140	59%	$410	$5,960	$11,690
Exterior	01	167 Buildings	$1,280	156%	$70	$600	$4,090
	02	554 Buildings	$3,040	123%	$330	$1,390	$11,010
	03	168 Buildings	$5,560	88%	$690	$4,260	$15,210
	04	121 Buildings	$9,400	50%	$3,020	$9,130	$17,320
	05	6 Buildings	$3,100	114%	$70	$1,860	$9,190
	01-05	1,016 Buildings	$3,930	115%	$250	$1,870	$13,080
Site	1	65 Buildings	$910	108%	$110	$560	$2,940
	2	56 Buildings	$1,810	209%	$120	$970	$3,860
	3	21 Buildings	$4,250	75%	$1,100	$2,700	$10,820
	4	15 Buildings	$6,620	83%	$1,200	$5,300	$19,020
	1-4	157 Buildings	$2,220	160%	$140	$1,080	$8,700

[1]**See Table 5-1 for Strategy Definitions**

Data from: Form 23 & SpecMaster
Data as of: June 1, 2000
Source of Data: UC Tables 401-I, 401-E, 401-S

Figure 6-1: Median and Interquartile Interior Lead Hazard Control Costs by Interior Strategy



The lack of variability within Interior Strategy 06 is largely due to the unique cost reporting system that was used for many of the dwellings that underwent this strategy. New York City conducted about 90 percent of the Interior Strategy 06 interventions. When New York City conducted these treatments, they were always done in conjunction with complete rehabilitation of the building that was paid for with other funding sources. The treatments were fairly homogeneous since the size and the scope of the work at each dwelling was quite similar. New York City set a cap of $10,000 to be spent on the removal and disposal of leaded components in the dwelling. The cost of replacing those leaded components as well as the cost of all other rehabilitation work was classified as concurrent work. Not surprisingly, contractors quickly learned of the $10,000 cap and prices for the lead removal were generally close to the cap. Lead hazard control costs for dwellings treated with full abatement in New York City were never above $10,000 and were rarely far below that value.

Costs for Interior Strategy 02 (cleaning/spot paint) were at the other extreme for variability; the coefficient of variation was 108 percent. The variation can be explained in part because the treatments and intervention designs were not homogeneous and were markedly different across grantees. Four grantees, Milwaukee, Vermont, Alameda County and Minnesota, conducted almost 90 percent of the Interior Strategy 02 interventions, with differing scopes of work, work requirements, and delivery mechanisms:

- *Milwaukee.* Milwaukee conducted approximately one-quarter of the lowest intensity interior strategies. Milwaukee's scope of treatments included cleaning only or cleaning supplemented by aluminum window wraps/caps on sills and troughs. City employees conducted these low level treatments. No special labor, insurance or warranty requirements were placed on these jobs, and Milwaukee did not consider the waste water generated from cleaning hazardous. Since the work was conducted by city employees, no profits or overhead were included in the costs reported. Costs were generally less than $100 per unit.

- *Vermont.* Vermont conducted approximately one-quarter of the Interior Strategy 02s. Vermont's scope of work was generally dictated by the state's Essential Maintenance Practices (EMP), which required spot paint stabilization, window trough caps, and cleaning (Vermont Act 165, 1996). Property owners conducted the work in their properties. Owners were required to carry their own insurance but were exempt from any hazardous waste requirements under the household exemption. Property owners were paid for their expenses but not a profit. Costs generally ranged from $400-500 per unit.

- *Alameda County.* Alameda County conducted approximately one-quarter of the Interior Strategy 02s. Alameda County's scope of work was the least standardized and at times the most intensive of the four major contributors. The treatments ranged from clean-only to spot paint stabilization with replacement of a few small leaded components. Work was conducted by private for-profit lead abatement contractors. The contractors were required to hold lead-specific insurance, warrant their work, and follow hazardous waste disposal regulations. Reported costs included the overhead and profit that the contractor charged the grantee. Costs generally ranged from $700-800 per unit.

- *Minnesota.* Minnesota conducted about 10 percent of the Interior Strategy 02s. The scope of work was solely clean-only. The work was completed by a private for-profit lead abatement contractor and was conducted at the Minneapolis subsite. The contractor, who did other lead hazard control work under this grant, was required to hold lead-specific insurance, post a performance bond, and pay Davis-Bacon wages. In addition, the State of Minnesota strictly interpreted hazardous waste regulations and expected that waste water and other materials generated would be treated accordingly. The prices for specific treatments were pre-negotiated as part of the bidding process, with cleaning costs established at $200 per room. Reported costs included the overhead and profit that the contractor charged the grantee. Costs generally ranged from $1,500-1,700 per unit.

The examples of these four grantees demonstrate that even when treatments are collapsed into a seemingly similar treatment group, there can be great variability in the design of a intervention that will influence the costs. The many unique features of the grantee programs posed challenges for generalizing the costs. Some of the factors that influence costs will be addressed in Section 6.3, but it was often difficult to separate factors that produced higher or lower costs. However, between the average costs presented above and these examples, one can get a sense of the programmatic costs for conducting lead hazard control to dwelling interiors.

6.2.3 Exterior Costs

Exterior interventions were performed on 1,016 buildings that met the three cost separation criteria. Another 262 buildings had no exterior treatments. The mean cost for exterior work on treated buildings was $3,930 while the median cost was $1,870 (Table 6-1). The 5th and the 95th percentile costs were $250 and $13,080, respectively.

Like interior costs, the exterior costs encompassed a broad range of treatments from minor paint stabilization to complete lead-based paint removal. As the levels of the Exterior Strategies increased, from partial paint stabilization (Exterior Strategy 01) through full paint stabilization (02) to partial abatement (03) and then full abatement (04), the median costs increased: $600, $1,390, $4,260, and $9,130, respectively.

The increasing trend of costs with increasing treatment intensity was broken when full removal of lead-based paint (Exterior Strategy 05) was conducted. The median costs were just $1,860 for this treatment. As with interior costs, this result is logical, since grantees chose this highest level of treatment only when the quantity of leaded surfaces to be removed was considered manageable and not cost prohibitive. In fact, only six buildings from three grantees underwent this level of treatment and met the cost analysis criteria.

Similar to interior strategies, the costs of exterior lead hazard control displayed a degree of variability within strategies. The coefficient of variation was 50 percent or above for all strategies. While exterior costs within a strategy were highly variable, the costs across strategies were more likely to differ from each other than interior strategies. Except for Exterior Strategy 02, the median costs of exterior strategies did not fall within the interquartile range of any adjacent strategy (Figure 6-2).

6.2.4 Site Costs

A limited number of properties had site or soil treatments. Of the 1,279 properties that were eligible for the cost analysis, 157 (12%) had site treatments. The mean cost for conducting site treatments at the treated properties was $2,220 while the median cost was $1,080 (Table 6-1). The 5^{th} and the 95^{th} percentile costs were $140 and $8,700, respectively.

Site Strategies 1 and 2 represent interim control treatments. The distinctions between these two strategies were not large, with both strategies generally including the installation of mulch and/or a ground cover such as seed or sod. Grantees tended to assign a higher-level strategy to properties where the area of treatment was larger, so it is appropriate that median costs for Site Strategy 2 were somewhat higher than Site Strategy 1 ($970 v. $560) although there was substantial overlap in the costs for each strategy.

Site Strategies 3 and 4 represent partial abatement treatments. Over 70 percent of these higher-level soil treatments were conducted in Alameda County so the observed costs may be less generalizable. The treatments included the full or partial removal of soil or the partial enclosure of soil with concrete, asphalt or brick, along with the installation of mulch and other ground covers. Like the lower level soil treatments, properties treated with a higher level strategy tended have to a larger surface area treated. Site Strategy 4 had a higher median cost than Site Strategy 3 ($5,300 v. $2,700), but the interquartile ranges for the two strategies were similar (Figure 6-3) and were indicative of the similarities between the two strategies.

6.2.5 Discussion

The results offer a picture of the costs that local programs and property owners might expect to pay contractors for the treatment of lead hazards and related housing rehabilitation and repair. The costs were reported by the "geography" of the property that was treated and by the intensity of treatments to those "geographies". The presentation of costs does not provide the total costs that would be incurred when conducting different levels of treatments to different "geographies" of a property. Combining the costs of the different treatment levels reported here would provide a fairly good estimate of the costs. For example, treating the interior with window replacement (05), the exterior with full paint stabilization (02) and conducting no site treatments would have a combined median cost of $8,190 and a combined mean cost of $10,190.

With a few exceptions, the categorization of lead hazard control work into "geographies" of the property and treatment intensities still left highly variable costs. The coefficient of variation was generally over 50% for each of the strategies examined. Some of this variation can be attributed to differences in the treatments applied within a strategy. An analysis of covariance of interior lead hazard control costs was conducted to examine other factors that might explain the variation. The description and results of this analysis is presented in the following section.

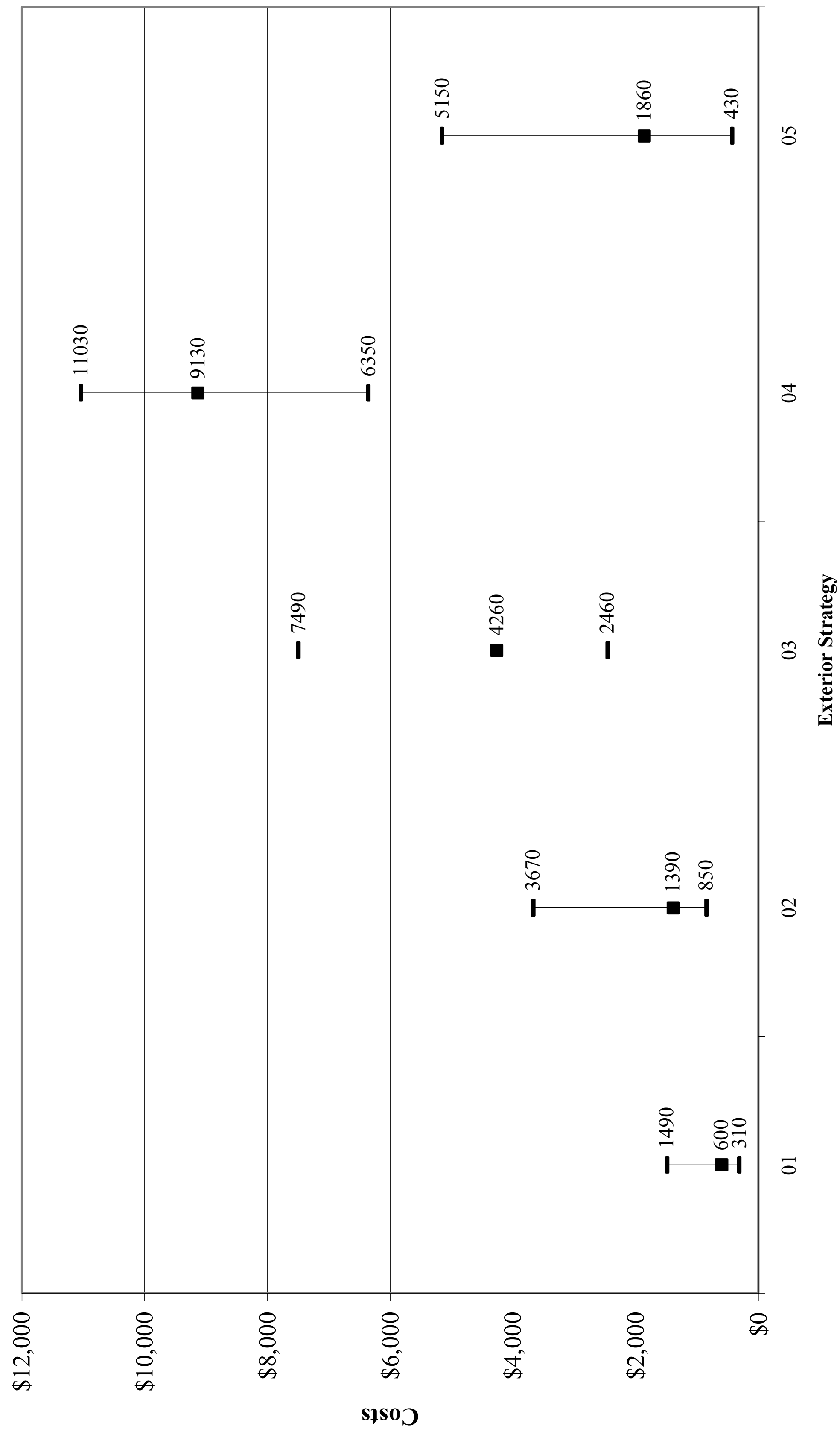
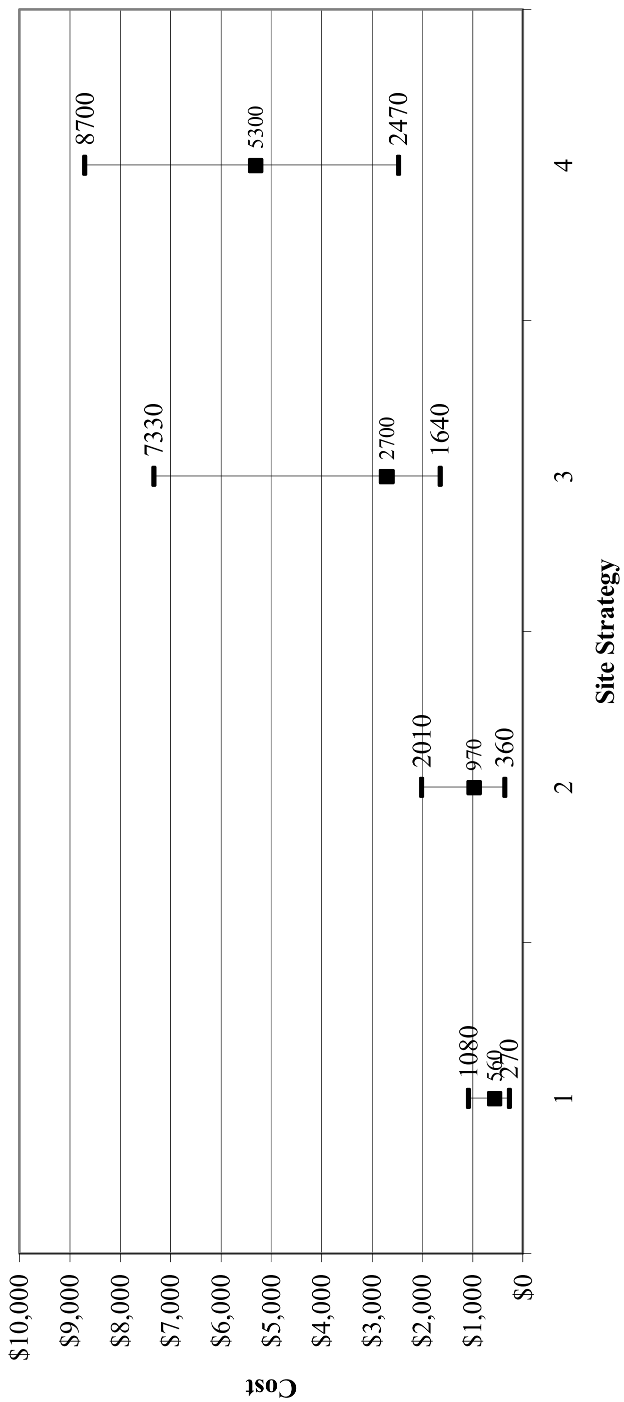


Figure 6-2: Median and Interquartile Exterior Lead Hazard Control Costs by Exterior Strategy

Figure 6-3: Median and Interquartile Site Lead Hazard Control Costs by Site Strategy



6.3 FACTORS CONTRIBUTING TO THE OBSERVED VARIATION IN INTERIOR COSTS

6.3.1 Methodology

An examination of factors that could explain the variation in interior lead hazard control costs at the dwelling unit level was conducted using multiple regression modeling. The analysis considered 19 variables believed to be possible influences on costs. The variables were categorized into six areas of interest: the intervention strategy, the pre-intervention building characteristics and condition, the occupancy status of the dwelling pre-intervention, the contractor's economies of scale, the general requirements placed on the contractor, and regional cost factors for general construction activities. The specific variables considered are listed in Table 6-2. The dependent variable of interior lead hazard control costs was log-transformed, as were the independent variable representing the square feet of living space and the three paint lead variables. Variables were considered significant at a p-value of 0.05.

A variable that was originally considered for the analysis to explain the variation in interior lead hazard control costs was the cost of concurrent work. However, it was determined that the cost of concurrent work was not independent of interior strategy, so it was dropped from the model. The cost of concurrent work is presented by strategy for each of the interior strategy levels in Table 6-3.

To be eligible for the analysis, a dwelling unit had to meet the requirements for cost separation described in Section 6.2.1. Based on analyses by the Evaluation team and ICF Consulting[3], a decision was also made to exclude the dwellings in New York City from the cost analysis. For many of the factors considered in the analysis, New York City displayed some of the most extreme values. New York City had the smallest dwellings, the most multi-unit buildings, the most dwellings with more than three stories, and the most dwellings treated by full abatement. Such extreme values created problems with confounding between variables. Furthermore, the use of alternative sources of funding in New York City resulted in a certain level of cost shifting between lead and non-lead cost categories. This made their reported lead hazard control costs somewhat less reliable. Excluding New York City, 1,223 dwellings were eligible for the analysis.

[3] ICF Consulting conducted an independent assessment of the Evaluation costs for HUD and reported that "The cost data for all grantees other than New York are much more consistent across strategy codes." ICF also excluded New York from its analysis. (Memo to HUD, August 8, 2000)

Table 6-2:Variables Examined in the Analysis of Interior Lead Hazard Control Cost

Intervention
- Interior Strategy

Pre-Intervention Building Characteristics
- Building Type (single-unit v. small multi-unit (2-4 units) v. large multi-unit)
- Entry Height in Stories
- Living Space (sq. ft.)*
- Number of Elements with Interior Building Deterioration*
- Presence of Roof Leak
- Presence of Plumbing Leak
- Percent Deteriorated Interior Lead-Based Paint (≥ 1 mg/cm^2 and poor condition)*
- Paint Lead on Interior Doors/Trim*Interior Strategy
- Paint Lead on Windows*Interior Strategy
- Paint Lead on Other Interior Surfaces*Interior Strategy

Occupancy Status

Contractor Effects
- Number of Units Treated by Each Contractor
- Number of Units in Building Treated by Contractor

General Requirements
- Insurance Requirements
- Waste Disposal Requirements*
- Performance Guarantee Required
- Wage Rate Required

Regional Cost Factors
- Regional Construction Labor Rates
- Regional Construction Materials Rates

*Interaction with Interior Strategy also tested

Table 6-3: Geometric Mean Interior Costs and Associated Concurrent Costs by Strategy

Strategy		Number of Units	Geometric Mean Interior Cost	Geometric Mean Concurrent Cost
Interior	02	194	$407	$1
	03	282	$4,056	$2
	04	341	$5,464	$104
	05	1,159	$6,400	$73
	06	122	$9,419	$29,357
	07	30	$3,097	$17,448

Data from: Form 23 & SpecMaster
Data as of: June 1, 2000
Source of Data: Descriptive Statistics from UC Cost Model (5/12/01)

6.3.2 Results

The median cost of interior lead hazard control and related housing rehabilitation for dwellings in this analysis was $5,635; or about $300 less than the median of the full data set. The 5th and the 95th percentile costs were $360 and $12,060, so the results remained highly variable. The model accounted for 77 percent of the variation in interior lead hazard control cost.

Six variables were identified as significant influences on the cost:

- the treatment intensity (interior strategy level),
- the size of the dwelling (in square feet),
- the type of building (single-unit v. multi-unit),
- the percentage of leaded interior paint in poor condition,
- the number of dwellings in the grant program treated by a contractor, and
- whether hazardous waste requirements were placed on the contractor.

6.3.3 Discussion of Findings

As discussed in Section 6.3.1, the variables in the models were categorized into five areas of interest: the intervention strategy, the pre-intervention building characteristics and condition, the pre-intervention occupancy status of the dwelling, the contractor's economies of scale, the general requirements placed on the contractor, and regional cost factors for general construction activities. For each of the six areas of interest, this section explores the influence of those sets of variables on intervention costs.

6.3.3.1 Intervention Strategy. The treatment intensity as defined by the interior strategy explained 65 percent of the variation in interior lead hazard control costs. When controlling for other factors, the trends of higher costs for higher intensity work described in Section 6.2 were supported by the analysis, with the exception that Strategy 06 and 07 were not significantly different in cost.

6.3.3.2 Pre-intervention Building Characteristics and Condition. The pre-intervention building characteristics, such as the size and configuration of the buildings, and the pre-intervention building condition such as the physical condition of the interior and exterior building components were examined. It was hypothesized that smaller dwellings would cost less to treat. It was also hypothesized that dwellings in better physical condition at pre-intervention would cost less to treat. The analysis provides evidence supporting both hypotheses.

Dwellings with more living space (measured in square footage) had significantly higher interior lead hazard control costs. The median dwelling in this analysis was reported to have a living area of 1,000 square feet. A dwelling with 800 square feet of living space (25^{th} percentile) was predicted to cost 10 percent less than the average unit, while a dwelling with 1,275 square feet of living space (75^{th} percentile) was predicted to cost 11 percent more than the average unit.

Forty-one percent of the dwellings were in single-unit buildings, while another 41 percent were in two- to four-unit buildings (small multi-unit) and the remaining units were in buildings with more than four units (large multi-unit). Homes in single-unit buildings were independently significantly higher in cost than those in multi-unit buildings. There was no significant difference in costs between small and large multi-unit buildings. Homes in single-unit buildings were predicted to cost 23 percent more than those in multi-unit buildings after controlling for dwelling unit square footage. These results appear reasonable because units in single-unit buildings had more windows and exterior doors than dwellings in multi-unit buildings.

While the number of building components with deterioration at pre-intervention was not found to significantly affect costs, dwellings with a higher percentage of painted surfaces with deteriorated lead-based paint (i.e., paint rated as in poor condition) had significantly higher interior lead hazard control costs. As might be expected, the higher the percentage of painted surfaces that needed to be treated, the more the lead hazard control activities cost, even after controlling for the interior strategy. In the median dwelling, seven percent of the painted surfaces tested had lead-based paint in poor condition. A dwelling at the 75^{th} percentile of paint condition, which had twice as much lead-based paint in poor condition (14%), was predicted to cost six percent more to treat.

6.3.3.3 Pre-intervention Occupancy Status of the Dwelling. It was hypothesized that dwelling units that were vacant prior to intervention could result in treatment cost savings. Contractors would not have to worry about possibly working around occupant belongings or dealing with the uncertainty of occupant relocation schedules. The occupancy status was not identified as a significant factor influencing interior lead hazard control costs. Contractors may not differentiate costs based on the occupancy status of the dwelling. It is also possible that because grantees often paid for the relocation of belongings (as well as families) from dwellings, the difference between treating occupied and vacant dwellings was not very great.

6.3.3.4 Contractor Economies of Scale. One of the hypotheses about costs was that when contractors were given the opportunity to treat more dwellings, either within a building or across a grantee, they would have economies of scale that could reduce prices. Conversely, the use of a single contractor by a grantee might indicate the lack of competition in a community that could drive up prices. The number of units within a building that a contractor treated was *not* a significant predictor of interior lead hazard control costs. However, the number of dwellings that a contractor treated for a grantee was found to be a significant predictor of cost; costs were lower when more units were treated.

For the median dwelling unit in this analysis, the dwelling was treated by a contractor who had treated a total of 41 other dwellings for that grantee. A dwelling at the 75^{th} percentile of number of dwellings treated by the contractor (85 other dwellings treated) was predicted to cost three percent less to treat, while a dwelling at the 25^{th} percentile (24 other dwellings treated) was predicted to cost one percent more to treat.

6.3.3.5 General Requirements Placed on the Contractor. The Evaluation tracked four of the general requirements that were placed on contractors. Those general requirements included: Insurance Requirements, Waste Disposal Requirements, Performance Bonding Requirements, and Wage Rate Requirements. It was hypothesized that as more or a higher level of requirements were placed on the contractor, the more the costs of treatments would rise.

Preliminary analyses of costs suggested that both insurance requirements and hazardous waste requirements added to the cost of interior lead hazard control costs. Further investigation of insurance requirements found that they were highly correlated with the treatments applied. The only grantees that imposed no insurance requirements on their contractors were Milwaukee when public employees conducted very low-level treatments and Wisconsin for a subset of their projects. When the effect of insurance requirements was examined separately for Wisconsin, it was not a significant factor in determining costs. In Milwaukee, the dwellings treated by very low-level treatments had no insurance requirements, but they also were treated by public employees with no profit and limited overhead, no hazardous waste requirements and no performance warranties. Insurance was dropped from the analysis because it was impossible from the data available to determine whether the lack of insurance requirements or some other element of this public sector program influenced its lower than expected costs.

A similar examination of effects of a hazardous waste requirement on costs was conducted. Overall, 75% of the dwellings in this analysis had hazardous waste requirements and eight of the grantees placed hazardous waste requirements on all of their interventions. The other five grantees in the analysis placed no hazardous waste requirements on at least a portion of the dwellings treated. The five grantees included Milwaukee and Wisconsin, which placed no hazardous waste requirements on any of their units. Every interior strategy except Interior Strategy 06 had some units where no hazardous waste requirements were placed on them. Enough contrasting data were available to suggest that a determination of the effect of hazardous waste requirements was feasible.

Interior lead hazard control costs were significantly higher when hazardous waste requirements were imposed. The magnitude of the effect varied significantly by the interior strategy. The cost difference of placing a hazardous waste requirement on Interior Strategy 03, 04 and 05 interventions was estimated to be 23%, 48%, and 31% greater, respectively, than when the requirement was not placed on the work. The magnitude of the effect was larger than expected and may be partially influenced by other factors related to the grantees. For example, if costs were lower in Milwaukee and Wisconsin because of other factors not controlled for in the models, these lower costs may be partially attributed to these grantees' choice of no waste requirements.

Comparisons between dwellings with and without hazardous waste requirements that were treated with Interior Strategy 02 were not conducted given the differing scopes of work, work requirements, and delivery mechanisms used by each grantee that performed this strategy (as described in Section 6.2.2). Because only 5 of the 30 dwellings treated with Interior Strategy 07 had hazardous waste requirements, comparisons for this strategy were also not made.

6.3.3.6 Regional Cost Factors for General Construction Activities. It was hypothesized that some of the cost variation identified could be attributed to the local economic conditions. Geographic regions of the country such as northern New Jersey where prices are above the national average were expected to have higher lead hazard control costs. To measure regional costs, estimates for the cost of construction labor and the cost of construction materials for each of the grantee sites were obtained. The source of the data was *R.S. Means Building Construction Cost Data 1997*(R.S. Means 1997), which reported a metropolitan 1996 *Means* Construction Cost Index for both labor and materials costs. The *Means* Labor Index sets a value of 100 for a community where construction labor costs were approximately the national average. A community where labor costs were 20 percent higher would receive a score of 120, while a community where labor costs were 20 percent lower would receive a score of 80. *R.S. Means* used a similar scale for the cost of construction materials. Both variables were considered in the analytical model.

Neither variable was a significant predictor of interior lead hazard control costs. While it is surprising that the local construction costs did not help explain costs, it may be that the index chosen was not appropriate. It is quite likely that lead hazard control costs did vary from community to community (see Section 6.4.3), but the variation did not correspond to differences in the local construction costs. For example, a lead-specific materials cost index might be more heavily weighted with window and paint costs and less weighted with lumber costs than a general construction cost index. Similarly, the construction labor market may be very different from the lead abatement worker market, because the former has few barriers to entry while the latter field requires special training and certification. A community with a fairly competitive construction market could still experience higher lead hazard control costs if there was a limited supply of lead abatement contractors/workers.

6.4 COSTS OF INDIVIDUAL LEAD HAZARD CONTROL TREATMENTS

As with lead hazard control activities, lead hazard control costs were collected at two different levels: overall costs for the dwelling unit and specific lead treatment costs. The presentation of the average costs for conducting interior, exterior and soil work found in Section 6.2 should prove helpful in understanding the general costs that can be expected when conducting different intensities of lead hazard control. However, as discussed above, these costs can vary widely based on the size and the condition of the dwelling. In order to estimate the cost of a specific intervention, spec writers needed to understand the costs of the specific lead treatments on a quantity treated basis (e.g., per square foot or per window). Furthermore, information about the costs of specific lead treatments allows for price comparisons between different treatments.

6.4.1 Methodology

At the specific lead treatment level, the SpecMaster® data reporting system was used to collect costs per treatment. For each room/location at a dwelling, the grantees reported the specifications conducted, the quantity of the treatment (e.g., 25 square feet), and the total cost of the treatments. To identify the cost per quantity, the total cost for each specification in a room was then divided by the total quantity of that treatment.

The specifications were organized into equivalent (cost) treatment categories[4] when the treatments and the costs of materials were determined to be similar. For example, grantees had four choices of materials for painting doors (acrylic, alkyd, urethane or other paint) and each material had its own unique specification. These four specifications were combined into one equivalent treatment because the costs of these materials were expected to be similar. When a specification was considered unique, the cost of the treatment was examined separately. For example, no other specification was similar to the specification for stripping paint from door sills.

The categorization of painting and sealant treatment costs posed a challenge to the evaluation team. As explained in Section 5.3.1, grantees used specifications for pure paint stabilization ("the process of wet scraping, priming and repainting surfaces coated with deteriorated lead-based paint") interchangeably with specifications for painting or sealing any surface. A decision was made to classify all painting and sealing as the stabilization of paint even if the evaluators did not have a specific report that the treatment included wet scraping or that the surface was coated with lead-based paint. Thus, the costs of paint stabilization refer to the costs for any painting activities conducted for lead purposes.

Sometimes grantees used a different measure of quantity treated for the same specification. For example, the stabilization of paint on trim was measured in linear feet and in square feet. When measures of quantity for a given specification differed, the costs per unit were treated as separate outcomes. The Evaluation team did not have enough information to convert differing measures of quantity to one standard measure so that the results could be combined.

The general procedure for recording the specification costs was to develop estimates for the costs for individual specifications and then adjust the estimates at each dwelling so that they approximated the contractor's total costs. The spec writers were to use their professional experience, and in some cases, guidance from the contractor, to estimate the costs for individual specifications. The total of the estimated specification costs was required to be within 20 percent or $200 (whichever was larger) of the total lead hazard control cost reported separately on Form 23. Dwellings where the costs did not meet this criterion were excluded from analysis. While this procedure was intended to improve the precision of the estimated costs, it must be recognized that the costs reported remain estimates of what the treatments cost.

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[4] These equivalent (cost) treatment categories treatments differ from the equivalent (effectiveness) treatment categories described in Section 5.3 because the latter categories include specifications that were not only expected have a similar cost but were expected to be of similar effectiveness (e.g., similar lead dust generation).

Some grantees reported the costs of general requirements separately while other grantees rolled the costs of these factors (e.g., insurance, waste, worksite preparation) into the treatment costs. To standardize the treatment costs across grantees, if general requirement costs were reported separately, these costs were first totaled for a building and then proportionally distributed by cost across all of the treatments.

Following preliminary analyses of the treatment costs per quantity treated, it became apparent that treatment costs varied from grantee to grantee. Some grantees had consistently higher costs; others had consistently lower costs, while other grantees had costs that were high for some treatment categories and low for others. Median costs for the grantee with the highest treatment costs were often three to four times higher than the median costs of the grantee with the lowest treatment costs. Consideration was given to adjusting costs by grantee, but the level of variation within some grantees made this adjustment difficult. Furthermore, even after collapsing the specifications into equivalent treatment categories, similar treatments were often conducted by only three or four grantees. The Evaluation team was concerned that with limited comparative data, any adjustments would introduce enough error that the final costs would not be reliable.

In order to address the concerns, the median treatment costs are presented by grantee. In addition, the maximum and minimum grantee median costs for each treatment are presented to offer an indication of the variation across grantees. To ensure that the costs are based on a reasonable sample of occurrences, a treatment had to be used in at least 25 room/locations by a grantee and had to be used by at least three grantees. Twenty-seven treatments met these criteria. In addition, when six or more grantees used a treatment at least 25 times, the median of the grantee costs is presented.

6.4.2 Results

The median treatment costs by grantee are presented in Table 6-4. The table includes three wall/ceiling treatments, three floor/stair treatments, four door treatments, seven window treatments and nine door treatments as well as an exterior treatment. No site treatments met the criteria for presentation.

6.4.2.1 Walls/Ceilings. The stabilization of paint on walls and ceilings was a treatment conducted by 13 of the 14 grantees. The enclosure of walls or ceilings with a drywall or laminate was also a commonly selected treatment with nine grantees conducting the treatment in at least 25 rooms. For both treatments, the most commonly used unit of treatment was square footage. For the nine grantees that conducted both enclosure and paint stabilization, the median cost of paint stabilization ranged from \$0.75 to \$1.83 per square foot, with a grantee median of \$1.45. The median cost of enclosure ranged from \$0.86 to \$3.50 per square foot, with a grantee median of \$2.01. In most cases, the cost of enclosure did not include the cost of finish painting, suggesting that additional costs would have to be incurred to bring the dwelling to a condition likely to satisfy residents. In Vermont, the paint stabilization treatment included only prepping and priming the surface. Non-lead contractors were used to repaint the whole room. Baltimore often had property owners complete the finish painting. These practices help explain the lower costs of paint stabilization for these two grantees.

A point of debate has been whether it is more cost effective to paint a limited area of a wall or ceiling, instead of a whole wall or a whole room. Anecdotally, some grantees reported that requiring spot paint stabilization was not a substantial cost savings because contractors charged more for a limited treatment. Six grantees reported costs for both full paint stabilization and limited paint stabilization. For two of these six grantees, the median cost per square foot of limited paint stabilization was less than full paint stabilization. When median costs of limited paint stabilization were higher than full paint stabilization, the costs for limited paint stabilization ranged from 2% to 200% more than full paint stabilization. The observed results do not definitively answer the question of the relative costs of full versus partial paint stabilization.

6.4.2.2 Floors/Stairs. Sufficient cost data were reported by six grantees that enclosed floors with underlayment and a vinyl covering. The median cost for this work ranged from $2.80 to $5.09 per square foot, with a grantee median cost of $3.23. Floor paint stabilization cost data were available from three grantees, with a range in median costs from $0.84 to $3.75 per square foot. Two grantees used both enclosure and paint stabilization of floors as separate treatments. For these grantees, floor enclosure cost was three to four times the cost of paint stabilization.

The stabilization of paint on stairs was conducted by four grantees in at least 25 of their stairways. Costs were reported per riser (or per step). The median cost ranged from $7.82 to $23.50 per riser.

6.4.2.3 Doors. Costs for the treatment of doors were reported on a per door basis. Replacement cost data were available from seven grantees that installed metal pre-hung exterior doors and from six grantees that installed wooden hollow-core interior doors. The median cost for exterior door replacement ranged from $200 to $705, with a grantee median of $581. The median cost for interior door replacement ranged from $86 to $212, with a grantee median of $174.

Vermont had a lower reported cost for exterior door replacement, partially the result of their two-phase method of lead hazard control. Lead abatement contractors were hired to remove doors, while non-lead contractors installed the new replacement doors. The price of $200 per door only included installation and did not include removal. Removal costs were reported to be approximately $25 per door.

Eight grantees applied a treatment in which interior doors were planed, adjusted (properly rehung), and stabilized in at least 25 rooms. The median cost for this treatment ranged from $64 to $140 per door, with a grantee median of $88. Eight grantees treated interior doors with just paint stabilization. The median cost for door paint stabilization ranged from only $29 to $180 per door, with a grantee median of $48. Five grantees reported costs for both paint stabilization/adjustment and paint stabilization only. For four of these grantees, the cost of paint stabilization and adjustment was more than paint stabilization only. The paint stabilization and adjustment treatments cost $15 to $48 more (12% to 125% more) per door. In Wisconsin, there was essentially no cost difference between the two treatments.

Five grantees reported costs for both paint stabilization and adjustment of interior doors and replacement of interior doors. The median cost of replacement was two to three times more than paint stabilization and adjustment at four of the grantee sites. In Rhode Island, the cost of replacement was lower, but by only 10%, which is not substantial given the method of estimation.

Table 6-4: Median Treatment Costs by Grantee: Treatments used at least 25 times by a grantee, by at least 3 grantees (Adjusted for General Requirement Costs)

Component System		Wall/Ceiling			Floor/Stair			Doors			
Treatment		Enclose Walls/Ceilings – Drywall	Stabilize Walls/Ceilings	Stabilize Walls/Ceilings –Limited Surface	Enclose Floors – Underlayment and Vinyl	**Stabilize Floors**	Stabilize Stairs	Replace Doors (Ext.) – Metal Pre-Hung	Replace Doors (Int.) – Wood Hollow-core	Stabilize Doors – Plane and Adjust	Stabilize Doors
UNIT		$/SF	$/SF	$/SF	$/SF	$/SF	$/RI	$/EA	$/EA	$/EA	$/EA
	AC	3.50	1.04							140.00	125.00
	BA	2.49	1.00		2.85				125.00	65.00	
	BO	2.35	1.51	2.67							
G	**CA**		1.65		3.25				162.00	85.10	37.70
R	**CH**	1.91	1.40					581.00	212.00		
A	**CL**	2.01	1.60		5.09	1.34					28.50
N	**MA**		2.45	2.09							48.20
T	**ML**	1.87	1.15				7.82			84.30	47.20
E	**MN**		7.10			3.75		700.00			180.00
E	**NJ**							705.00			
	NY	1.65	1.59	1.90	3.21		23.50	590.00	211.00	63.50	31.60
	RI		1.22	0.56	2.80	0.84		501.00	85.70	94.80	
	VT	0.86	0.75	0.77	3.35		17.00	200.00		90.00	
	WI	3.06	1.83	5.47			19.30	525.00	185.00	95.20	96.80
Grantee Min		0.86	0.75	0.56	2.80	0.84	7.82	200.00	85.70	63.50	28.50
Grantee Med.*		2.01	1.51	2.00	3.23	-	-	581.00	174.00	87.60	47.70
Grantee Max		3.50	7.10	5.47	5.09	3.75	23.5	705.00	212.00	140.00	180.00
Total # Uses		1786	4001	1630	1417	459	262	607	649	4206	1139

EA= Each, LF= Linear Feet, RI= Per Riser, SF=Square Feet

*Grantee Median only presented when six or more grantees qualified for table.

Data from: SpecMaster
Data as of: June 1, 2000
Source of Data: NCLSH Table C8

Table 6-4 (continued): Median Treatment Costs by Grantee:
Treatments used at least 25 times by a grantee, by at least 3 grantees
(Adjusted for General Requirement Costs)

	Component System	Trim								
	Treatment	Replace Trim – Historic Molding	Replace Trim – Modern Molding	Replace Door Sill	Strip Trim – Scrapers	Strip Door Sill	Stabilize Trim	Stabilize Trim – Limited Surface	Stabilize Radiator	Stabilize Cabinet
	UNIT	$/LF	$/LF	$/EA	$/LF	$/EA	$/LF	$/LF	$/EA	$/LF
	AC		5.60				6.01	8.48		
	BA		3.00	15.00		16.00	1.00		50.00	
	BO	5.07	2.24		1.32		1.77			
G	CA		2.38				2.05			
R	CH		2.29				2.66			
A	CL						1.64			
N	MA	4.14	2.54		1.29			1.26		
T	ML						2.15			28.60
E	MN						6.00			
E	NJ			37.30						
	NY		2.68				0.95		42.90	31.50
	RI		2.80			33.40	1.39	0.85	44.50	16.80
	VT	6.09	3.00	70.00	3.53	40.00	1.50			
	WI						3.36		142.00	
	Grantee Min	4.14	2.24	15.00	1.29	16.00	0.95	0.85	42.90	16.80
	Grantee Med.*	-	2.68	-	-	-	1.91	-	-	-
	Grantee Max	6.09	5.60	70.00	3.53	40.00	6.01	8.48	142.00	31.50
	Total # Uses	303	2046	92	191	654	6044	193	1153	211

EA= Each, LF= Linear Feet, RI= Per Riser, SF=Square Feet

*Grantee Median only presented when six or more grantees qualified for table.

Data from: SpecMaster
Data as of: June 1, 2000
Source of Data: NCLSH Table C8

Table 6-4 (continued): Median Treatment Costs by Grantee:
Treatments used at least 25 times by a grantee, by at least 3 grantees
(Adjusted for General Requirement Costs)

Component System		Windows							Exterior Clad/Trim
	Treatment	Replace Window - Wood	Replace Window – Vinyl	Replace Window – Aluminum	Replace Window – Sash Only	Install Window Jamb Liner	Stabilize Window & Enclose Trough	Stabilize Window	Stabilize Exterior Cladding/Trim
UNIT		$/EA	$/EA	$/EA	$/EA	$/EA	$/EA	$/EA	$/SF
	AC	563.00	500.00	246.00	238.00			115.00	2.68
	BA		285.00					30.00	1.36
	BO		241.00						3.80
G	**CA**			300.00				30.60	2.22
R	**CH**		507.00			104.00			
A	**CL**		220.00		162.00			38.10	
N	**MA**		261.00						1.25
T	**ML**		427.00			120.00		50.00	2.17
E	**MN**	372.00	320.00				149.00	145.00	
E	**NJ**		567.00						
	NY			316.00		84.30		24.70	
	RI	335.00	226.00				112.00	27.40	0.83
	VT	225.00	205.00		165.00			75.00	0.77
	WI	425.00	400.00				119.00	85.00	2.66
Grantee Min		225.00	205.00	246.00	162.00	84.30	112.00	24.70	0.77
Grantee Med.*		-	303.00	-	-	-	-	44.10	2.17
Grantee Max		563.00	567.00	316.00	238.00	120.00	149.00	145.00	3.80
Total # Uses		1139	5682	399	332	521	139	1911	729

EA= Each, LF= Linear Feet, RI= Per Riser, SF=Square Feet

*Grantee Median only presented when six or more grantees qualified for table.

Data from: SpecMaster
Data as of: June 1, 2000
Source of Data: NCLSH Table C8

6.4.2.4 Trim[5]. Nine grantees replaced trim (e.g., baseboards, casings, other molding) with modern molding. Three of these grantees also replaced some of their molding with historic stock. For all nine grantees, the median cost of replacement ranged from $2.24 to $5.60 per linear foot, with a grantee median of $2.68. The median cost of using historic molding was one and one half to two times the cost of modern molding at each of the three grantees that reported such costs.

The three grantees that used historic trim (Boston, Massachusetts and Vermont) also reported the use of scrapers to strip paint from trim in at least 25 rooms. The specifications for these treatments called for the trim to be primed and painted after replacement or stripping. While the median cost of replacing trim ranged from $4.14 to $6.09 for these three grantees, the median cost of removing the paint and leaving the trim in place ranged from $1.29 to $3.53 per linear foot. The median cost of replacement of trim with historic molding was about $2.50 to $3.50 per linear foot more than stripping.

Twelve of the fourteen grantees stabilized their trim as a common treatment. The median cost of paint stabilization ranged from $0.95 to $6.01 per linear foot, with a grantee median of $1.91. Eight of the grantees conducted both paint stabilization and replacement of trim separately. For six of these grantees, the median cost of replacement was higher than the median cost of paint stabilization, with replacement ranging from 16% to 200% more.

Three grantees used a specification for the stabilization of a limited amount of paint on the trim. Only two of these grantees, however, reported both full paint stabilization and limited paint stabilization of trim so a comparison of these costs is not very informative. Of the two grantees that conducted both treatments, limited paint stabilization cost more for one grantee and less for another.

Grantees also used specifications to identify the treatment to specific trim components. Three grantees replaced door sills and three grantees stripped door sills as common treatments. Baltimore and Vermont conducted both treatments. In Baltimore, the median costs were generally the same ($15 v. $16 per sill), while in Vermont the median cost of replacement was higher ($70 v. $40 per sill). Grantees also reported the cost of stabilizing paint on radiators and on cabinets. The range of median cost for the four grantees stabilizing radiators was $42 to $142 per radiator. The range of median cost for the three grantees stabilizing cabinets was $16.80 to $28.60 per linear foot of cabinetry.

6.4.2.5 Windows. Grantees commonly selected four types of window replacement: wood, vinyl, aluminum and sash only. The most common type of window selected was vinyl replacement, which was installed in at least 25 rooms for all grantees except California and New York City. The median cost of vinyl window replacement ranged from $205 to $567 per window, with a grantee median cost of $303. Five of the grantees also selected wood replacement windows for some of their dwellings. The cost of wood windows was universally higher, with a median cost that was 6% to 48% more.

As with door installation, Vermont's method of conducting lead hazard control made their cost values less comparable to the other grantees. Lead abatement contractors were hired to remove windows, while non-lead contractors installed the new replacement windows. The price of $205-

[5] Trim as defined here includes traditional trim work such as casings, baseboards and other moldings as well as other building components such as cabinetry, radiators and radiator covers that are often coated with trim paint.

225 per window did not include the price of removal. Removal costs were reported to be approximately $35 per window.

Three grantees (Alameda County, California and New York City) commonly used aluminum replacement windows. Because these windows were often used to replace windows in units of more modern construction or in larger multi-unit buildings, the window systems were not very comparable to the wood and vinyl windows discussed above. The aluminum windows were generally single-hung or slider windows, while the wood and vinyl windows were commonly double-hung windows. The median cost of the aluminum windows ranged from $246 to $316 per window.

Alameda County, Cleveland and Vermont selected the replacement of window sashes in at least 25 of the rooms that each grantee treated. The median cost of window sashes ranged from $162 to $238 per window. At all three sites, the cost of replacement of the sash only was 20% to 52% less than full replacement of vinyl windows. However, grantees that conducted sash only treatments may have incurred further costs to treat window components other than the sash.

Three grantees (Chicago, Milwaukee and New York City) selected the installation of jamb liners as a common window treatment. The median cost ranged from $84 to $120 per window. The installation of jamb liners was often accompanied by additional window work including paint stabilization and the use of aluminum caps on window sills and/or troughs. In Chicago and Milwaukee, where vinyl windows were also a common treatment, the cost of replacement was three to four times higher than the jamb liners. A treatment of stabilizing the whole window and enclosing the troughs with caps had a median cost of $112 to $149 per window for the three grantees that used this specification. Ten grantees used a full window paint stabilization specification in at least 25 of their rooms. The median cost ranged from $25 to $145 per window, with a grantee median of $44.

6.4.2.6 <u>Exterior Treatments.</u> Only one treatment to the exterior of the building or to the soil was reported by at least three grantees in at least 25 of the properties they treated. The paint stabilization of the exterior cladding and trim of the building was conducted by nine of the grantees. The median cost of this treatment ranged from $0.77 to $3.80 per square foot, with a grantee median cost of $2.17. The median cost of exterior paint stabilization was higher than interior wall and ceiling paint stabilization for six of the nine grantees, with one grantee having roughly equal costs and two grantees having lower exterior costs. As with interior paint stabilization costs, the exterior paint stabilization costs in Vermont were somewhat deflated because the treatment included only the cost of prepping and priming the surfaces.

6.4.3 Discussion

Table 6-4 provides an opportunity to examine costs by treatment and to make cross treatment comparisons. While the flexibility given to grantees in defining and revising their specifications places some limitations on the comparability of some data, particularly from Vermont, the specifications are similar enough that the values presented should prove useful.

The Evaluation team examined reported data and used field observations to try to explain cost differences. In Vermont, the lower costs were clearly attributable to the two-phased contracting system. In other sites, including Baltimore, Rhode Island, and New York, costs for finish work were sometimes shifted to a property owner or non-lead contractor paid by non-lead funds. The

Baltimore program made property owner contributions a requirement for participation in the program. Property owners in Rhode Island were often dissatisfied with the appearance of the limited paint stabilization conducted and paid the contractor extra for full repainting. Because of New York City's practice of coupling HUD LHC Grant funds with other funding sources, the full cost of the final painting is not always included in these estimates, because the cost of such work was paid for separately.

In many cases, however, the wide variation in costs across grantees could not be explained by specification differences or reporting differences. Prices were almost always higher in Alameda County, Minnesota and Wisconsin, and the Evaluation team did not observe any unique reporting practices that might explain these costs. These costs may simply reflect the higher costs for lead abatement in these communities during the period of the Evaluation.

6.5 Final Commentary on Lead Hazard Control Costs

The results presented here offer a large pool of empirical data on lead hazard control costs. Because of design issues, there were limits to what data was reported. The gathered information was limited to the costs of conducting construction-related activities and did not include costs for testing, relocation, construction oversight or other grantee-related costs. The costs represent the full costs of interior, exterior, and site lead hazard control. Incremental costs are not provided in this report. Because data were reported based on the intent of the grantee when applying the treatments, some variation in the costs from grantee to grantee was expected from the beginning because grantees interpreted cost allocation slightly differently. Finally, the data presented here are based on costs of interventions conducted between 1994 and 1997, so some adjustments in lead hazard control markets may have occurred since then.

While these limitations create barriers to identifying a single set of national cost values, the information presented here offers important cost data that have not been available. A property owner or lead poisoning prevention program should be able to better estimate their costs after giving some consideration to the local conditions that they face.

7.0 OBSERVED OUTCOMES IMMEDIATELY POST-INTERVENTION

7.1 INTRODUCTION TO IMMEDIATE POST-INTERVENTION PERIOD

At the conclusion of every lead hazard control intervention supported by the HUD Lead Hazard Control Grant Program, grantees are required to have a clearance examiner verify that the work was satisfactorily completed. This review process is referred to as *clearance*. The principles of clearance as described in the HUD Guidelines[1] (HUD 1995) are to determine if:

- The lead hazard control work was actually completed as specified.
- The area is safe for unprotected workers to enter.
- The area is a safe place for residents and young children to live.

Clearance examiners determine that clearance has been achieved in two steps. First, a visual examination of the worksite is conducted to determine that all specified work was completed, that lead-based paint hazards were satisfactorily controlled and that no visible settled dust or debris remains. If the dwelling passes the visual examination, the clearance examiner collects dust wipe samples from the floor and window in at least four rooms of the dwelling. When all dust samples from each surface have dust lead loadings at or below the clearance standards for that surface (defined either by HUD/EPA or by a more stringent state standard), then the dwelling unit passes clearance and the lead hazard control work is considered complete. Should the clearance examiner determine that the dwelling unit did not pass the visual examination or that any dust sample had a dust lead loading above the applicable standards, then the dwelling fails clearance. For dwelling units that fail clearance, grantees are required to have the work completed and/or be recleaned, so that they may be reexamined and eventually pass clearance.

This chapter provides details about the specific clearance procedures used by grantees in the HUD Lead Hazard Control Grant Program during the first two rounds of funding and the clearance data that were collected for the Evaluation. A key part of this discussion concerns the clearance dust lead standards that were in place at the time of the Evaluation, including the local standards under which some grantees were working. This chapter will examine the effects of lead hazard control interventions, as categorized by strategies, on initial clearance dust lead loadings and on the probability of failing initial clearance dust lead testing. An examination of the incidence of dwelling units failing to pass initial clearance tests was an original objective of the Evaluation.

This chapter also includes sections that describe the occupant protection procedures for resident families during the intervention through clearance. Because many lead hazard control activities generate substantial amounts of leaded dust and debris, HUD directed grantees at the outset of the program to take "appropriate action to protect occupants, especially young children and pregnant women, from lead hazards associated with lead hazard reduction activities." (HUD 1993) Occupant protection activities, including family relocation, are summarized based on information systematically collected from the families.

This section on occupant protection also includes an analysis of the factors associated with a rise in a child's blood lead level of 5 micrograms/deciliter (µg/dL) or more from pre-intervention to

[1] Clearance procedures described in the 1995 Guidelines differ somewhat from EPA and HUD regulations, but those regulations were not in effect when Evaluation clearance were being performed.

immediate post-intervention. HUD's emphasis on children being protected during the lead hazard control work prompted the Evaluation team and HUD to make the analysis of "significant" increases (≥ 5 µg/dL) of individual blood lead levels identified during immediate post-intervention, testing one of the nine original study objectives. Since inadequate occupant protection was just one factor that might have caused such blood lead elevations, HUD wanted to fully understand what factors were related to the increases and what, if anything, could be done to prevent them in the future. The analysis includes a discussion of the results of grantee feedback concerning each child whose blood lead level increased 5 µg/dL or more and an examination of factors that significantly differed between children who experienced such increases in blood lead levels and those who did not.

7.2 OCCUPANT PROTECTION POLICIES

HUD stipulated that grantees design interventions in a manner that would protect the occupants and prevent their exposure to lead that was made more available during the process of intervention. Previous research has indicated that large increases in blood lead can occur as a result of lead abatement activities unless special precautions are taken to keep the child away from the work area during intervention (Amitai 1987; Farfel 1990). Furthermore, a thorough cleaning of the work area must occur after the intervention but prior to reoccupancy in order to protect the occupants. Based on these findings, HUD offered guidance on occupant protection/relocation in order to protect residents during interventions and required clearance testing in order to protect residents at reoccupancy.

7.2.1 HUD Occupant Protection Policies under the HUD LHC Grant Program

HUD issued guidance that prohibited access by occupants to work areas or designated adjacent areas while lead hazard control activities were taking place (HUD 1993). The memo explicitly stated "occupants may not reoccupy a work area or adjacent area until post-lead hazard reduction clearance standards have been met." The guidance further stated that when work required more than eight hours to complete, families should, in general, be relocated from the dwelling. Grantees that did not relocate all families were required to prepare detailed descriptions of their occupant safety strategies. The only situations for which relocation was not required were when the lead hazard control activities:

- Did not disturb lead-based paint, and the intervention involved cleaning only;
- Were kept to a limited number of rooms so that occupants had access to bathroom, kitchen, sleeping facilities and adequate egress; dust and debris were properly contained within those rooms undergoing lead hazard control; and acceptable clearance results from work area samples were available prior to allowing reoccupancy; and/or
- Were limited to exterior treatments; windows and doorways within the work area were sealed; and occupants had adequate egress from the building that did not pass through the work area.

7.2.2 HUD Clearance Policies under the HUD LHC Grant Program

The original NOFA for the HUD Lead-Based Paint Hazard Control Grant Program (HUD 1992) stated that dwelling units "shall not be reoccupied until acceptable clearance levels are achieved." To achieve clearance, grantees were required to collect post-intervention dust wipe samples and have the levels of lead analyzed by an independent, accredited laboratory. At the start of the Grant Program, clearance thresholds were determined by the values listed in the *HUD Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing* (the HUD Interim Guidelines) (HUD 1990). At the time, a dwelling unit failed clearance if any one sample had lead levels above:

200 micrograms per square foot ($\mu g/ft^2$) on floors
500 $\mu g/ft^2$ on window sills, or
800 $\mu g/ft^2$ on window troughs (known then as window wells).

Because there were no applicable Federal standards in 1992, HUD incorporated Maryland and Massachusetts's standards into the HUD Interim Guidelines. When Title X was passed in October 1992, the EPA was given authority to promulgate regulations identifying lead-contaminated dust hazards, as well as paint and soil hazards. While no health-based standards were established for leaded dust during the period of data collection for the Evaluation, HUD and EPA released guidance in 1994 identifying revised clearance guidance for dust lead hazards. The revised guidance retained the previously identified 500 $\mu g/ft^2$ and 800 $\mu g/ft^2$ for window sills and window troughs, respectively, but lowered the threshold for floors to 100 $\mu g/ft^2$.

Because the Round One and Two NOFAs for the HUD LHC Grant Program had established 200 $\mu g/ft^2$ as the clearance threshold for floors, HUD left the decision whether to use the revised interim guidance of 100 $\mu g/ft^2$ to the grantees. Three grantees, Cleveland, New Jersey and New York City, chose to clear floors at the lower guidance level. The Minnesota grantee used its state regulatory standard of 80 $\mu g/ft^2$ for floors to clear dwelling units in Round One of the Grant Program. All other grantees retained 200 $\mu g/ft^2$ as the standard for floors.

In 2000, HUD promulgated regulations setting new interim clearance standards for all Federally-assisted housing. EPA published final clearance standards which took effect in January 2001 and which have been adopted by HUD (EPA 2001a). Those standards are:

40 $\mu g/ft^2$ on floors,
250 $\mu g/ft^2$ on window sills, and
400 $\mu g/ft^2$ on window troughs.

Under these standards, a dwelling fails clearance when any single dust lead sample result is equal to or above the appropriate standard[2]. While these levels are provided as a reference, it must be emphasized that these standards were not publicly available prior to the completion of all dwelling unit interventions in the Evaluation in October 1997, and were not used as clearance standards for any Evaluation units immediately post-intervention.

The clearance requirements for the Grant Program called for dust wipe testing on interior floors, window sills and window troughs (if present). The Grant Program recommended that grantees

[2] For risk assessment purposes, a floor or window sill is considered a hazard under these regulations when the *arithmetic mean* dust lead loading for a surface is above the appropriate standard.

follow the guidance found in the 1990 HUD Interim Guidelines, which called for one single-surface sample from each room treated if paint removal was not conducted and three single-surface samples from each room if paint removal was conducted. In 1995, HUD released the *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing* (HUD 1995), which revised the clearance recommendations to two dust samples (a floor and window surface) in at least four treated rooms. Grantees were allowed to comply with either guidance or with state or local standards, if more protective.

7.3 Treatment Effectiveness at Clearance

One of the principal objectives of the Evaluation (Objective 3) was an assessment of the clearance failure rates. The Evaluation designers were interested in the possible effects of the different treatment strategies on a contractor's ability to achieve clearance after construction work and final cleaning had been completed. The section describes analyses examining treatment effectiveness at clearance and the findings of these analyses. This section focuses on the initial clearance tests that were performed on the dwellings. All dwellings analyzed in this section passed clearance and had final clearance dust lead loadings that were at or below the standards observed by the grantees.

The Evaluation team hypothesized that the different interior lead hazard control strategies would primarily affect dust lead loadings at clearance in three ways:

- First, the work conducted under the different strategies was expected to generate different levels of lead dust. For example, a clean-only treatment should generate very little leaded dust, while an on-site paint removal project would likely generate much more leaded dust and debris.
- Second, the containment and cleaning practices associated with a strategy were expected to have different effects on reducing any pre-existing dust lead and any dust lead that was generated. For example, under the HUD Guidelines lower level strategies required lower levels of containment. At the same time, the effectiveness of cleaning/containment was also expected to be largely influenced by the contractors' experience and their compliance with the guidelines and each grantee's enforcement of the guidelines.
- Third, the treatments conducted as part of the different strategies were expected to have different impacts on the "cleanability" of surfaces. A clean-only treatment was not expected to improve the surface condition of components, while the replacement of a window or enclosure of a floor conducted as part of a higher-level strategy was expected to improve surface condition (and possibly change the type of surface).

The long-term benefits of a higher-level strategy, such as the reduction of leaded sources in a dwelling, was not expected to be apparent at clearance. In fact, if substantial amounts of leaded dust were generated by a higher level strategy and the dust was not well contained, then a higher-level strategy may not perform as well as lower level strategies at clearance given similar pre-intervention conditions.

7.3.1 Methodology

A fundamental part of the Evaluation was the use of a standard protocol for collecting dust lead samples at all data collection phases. The Evaluation protocols called for dust sampling to be conducted in the interior entry to the dwelling, a living area (or child's play area), the kitchen, and the two youngest children's bedrooms[3] during each phase of the study. The protocols called for the collection of floor samples in all of these areas and a window sill or window trough sample in rooms other than the entry (as described in Section 3.1). Regardless of the procedures used by grantees to select clearance sampling locations to meet programmatic requirements, the Evaluation protocols required that clearance dust sampling include single-surface samples from the alternate side of the doorways and windows that were tested pre-intervention.

While grantees recorded and data-entered all clearance dust lead results for the dwelling units they tested, the Evaluation team determined that only the minimum Evaluation dust samples (as required to be reported on the first page of the dust collection form) would be used for analyses of clearance results. Because some grantees collected only the minimum number of samples at clearance and other grantees collected many additional samples, comparisons of failure rates would be biased if all samples were included in these analyses. The basic principles of probability would result in dwelling units having a higher chance of having one sample above the clearance standards (and fail clearance) if more clearance samples were collected.

In order to compare clearance failure rates across treatment strategies (or any other factor), the Evaluation team adopted a single set of dust lead comparison values for all dwellings: 100 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window troughs. Although a floor standard of 200 $\mu g/ft^2$ was most commonly used by grantees in the Evaluation, 100 $\mu g/ft^2$ was selected because it was the Federal guidance level at the time when most Evaluation interventions were conducted and at the point when the final analysis plan for this report was developed. Furthermore, an analysis of initial clearance "failure rates" by grantee determined that the grantee's choice of a floor clearance standard of either 100 or 200 $\mu g/ft^2$ did not affect the probability of failure at 100 $\mu g/ft^2$.

Clearance findings are presented at two levels: overall findings about the initial clearance failure rates and analyses of the effect of treatment strategies on clearance dust lead loadings. The overall findings are presented as tabled results of clearance failure rates by grantee. For a dwelling unit to be included in these tables, grantees had to provide evidence that the dwelling unit had achieved clearance.

Two methods of statistical modeling were used to examine variables influencing immediate post-intervention dust lead loadings. Nested and logistic regression models were fit to the clearance dust data to determine predictors of clearance dust lead loadings. For these analyses, entry floor, bare floor, all floor, window sills and window troughs were separately modeled. Nested models used the dust lead loading values of each individual dust lead sample in a dwelling as the outcome. Logistic regression was used to model the probability of failure of the appropriate HUD/EPA guidance: 100 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window troughs. Each dwelling was classified as passing or failing clearance based on the maximum dust lead loading (for each surface type) in the dwelling.

Exhibit 7-1 at the end of this chapter presents the possible predictors that were examined in the statistical models. Backward elimination of the possible predictors in each model was performed; the interior strategy was retained in all models regardless of statistical significance to allow for a

[3] In dwelling units with only one child's bedroom, then just the one bedroom was sampled. If no child was present, then the smallest bedrooms were sampled.

test of its potential effects in the final, reduced models. The SAS procedures, PROC MIXED and PROC GENMOD (with a logit link), were used to run the nested and logistic models, respectively. All lead variables (i.e., dust and paint) were transformed to their natural logarithm to normalize their statistical distributions.

7.3.2 Initial Clearance Failures

This report focuses on the 2,682 dwelling units that had data available to demonstrate that the dwelling unit passed clearance. Of these dwellings, 526 dwellings (20%)[4] did not pass clearance on the first attempt based on the grantee-specified clearance standards described in Section 7.2.2. An additional 39 dwellings were retested by grantees at clearance indicating that the grantees may have identified additional hazards outside of those reported for Evaluation purposes. When these additional failures are included, 21 percent of units that eventually passed clearance failed the initial clearance dust tests.

For the 565 dwelling units that were retested, an average of 1.13 recleanings and retests were required per dwelling to pass clearance. The vast majority of the dwellings that were retested passed clearance after just one additional cleaning. The number of retests needed was not related to the interior strategy that was applied.

Using a universal floor comparison value of 100 $\mu g/ft^2$, 701 dwellings (26%) would have failed the initial clearance test. Even using a universal value, the initial clearance failure rates varied by grantee, with failure rates above 40 percent in Boston (56%), Milwaukee (47%) and Massachusetts (46%) and at or below 10 percent in New York City (10%), Rhode Island (9%) and New Jersey (0%) (Table 7-1). Initial clearance failure rates also varied by surface type sampled. Twenty percent of the dwelling units had at least one floor sample above 100 $\mu g/ft^2$. Window sills and troughs failed at lower rates: 6% and 7%, respectively (Table 7-2).

The number of surfaces tested for each surface type can explain, in part, the difference in failure rates. On average, five floor samples, two window sill samples, and one window trough sample were collected from each dwelling. The higher rate of failures on floors can be explained in part because the chance of finding one failure out of five samples is greater than the probability of finding a failure from one or two samples.

The clearance failure rates for specific surfaces also varied by grantee (Table 7-2). Thirty percent or more of the dwellings had at least one initial floor dust lead clearance sample above 100 $\mu g/ft^2$ in Boston (56%), Massachusetts (42%), and Milwaukee (30%). Less than 10 percent of the dwellings had at least one initial floor dust lead clearance sample above 100 $\mu g/ft^2$ in California (9%), Rhode Island (8%), New York City (4%) and New Jersey (0%). Two grantees had initial clearance failure rates above 10 percent on both window sills and window troughs: Milwaukee (13% and 18%, respectively) and Minnesota (11% and 12%, respectively). Rhode Island (1%) and New Jersey (0%) had initial clearance failure rates of one percent or less on both window sills and troughs.

[4] When all dwellings with an Evaluation clearance dust test are considered, including those with no evidence of final clearance, 24 percent of the dwellings (686 of 2,842) failed the initial clearance.

Table 7-1: Number and Percentage of Dwellings with Initial Post-Intervention Dust Lead Loadings Above 1995 HUD/EPA Clearance Guidance Levels[a] - by Grantee (Initial Clearance Failures)

Grantee	Number of of Dwellings Tested	Number of Dwellings with Failuresb	Percentage of Dwellings with Failures[b]
Alameda County	167	52	31%
Baltimore	393	124	32%
Boston	68	38	56%
California	103	17	17%
Chicago	120	38	32%
Cleveland	152	47	31%
Massachusetts	134	61	46%
Milwaukee	223	104	47%
Minnesota	143	45	31%
New Jersey	27	0	0%
New York City	420	43	10%
Rhode Island	160	15	9%
Vermont	391	80	20%
Wisconsin	181	37	20%
All Grantees	2,682	701	26%

aThe 1995 HUD/EPA Clearance Guidance Levels of 100 ug/ft2 -floors; 500 ug/ft2 -window sills; and 800 ug/ft2 -window troughs were used as comparison values, regardless of clearance standards used by a specific grantee.

bA single failure of any component (floor, window sill, or window trough) constitutes a dwelling unit failure

Data from: Form 19.
Data as of: June 1, 2000
Source of Data: UC Table 80-I

Table 7-2: Number and Percentage of Dwellings with Initial Post-Intervention Dust Lead Loadings Above 1995 HUD/EPA Clearance Guidance Levels[a] - by Grantee and Sample Type (Initial Clearance Failures)

Grantee	Floor		Window Sill		Window Trough	
	Number of dwellings tested	Dwellings with Initial failures[b] (%)	Number of dwellings tested	Dwellings with Initial failures[b] (%)	Number of dwellings tested	Dwellings with Initial failures[b] (%)
Alameda County	167	25%	167	15%	110	5%
Baltimore	392	27%	390	2%	387	5%
Boston	68	56%	68	6%	67	7%
California	103	9%	93	4%	47	6%
Chicago	120	28%	117	8%	111	5%
Cleveland	152	24%	152	9%	127	9%
Massachusetts	134	42%	134	10%	133	7%
Milwaukee	223	30%	223	13%	219	18%
Minnesota	143	21%	141	11%	135	12%
New Jersey	27	0%	25	0%	20	0%
New York City	420	4%	415	1%	380	8%
Rhode Island	160	8%	159	1%	158	1%
Vermont	391	15%	384	4%	324	6%
Wisconsin	179	16%	172	3%	168	5%
All Grantees	2679	20%	2640	6%	2386	7%

aThe 1995 HUD/EPA Clearance Guidance Levels of 100 ug/ft2 -floors; 500 ug/ft2 -window sills; and 800 ug/ft2 -window troughs were used as comparison values, regardless of clearance standards used by a specific grantee

bA single failure of a floor, window sill, or window trough wipe constitutes a dwelling unit failure for that component

Data from: Form 19.
Data as of: June 1, 2000
Source of Data: UC Table 081 & 082.

The findings suggest that the likelihood of failing clearance on the initial attempt was partially influenced by factors related to the grantee. For example, across surfaces, Milwaukee's dwellings were among those most likely to fail initial clearance dust tests, while Rhode Island's dwellings were among those most likely to pass initial clearance dust tests. However, while failure rates for a grantee tended to be consistently high or consistently low across surfaces, there were some variations. Boston and Massachusetts had floor clearance failure rates that were more than twice the Evaluation average for floors, but their window sill and trough failure rates were close to the Evaluation averages. Conversely, Minnesota's floor clearance failure rate was approximately equal to the Evaluation average for floors, but its window sill and trough rates were nearly double the Evaluation averages. Alameda County's window sill failure rates were almost three times the Evaluation average for sills, while its failure rates on other surfaces are close to the Evaluation average. New York City's floor and window sill clearance failure rates were one-fifth of their respective Evaluation averages, yet this grantee's window trough levels were close to the Evaluation average.

Because the relative rates of failure were not always consistent across surfaces for a grantee, it does not necessarily follow that a broad grantee-related factor such as contractor experience or grantee oversight was a cause for the grantee-by-grantee variation. Other factors such as the choices of treatments conducted or the local housing conditions are likely candidates to explain the variation across grantees. The following sections explore the factors that were associated with initial clearance failures and initial clearance dust lead loadings.

7.3.2.1 Results of Statistical Modeling: Clearance Failures. Five statistical analyses were developed exploring the factors that significantly affected the initial clearance dust lead failure rates. The analyses produced models that separately examined the factors influencing failure rates on 1) interior entry floors, 2) bare floors, 3) all floors, 4) window sills and 5) window troughs. The results presented here focus on the latter three models. The first two models offer additional insights into why dust lead loadings on floors failed.

Failure rates for floors were calculated using 100 $\mu g/ft^2$ as a uniform threshold in order to avoid introducing grantee bias.

7.3.2.1.1 Floors

Factors that statistically significantly influenced floor clearance dust lead failures across the three floor analyses were:

Pre-intervention dust lead loadings log-transformed (lower levels yielded fewer failures)
Pre-intervention paint lead loadings log-transformed (lower levels yielded fewer failures)
Occupancy status-pre-intervention (vacant dwellings yielded fewer failures)
Entry Height (dwellings on higher stories of building yielded fewer failures)

In addition to these factors, the interior lead hazard control strategy[5] had a significant effect on clearance failure rates for all floors and bare floors. These effects are described below. The treatment of exterior soil was significantly related to clearance failure rates on all floors and bare floors, with site treatments associated with lower clearance failure rates. However, neither

[5] See Table 7-3 for strategy definitions. See Section 5.2 for a more detailed description of dwelling unit interventions.

interior lead hazard control strategy nor site treatment was significantly related to failure rates on entry floors, after controlling for other factors.

After controlling for factors listed above as well as the number of dwellings treated by the contractor, dwellings treated with lower level interior strategies were more likely to clear on the initial attempt than those treated with higher level interior strategies. At clearance, the failure rate on floors in dwelling units treated with Interior Strategy 02 or 03 was significantly different (lower) from those in dwellings units treated with Interior Strategies 04 and 05, when controlling for other factors (Table 7-4). Table 7-5 presents the actual failure rates for the dwellings in the all floors model. Initial clearance failure rates were more than twice as high when Interior Strategies 04 or 05 were conducted than when Interior Strategies 02 or 03 were conducted.

Table 7-3: Interior Strategy Code Definitions

Strategy		Definition
Interior	01	No Action
	02	Cleaning, Spot Paint Stabilization Only
	03	Level 02 plus Complete Paint Stabilization, Floor Treatments
	04	Level 03 plus Window Treatments
	05	Level 04 plus Window Replacement, Wall Enclosure/Encapsulation
	06	All Lead-Based Paint Enclosed, Encapsulated, or Removed (Meets Public Housing Abatement Standards)
	07	All Lead-Based Paint Removed

Glossary of Treatments

Encapsulation - The application of a covering or coating that acts as a barrier between lead-based paint and the environment, the durability of which relies on adhesion and which has an expected life of at least 20 years.

Enclosure - The application of rigid, durable construction materials that are mechanically fastened to the substrate to act as a barrier between lead-based paint and the environment.

Paint Stabilization - The process of repainting surfaces coated with lead-based paint, which includes the proper removal of deteriorated paint and priming.

Paint Removal - The complete removal of lead-based paint by wet scraping, chemical stripping, or contained abrasives.

Removal/Replacement - The removal/replacement of a building component that was coated with lead-based paint.

Window Treatments - The process of eliminating lead-containing surfaces on windows that is subject to friction or impact through the removal of paint or enclosure of certain window components.

Table 7-4: Predicted Odds Ratios of a Clearance Failure[a] on All Floors[b] by Interior Strategy

Interior Strategy	Odds Ratio of Dwellings treated with Interior Strategies Listed Below Failing Clearance Compared to Interior Strategies at Left				
	02	03	04	05	06/07
02		1.47	2.36**	2.20**	1.96*
03			1.61**	1.50**	1.34
04				0.93	0.83
05					0.89

[a]The 1995 HUD/EPA Clearance Guidance Level of 100 µg/ft^2 –floors was used as a comparison value regardless of the clearance standard used by a specific grantee.
[b]All floors include entry and interior floor samples.
**: Statistically Significant ($p<0.05$)

Data from: Form 19
Data as of: June 1, 2000
Source of Data: Model Results Associated with Clearance Models
(Outcome: Clearance failure)

Table 7-5: Number and Percent of Dwellings with Initial Post-Intervention Dust Lead Loadings Above 1995 HUD/EPA Clearance Guidance Levels[a] by Interior Strategy and Sample Type (Initial Clearance Failures)

Interior Strategy	All Floors[b]		Window Sills		Window Troughs	
	Number of Dwellings Tested	Percent Failures (>100 µg/ft^2)	Number of Dwellings Tested	Percent Failures (>500 µg/ft^2)	Number of Dwellings Tested	Percent Failures (>800 µg/ft^2)
02	218	11%	214	10%	190	12%
03	336	13%	335	8%	305	8%
04	422	24%	419	8%	402	10%
05	1,436	23%	1,414	4%	1,252	5%
06/07	185	11%	178	1%	169	10%
All	2,597	20%	2,560	6%	2,318	7%

[a]The 1995 HUD/EPA Clearance Guidance Levels of 100 µg/ft^2 –floors; 500 µg/ft^2 –window sills; and 800 µg/ft^2 –window troughs were used as comparison values regardless of the clearance standards used by a specific grantee.
[b]All floors include entry and interior floor samples.

Data from: Form 19
Data as of: June 1, 2000
Source of Data: Descriptive Statistics from Logistic Models

The effect of strategies on *bare interior floor* clearance failure rates was similar to all floors. Failure rates on *entry floors* were *not* significantly related to Interior Strategy. The findings of these analyses suggest that the effect of strategies on floor failure rates differ for entry and non-entry floors.

7.3.2.1.2 Window Sills and Troughs

Factors that influenced clearance dust lead failures on window sills and troughs were:

> Pre-intervention dust lead loadings log-transformed (lower levels yielded fewer failures)
> Date of Sampling (March-April samples yielded most failures
> /September-October samples yielded fewest failures)
> Interior Strategy (effects described below)

Other factors associated with window sill clearance dust lead failures were (direction of relationship in parentheses): number of samples collected (+), window paint lead levels (+), occupancy (+), number of stories from entry (-). Other factors associated with window trough clearance failures were: door/trim paint lead levels (+) and number of dwellings treated by contractor (-).

Table 7-5 presents the actual failure rates for the dwellings in the window sill and window trough models. The analysis of initial clearance failures on window sills and troughs identified a significant statistical effect of interior lead hazard control strategy on the probability of failure. Window *sills* in dwelling units treated with Interior Strategy 05 and 06/07 tended to have lower clearance failure rates than other Interior Strategies when controlling for other factors (Table 7-6). The effect of interior interventions on window *trough* failure rates interacted with the pre-intervention trough dust lead loadings. Dwelling units treated with Interior Strategy 05 tended to have significantly different (lower) window trough failure rates than units treated with other interior interventions across the range of pre-intervention trough dust lead loadings. The failure rate on window *troughs* in dwelling units treated with Interior Strategy 02 tended to be significantly different (higher) from those in dwellings units treated with other interior strategies when pre-intervention dust lead loadings were high (e.g., at the 75th percentile). Table 7-6 presents the odds ratios and results of the tests of significance contrasting Interior Strategies, for low, medium and high pre-intervention trough dust lead loadings (25th, Median and 75th percentile, respectively). As pre-intervention trough dust lead loadings increase, dwellings treated with Interior Strategy 02 were predicted to have more clearance failures when compared to other Interior Strategies. All other odds ratios were relatively stable across the range of pre-intervention trough dust lead loadings.

7.3.2.2 Results of Modeling: Clearance Dust Lead Loadings. Although the results of clearance testing generally focus on whether a household passes the clearance testing, an equally important element of the results is an assessment of the treatments/cleaning practices' ability to reduce the dust lead loadings to levels as low as possible. A second set of five analytical models (i.e., all floors, entry floors, bare interior floors, window sills and window troughs) considered the factors influencing the initial clearance dust lead *levels.* The findings primarily focus on three of the models: all floors, window sills and window troughs. The dependent variable in the models was dust lead loading on a given sample type (e.g. all floors) as measured by *individual* dust samples. The factors influencing dust lead loadings were consistent with the factors identified in the models of clearance failures.

Table 7-6: Predicted Odds Ratios of a Clearance Failure[a] on Window Sills and Troughs by Interior Strategy (with contrast results)

Interior Strategies Contrasted	Window Sills	Window Troughs By Pre-Intervention Dust Lead Loading		
		756 µg/ft²	Median: 5,014 µg/ft²	28,567 µg/ft²
02 v.03	0.84 p=0.606	0.75 p=0.536	1.68 p=0.161	3.56 p=0.003**
02 v.04	1.28 p=0.443	0.79 p=0.624	1.49 p=0.242	2.69 p=0.003**
02 v. 05	2.24 p=0.008**	1.55 p=0.344	3.41 p<0.001**	7.08 p<0.001**
02 v. 06/07	5.95 p=0.033**	0.47 p=0.185	1.06 p=0.897	2.23 p=0.099*
03 v. 04	1.52 p=0.181	1.05 p=0.903	0.89 p=0.707	0.76 p=0.479
05 v. 02	0.45 p=0.008**	0.65 p=0.344	0.29 p<0.001**	0.14 p=0.003**
05 v. 03	0.37 p<0.001**	0.48 p<0.032**	0.49 p<0.022**	0.50 p<0.095*
05 v. 04	0.57 p=0.023**	0.51 p=0.069*	0.44 p=0.002*	0.38 p<0.001**
05 v. 06/07	2.66 p=0.272	0.30 p=0.017**	0.31 p=0.003**	0.31 p=0.015**
06/07 v. 02	0.17 p=0.033**	2.12 p=0.185	0.95 p=0.897	0.45 p=0.099*
06/07 v. 03	0.14 p=0.015**	1.59 p=0.350	1.59 p=0.270	1.60 p=0.384
06/07 v. 04	0.21 p=0.067*	1.67 p=0.319	1.41 p=0.383	1.21 p=0.672
06/07 v. 05	0.38 p=0.272	3.28 p=0.017**	3.23 p=0.003**	3.18 p=0.015**

[a]The 1995 HUD/EPA Clearance Guidance Levels of 500 µg/ft² –window sills and 800 µg/ft² –window troughs were used as clearance standards by all grantees.
**: Statistically Significant (p<0.05); *: Marginally Significant (p<0.10)

Data from: Form 19
Data as of: June 1, 2000
Source of Data: Model Results Associated with Clearance Models
(Outcome: Clearance Failure)

Factors associated with clearance dust lead loadings in the three main models were:

Pre-intervention dust lead loadings log-trans. (lower levels yielded less dust lead at clr.)
Pre-intervention paint lead loadings log-trans. (lower levels yielded less dust lead at clr.)
Damage caused by a plumbing leak pre-intervention (yielded more dust lead at clr.)
Interior Strategy (effects described below)

The sample's surface condition pre-intervention and the pre-intervention occupancy status of the dwelling were also significant factors in at least two of the three models. Surfaces in poorer condition were likely to have higher floor and window trough dust lead loadings at clearance, while occupied dwellings were likely to have higher floor and window sill dust lead loadings when controlling for other factors including pre-intervention dust lead loadings (Further interpretation of this latter finding is presented in Section 7.3.3.2).

The completion of lead hazard control work on the site was associated with significantly different (lower) clearance window trough dust lead loadings. Exterior lead hazard control work was also associated with clearance dust lead loadings on entry floors, window sills and window troughs when exterior paint lead loadings were taken into consideration. As exterior paint lead levels increased in buildings where the exterior was treated, initial clearance dust lead loadings were significantly different (higher). Compared with dwellings without exterior treatments, exterior work was associated with larger declines in window dust lead loadings from pre-intervention to clearance only in buildings with lower exterior paint levels (i.e., < 1.9 mg/cm^2). On entry floors, exterior work was associated with *smaller* declines of dust lead loadings from pre-intervention to clearance in buildings with higher exterior paint levels (i.e., >3.0 mg/cm^2). Although such findings may simply be artifacts of the close interrelationships between pre-intervention environmental lead levels, interior strategies and exterior work, the findings support future studies of exterior containment efficacy.

7.3.2.2.1 Effect of Interior Strategy

The descriptive statistics for dust lead loadings by Interior Strategy are presented on Table 7-7. Across the all floor, window sill and window trough models, interior lead hazard control strategy was a significant factor influencing the immediate post-intervention dust lead loadings. The effect of the interior strategies was influenced by (interacted with) the pre-intervention dust lead loadings for each of the surfaces (floors, sills and troughs). Figures 7-1 to 7-3 present the predicted values for immediate post-intervention dust lead loadings for specified Interior Strategies across the range of pre-intervention dust lead loadings, while holding all other significant factors constant at their mean values. Because the analyses examined individual samples (as opposed to dwelling unit averages used in other sections of this report), there were enough data to examine Interior Strategies 06 and 07 separately in the all floor and window sill models. Given the relatively small sample sizes of the Interior Strategy 07 data (1% or less of the samples), these findings are not discussed in further detail.

Table 7-7: Geometric Mean Dust Lead Loadings at Pre-Intervention and Initial Clearance by Interior Strategy and Sample Type

Interior Strategy	All Floors[a]		Window Sills		Window Troughs	
	Pre-Intervention (µg/ft²)	Initial Clearance (µg/ft²)	Pre-Intervention (µg/ft²)	Initial Clearance (µg/ft²)	Pre-Intervention (µg/ft²)	Initial Clearance (µg/ft²)
02	10	8	116	28	1,843	67
03	16	14	120	40	990	75
04	25	17	287	43	6,613	71
05	47	11	385	16	5,032	29
06	112	18	440	40	3,020	142
07	4	3	18	6	-	-
All	29	12	271	23	3,722	44

[a]All floors include entry and interior floor samples.

Data from: Form 19
Data as of: June 1, 2000
Source of Data: Descriptive Statistics Associated with Clearance Models
(Outcome: Continuous Variable)

Within the interquartile range (i.e., between the 25th and 75th percentiles) of dust lead loadings for each surface type, certain patterns emerged across models. The dwellings treated with Interior Strategy 05 had significantly different (lower) dust lead loadings than dwellings treated with Interior Strategies 03, 04 and 06 across the interquartile range after adjusting for other factors. Clearance *trough* dust lead loadings in dwellings treated with Interior Strategy 05 were also significantly different (lower) than in dwellings treated with Interior Strategy 02 across all pre-intervention trough dust lead loadings. Dwellings treated with Interior Strategy 02 had clearance *floor* dust lead loadings that were lower than dwellings treated with Interior Strategies 03, 04 and 06 when pre-intervention floor dust lead loadings were in the mid to low levels (e.g., at the median or 25th percentile) (Table 7-8). The results were similar on entries and bare floors.

Figure 7-1: Predicted Initial Clearance All Floor Dust Lead Loading by Pre-Intervention Floor Dust Lead Loading and Interior Strategy

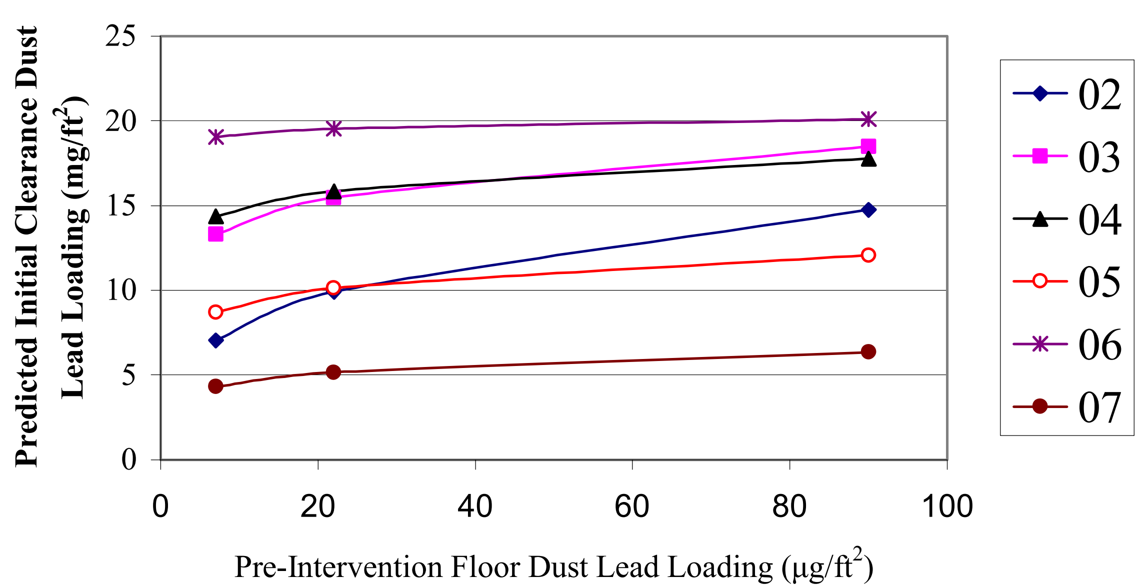

Figure 7-2: Predicted Initial Clearance Window Sill Dust Lead Loading by Pre-Intervention Sill Dust Lead Loading and Interior Strategy

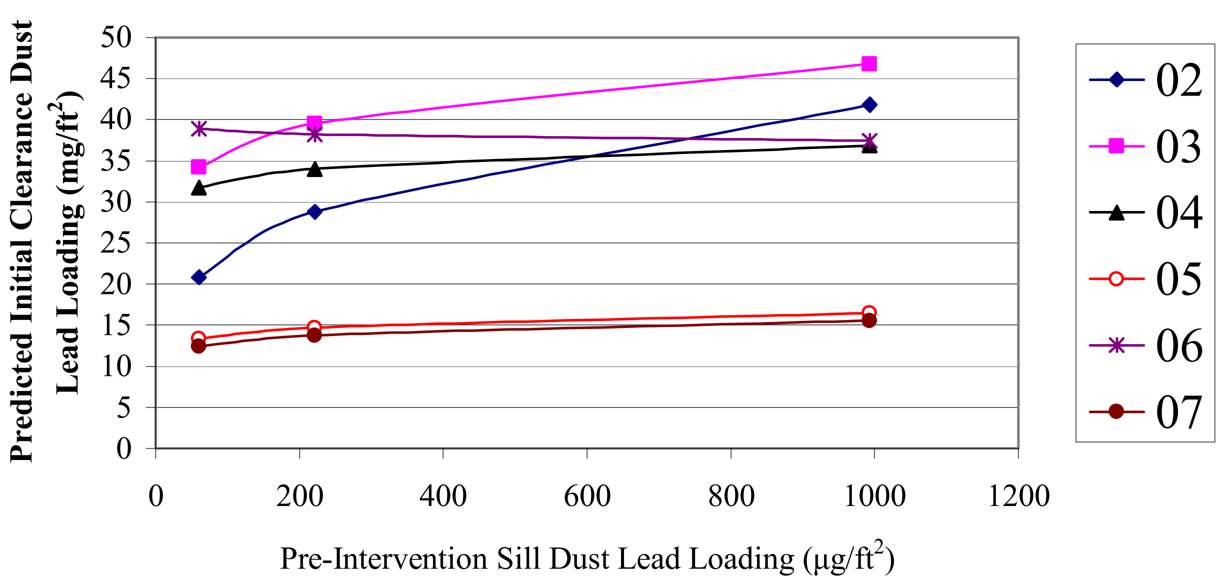

Figure 7-3: Predicted Initial Clearance Window Trough Dust Lead Loading by Pre-Intervention Trough Dust Lead Loading and Interior Strategy

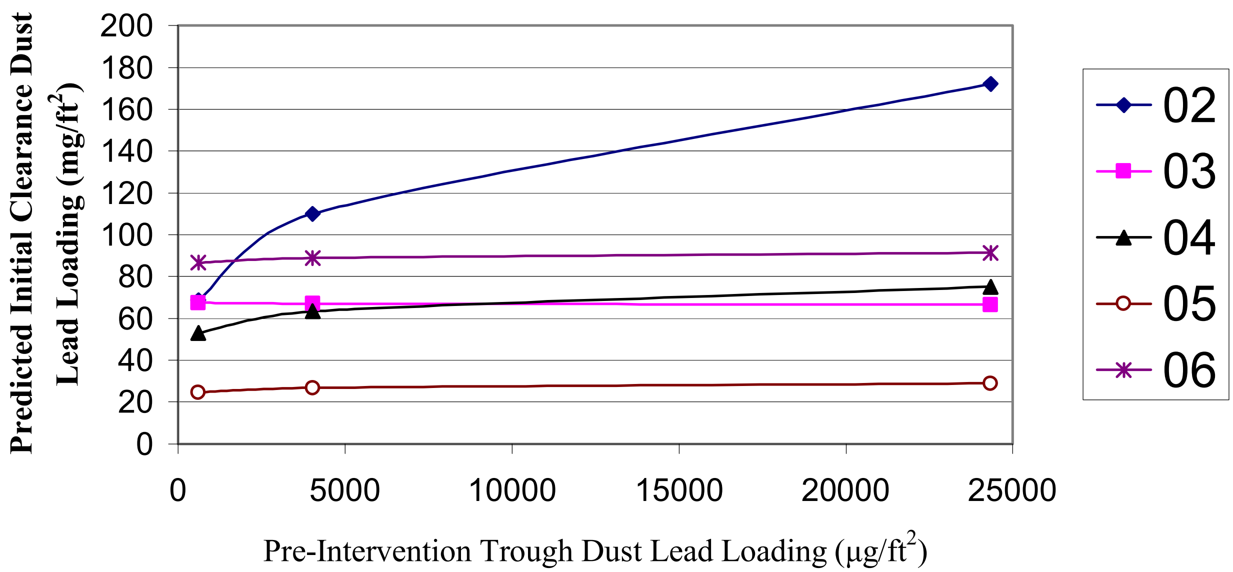

Table 7-8: Statistical Significance of Results Comparing Predicted Clearance Dust Lead Loadings in Dwellings Treated with Interior Strategy 02 with Other Interior Strategies by Pre-Intervention Dust Lead Loading (when Interior Strategy 02 associated with lower clearance loadings)

Interior Strategies Contrasted	All Floors Pre-Invention Dust Lead Loading			Window Sills Pre-Invention Dust Lead Loading		
	25th Percentile: 7 µg/ft²	Median: 22 µg/ft²	75th Percentile: 90 µg/ft²	25th Percentile: 60 µg/ft²	Median: 221 µg/ft²	75th Percentile: 993 µg/ft²
02 v. 03	p<0.01**	p<0.01**	p=0.09*	p<0.01**	p<0.01**	p=0.48
02 v. 04	p<0.01**	p<0.01**	p=0.13	p<0.01**	p=0.14	-
02 v. 05	p=0.01**	p=0.82	-	-	-	-
02 v. 06	p<0.01**	p<0.01**	p=0.07*	p<0.01**	p=0.15	-

Note: "-" indicates that Interior Strategy 02 was associated with higher clearance loadings, although those associations were not necessarily significant.

Data from: Form 19
Data as of: June 1, 2000
Source of Data: Model Results Associated with Clearance Models
(Outcome: Continuous Variable)

7.3.3 Discussion of Findings

7.3.3.1 Treatment Effects. The findings of the Evaluation provide evidence that different interior lead hazard control strategies have significantly different effects on initial clearance failure rates and initial clearance dust lead loadings. Although a number of varying effects have been described in the previous sections, three observations stand out:

1. Interior Strategy 05 out-performed other lower intensity strategies based on window dust lead loadings and failures at clearance.

Dwellings treated with Interior Strategy 05, the strategy that included window abatement, are predicted to have lower initial clearance dust lead loadings and lower failure rates on both window sills and window troughs than those treated with any other interior strategy when all other conditions are equal. This finding may seem obvious, but it does demonstrate that windows painted with lead-based paint can be removed and replaced (or in some cases, stripped of paint) while keeping dust lead loadings low. Dwellings where Interior Strategy 05 was conducted had the lowest geometric mean window sill and window trough dust lead loadings at clearance: 16 and 29 µg/ft^2, respectively. In addition, dwellings treated with Interior Strategy 05 generally had the lowest clearance failure rates of any strategy on window sills and window troughs: four and five percent, respectively.

2. Low-intensity lead hazard control activities generally performed as well or better than other strategies based on floor dust lead loadings and failures at clearance.

Dwellings treated with Interior Strategy 02, the strategy that generally included cleaning and possibly limited paint stabilization, had clearance floor dust lead loadings and failure rates at or below all other strategies. These results support the hypothesis that treatments that generate a limited amount of leaded dust can perform better at clearance than treatments that generate more leaded dust. Similarly, Interior Strategy 03, the strategy that generally included full paint stabilization and should have generated limited dust lead, had clearance failure rates at or below all other strategies on floors.

However, clearance results do not necessarily predict future treatment success. Although pure cleaning treatments may perform well at clearance because little dust lead is generated during treatment and the focus of the contractor is on proper cleaning, such treatments are not expected to eliminate or reduce lead dust generation in the future. Chapter 8 provides information about the effectiveness of lead hazard control strategies on dust lead loadings one to three years after clearance.

3. The relationship between average initial dust lead loadings at clearance and clearance failure rates varies by interior lead hazard control strategy.

Although generally, the average initial dust lead loadings at clearance and clearance failure rates have a similar relationship for each Interior Strategy, there are exceptions and in at least two instances, the relationship substantially varied. Dwellings treated with Interior Strategy 05 had a geometric mean floor dust lead loading at clearance (11 µg/ft^2) that was lower than those for most other strategies, yet at least one floor sample was above 100 µg/ft^2 in 23 percent of the dwellings, which was higher than most other strategies. Dwellings treated with Interior Strategy 02 had a relatively low geometric mean window sill dust lead loading at clearance (28 µg/ft^2), yet at least one sill sample was above 500 μg/ft^2 in 10 percent of the dwellings, a relatively high percentage.

This observation has major implications for interpreting these findings in light of the 2001 EPA clearance standards. Because the distribution of dust lead loadings appears to vary by Interior Strategy, it is difficult to reliably predict the percent of samples above a given level. In other words, knowing the average dust lead loading for a certain lead hazard control strategy does not mean that the failure rate at an alternative clearance standard can be reliably predicted. As a result, the relative effects of interior strategies on clearance failure rates may differ at the lower dust lead clearance standards (40, 250 and 400 μg/ft^2) issued by EPA in 2001 than those reported here.

Finally, the Evaluation team recognizes an additional limitation for interpreting these results. There appear to be differences in clearance failure rates and clearance dust lead loadings by grantee. During preliminary analyses, "Grantee" was included as a variable in the modeling and grantees were found to have significantly different effects on all clearance outcomes. After reviewing these findings, the Evaluation team determined that some effects attributed to "Grantee" could have been influenced by other factors that are more generalizable on a national level. A principal concern was the strong correlation between certain grantees and the strategies they used (e.g., Milwaukee and low-level strategies, New York City and New Jersey and high-level strategies). Out of concern that the "Grantee effect" might dampen or hide the effects of variables such as lead hazard control strategies that could have more universal applicability, the "Grantee" variable was excluded from these final models.

Even so, the Evaluation team recognizes that the "Grantee effect" may have been in part a valid effect. Potentially important factors that were captured by the Grantee variable in the analyses, such as the amount of grantee program oversight over contractor operations or the levels of exterior street dust lead in a community, are not accounted for by any other variable. Of concern is the possible unintended consequence of attributing to another variable, such as Interior Strategy, an effect that might have better been explained by the "Grantee effect." For example, as reported in Section 5.2.1, New York City contributed 89 percent of the Interior Strategy 06 dwellings. In the preliminary analyses, dwellings treated with Interior Strategy 06 had the *lowest* predicted clearance dust lead loadings on floors, while dwellings treated in New York City had the highest predicted floor dust lead loadings among grantees. The final analyses, which did not consider the "Grantee effect" indicated that dwellings treated with Interior Strategy 06 had the *highest* predicted floor dust lead loadings. When a grantee was closely related to a factor, such as New York City and Interior Strategy 06, it became difficult to determine whether the "Grantee effect" was masking a poorly performing treatment or whether by not taking into account the "Grantee effect," the success of a strategy was discounted. Because no other grantee had such a close relationship with a lead hazard control strategy, the Evaluation team decided to exclude the "Grantee effect." However, caution should be used when drawing conclusions about the effects of Interior Strategy 06/07.

7.3.3.2 Other Effects

7.3.3.2.1 Surface Condition

The effect of adding the condition of the wiped surface at clearance and the surface type (painted, unpainted and, for floors, carpeted) to the previously described clearance models was examined. The Evaluation team recognized that the surface condition is related to the interior strategy; higher-level strategies are more likely to create better surface conditions (Table 7-9). Therefore, if clearance surface condition had been included in the original models, the effects of strategy on dust lead could have been different.

The effect of the condition of the wiped surface at clearance was significant in all analyses. The surfaces in better condition at clearance had lower clearance dust lead loadings and lower failure rates. The Evaluation team hypothesized that when surface condition at clearance was included in the models, the reductions in dust lead attributed to higher intensity strategies would be dampened because those effects would be attributed to the surface condition. Although this hypothesis proved true, the significant differences between Interior Strategies generally remained the same. There was one exception: when clearance surface condition was included, failure rates on entry floors were significantly related to Interior Strategy. The results suggest that when the impact of improving the surface condition is removed from the Interior Strategy effects, the other elements of interior lead hazard control had no significant difference on failure rates on entry floors.

Table 7-9: Arithmetic Mean Surface Condition of Wipe Surfaces at Clearance by Interior Strategy

Surface	Interior Strategy				
	02	03	04	05	06
Entry	1.4	1.4	1.3	1.2	1.0
Bare Floors	1.3	1.3	1.2	1.2	1.0
All Floors	1.3	1.3	1.3	1.2	1.0
Window Sill	1.3	1.2	1.2	1.2	1.0
Window Trough	1.6	1.2	1.1	1.1	1.0

Surface Condition: 1= Good, 2=Fair, 3=Poor

Data from: Form 19
Data as of: June 1, 2000
Source of Data: Descriptive Statistics Associated with Clearance Models (Outcome: Continuous Variable)

7.3.3.2.2 Pre-Intervention Occupancy

Dwellings that were occupied prior to intervention were more likely to fail clearance dust testing. Overall, 28 percent of occupied dwellings failed versus 23 percent of vacant dwellings using a floor dust lead comparison value of 100 µg/ft^2. These results could offer support to the hypothesis that it is easier to treat and clean a dwelling unit that is vacant. Contractors did not have to work around occupants who did not relocate, nor did they have to work around belongings left by relocated households. However, support for this hypothesis is tempered by a supplemental examination of overall clearance failures (i.e., a failure on any surface) which found that when both the "Grantee effect" and the occupancy of the dwelling were considered, initial clearance failure rates for vacant units and occupied units were not significantly different ($p = 0.45$).

Model predicted floor and window sill clearance dust lead loadings in occupied dwellings were higher than those in vacant dwellings, after controlling for all other factors. However, it is important to recognize that pre-intervention dust lead loadings were among the factors controlled for in the clearance models. If pre-intervention dust lead loadings were *the same* in occupied and vacant units, then occupied dwellings were predicted to have higher dust lead loadings than vacant dwellings at clearance. Yet, as reported in Section 4.3.2, vacant dwellings had significantly higher dust lead loadings on floors and window sills at pre-intervention than occupied dwellings. The actual clearance dust lead loadings in occupied dwellings are not higher than in vacant dwellings. The geometric mean floor dust lead loading at clearance in occupied dwellings was 14 µg/ft^2 versus 15 µg/ft^2 in vacant dwellings. The geometric mean window sill dust lead loading at clearance in occupied dwellings was 28 µg/ft^2 versus 34 µg/ft^2 in vacant dwellings.

The findings do not necessarily support a policy of preferentially selecting vacant dwellings for treatment. Waiting for occupied dwellings to become vacant and sit unoccupied for a period of time, as did units in the Evaluation, would be expected to result in higher pre-intervention dust lead loadings. While dust lead loadings declined from pre-intervention to clearance by a greater percentage in dwellings that were vacant, it is not apparent from the findings that treating a vacant dwelling would result in lower clearance dust lead levels than treating the same dwelling before it became vacant.

7.3.3.3 Overview of Initial Clearance Results. Even though statistically significant differences in clearance dust lead loadings were identified between interior strategies, all interventions performed well. The maximum strategy specific geometric mean dust lead loadings for floors, window sills and troughs at initial clearance were: 18 µg/ft^2, 43 µg/ft^2, and 142 µg/ft^2, respectively (Table 7-7). These dust lead loadings were each at least 80 percent lower than the respective clearance standards (200, 500, and 800 µg/ft^2) commonly used during the Evaluation. While some strategies performed better than others, no strategy could be considered ineffective at clearance.

The focus of this section has been on the initial clearance dust lead loadings. Because dust lead loadings would have further declined following recleaning and retesting in the 20 percent of dwellings that failed to pass initial clearance, the dust lead loadings presented on Table 7-7 are higher than the final levels following all clearance activities.

As discussed earlier, a principal measure of success at clearance is the creation of an environment where dust lead loadings are below applicable standards. This is achieved by conducting an intervention that creates as little lead dust as possible, properly contains the leaded dust that is created, and then removes as much of the original dust lead and newly generated dust lead as possible. This section examined differences in how well the interior strategies were successful in this task. However, clearance measurements cannot predict how well the different interior strategies will prevent the future generation of leaded dust. These outcomes are the focus of the analyses examined in Chapter 8.

7.4 OCCUPANT PROTECTION

As discussed in Section 7.1, the HUD LHC Grant Program established the clearance testing requirements and other procedures to protect residents following treatments. At the same time, the HUD LHC Grant Program also had policies in place to protect residents while lead hazard control activities were underway. This section describes the measures that were taken to protect residents, their effectiveness as judged by resident satisfaction and by the incidence of blood lead increases of 5 µg/dL or more from pre-intervention testing to immediate post-intervention testing.

7.4.1 Assessment Methods

7.4.1.1 Methodology for Assessing Occupant Protection. Occupant protection was assessed using an occupant protection questionnaire. The purpose of the occupant protection questionnaire was to learn more about factors that determine the success or failure of the various occupant safety strategies used by grantees. Grantees were expected to administer the questionnaire to all households who were enrolled prior to intervention and who remained in the dwelling after intervention. The questionnaire determined whether families were temporarily relocated from the dwelling unit or were kept away from the work area but not relocated during the intervention. The questionnaire assessed the degree of, and reasons for, non-compliance of family members with grantee safety procedures (e.g., whether they returned to the home during the intervention and why). The Evaluation team also expected the information about occupant protection effectiveness to be an important modifier of change in blood lead levels after intervention.

A total of 1,149 households participated in the occupant protection interviews. The Evaluation protocols called for the occupant protocol questions to be asked of an adult household member as soon as feasible after the completion of the lead hazard control intervention. Because the protocols required that this interview be conducted in person in each family's home, the Evaluation team provided the grantee with the option of conducting it shortly after clearance (e.g., at the same time as the immediate post-intervention blood lead test) or during the 6-month follow-up inspection. In a small percentage of cases, the interviews were conducted during the 12-month follow-up inspection.

7.4.1.2 Methodology for Assessing Blood Lead Results. The HUD LHC Grant Program required grantees in Rounds One and Two to offer blood lead testing for children between the ages of six months and six years living in homes undergoing lead hazard control activities. Blood lead levels were to be used primarily to measure the safety and effectiveness of the lead hazard control activities that the grantees selected.

The Evaluation team expected a substantial portion of the enrolled dwelling units to contain a child less than six years of age. Grantees often targeted homes for enrollment because the children inhabiting the homes had elevated blood lead levels or because the homes were in communities where children had an elevated risk of lead poisoning. Blood lead testing was to be conducted prior to intervention, immediately after intervention and 6 and 12 months after intervention. Parents decided whether their children would be tested for lead at each sampling phase. Neither the presence of a child nor the participation of the child in the Evaluation was a requirement for a dwelling unit to be eligible for LHC Grant funds. Section 3.1.1 provides details on the process used to obtain the participant's informed consent.

The Evaluation protocols required the collection of the pre-intervention blood lead sample within six weeks before the lead hazard control intervention. This sample served as a baseline level for each child. The grantee was allowed to substitute a previously collected blood lead sample from a child for the pre-intervention sample as long as the grantee was able to verify the results through medical records.

The protocols required the collection of the immediate post-intervention blood lead sample within six weeks after clearance was achieved. The second sample was used to help determine if a child was exposed to lead during the conduct of the intervention or occupant protection activities. The immediate post-intervention blood sample collection allowed Objective 8 of the study objectives to be fulfilled (i.e., to identify factors associated with blood lead increases equal to or greater than 5 μg/dL occurring between pre-intervention and post-intervention measurements). A 5 μg/dL change was selected as a level of concern because it is greater than the difference that might result from normal laboratory variation.

A Generalized Estimating Equation (GEE) analysis was used to identify factors that were statistically significantly associated with the immediate post-intervention blood lead increases. Variables were considered significant at a p-value of 0.05. The variables tested in the analysis are listed on Exhibit 7-2 at the end of the chapter.

7.4.2 Occupant Protection Findings

Of the 1,548 households that were enrolled and participated in a household interview prior to the lead hazard control intervention, 1,082 households (70%) participated in an occupant protection interview after intervention. An additional 67 households were enrolled and completed an occupant protection intervention but did not complete the household interview prior to the intervention. Thus, a total of 1,149 occupant protection questionnaires were available for analysis. The households that completed the questionnaires resided in 1,133 dwelling units. The occupant protection interviews were generally conducted immediately after clearance (80%) although 207 (18%) were conducted approximately 6 months after clearance and 23 (2%) were conducted approximately 12 months after clearance.

7.4.2.1 Relocated Households. For most households, occupant protection involved relocation from the dwelling unit for the total period of lead hazard control. Eight hundred nineteen (819) [6] households (71%) relocated during the lead hazard control work. Of the households who reported that they relocated, 776 (95%) relocated prior to the start of the work.

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[6] One household was known to have relocated based on other responses, but the specific point of relocation was not reported.

Based on interview information, the median period of relocation was 13 days, with an interquartile range of 7 to 27 days. Twenty-two (22) percent of households (180) reported that someone in the household returned to the dwelling unit while the intervention was being conducted. The longer the relocation period, the less likely the family was to return ($p<0.01$).

The return visits to the dwellings were often brief. Most households returning to their home spent less than one hour in the dwelling (125 households (69%)). Ten percent of returning households (18) spent less than eight hours in the dwelling. Most of the remaining 21 percent of households spent no more than four hours in the dwelling (34 households).

For 112 of the 180 households that returned during relocation, a single person returned to the home. In 44 households, two people returned to the dwelling, while more than 2 people returned to the dwelling from the other 24 households. Ten percent of the households that returned during relocation included a child, including 20 children enrolled in the Evaluation.

The primary reasons (besides "other" - 75 households) for returning home were to pick up personal belongings (77 households) and pick up mail (55 households). The primary reason given when households spent more than eight hours at the dwelling and the primary reason given when households returned with a child was "the work took longer than told" (12 households).

Over half of the households (438 (54%)) relocated outside the neighborhood. When the household remained in the neighborhood, 41 percent of the households remained in the same building in a different dwelling, while 12 percent of the households moved next door. The farther away a household relocated, the more likely a member was to return to the dwelling during intervention. Thirty percent of the households that relocated to a different neighborhood returned to the dwelling during intervention, while just five percent returned when they were relocated within the building.

Sixty-one percent (496) of the households believed that they relocated to a "lead-safe" home, while 21 percent (173) did not know whether the housing they moved to was "lead-safe." The Evaluation protocols did not define "lead-safe," so lead-safe status was based on the assessment of the respondent.

7.4.2.2 Non-Relocated Households. Three hundred twenty-nine (329) households (29%) did not Three hundred relocate from the dwelling unit during lead hazard control work. As discussed in Section 7.2.1, HUD placed a number of requirements on grantees that chose not to relocate a household from a dwelling, and in general, it appeared that grantees complied with those requirements. Twenty-four percent of the households (78) stayed out of the dwelling unit during the work period but returned at night. Of the 249[7] households that remained in the dwelling unit during the day, 89 percent reported that they stayed out of the work area. Twenty-six households (8% of all non-relocated households) reported that they remained in the dwelling unit and entered or may have entered the work area. Half of these households reported that someone in the household entered the work area while work was *in progress*.

Eighty percent of the 249 households that remained in the dwelling unit during the work reported that all dust and debris were cleaned up each day, and another five percent (13) were not sure. The remaining 38 households did not believe that dust and debris were completely cleaned up each day.

[7] Two non-relocated households did not respond to the questions concerning activities during the work.

7.4.2.3 Relationship of Relocation and Treatment Strategy. Homes where households did not relocate were expected to be treated with lower intensity treatments that would create little or no dust and debris. The grantees tended to follow this expectation. One hundred percent of the households that lived in abated units (Interior Strategies 06-07) were relocated and 83 percent of households that lived in dwellings treated with Interior Strategies 04-05 (window treatments or replacement) were relocated, while just 26 percent of households that lived in dwellings treated with Interior Strategies 01-02 (no interior work or cleaning/spot painting) were relocated.

Although grantees tended to relocate families living in dwellings with higher intensity lead hazard control interventions, a substantial portion of the non-relocated households lived in homes with higher levels of treatment. One hundred thirty-two of the 329 non-relocated households (40%) lived in homes treated by Interior Strategy 04 or 05, while 94 such households (29%) lived in homes treated by Interior Strategy 03. The remaining[8] 96 households (29%) that did not relocate lived in dwellings where no interior lead hazard control work was conducted (13 households) or where Interior Strategy 02 (spot painting/cleaning) was done (83 households).

7.4.2.4 General Occupant Findings. Overall, households felt that they were adequately protected by the occupant protection measures. Households that did not relocate had opinions about their protection that were not significantly different than relocated households. Overall, eighty-seven percent of interviewed households reported that they were adequately protected, while another seven percent were not sure or had no opinion.[9] Eighty-five percent of non-relocated households felt adequately protected compared to 88 percent of relocated households (Table 7-10). Households living in dwellings treated by Interior Strategy 01 or 02 felt more protected (94% adequately protected) than households living in homes treated by higher level interior strategies (86% adequately protected). This finding was found to be statistically significant in an analysis that controlled for the effects of grantee ($p<0.01$).

Taken as a whole, the occupant protection findings suggest that grantees and households generally followed HUD guidance for occupant protection. Most households were relocated from the dwellings during the duration of the treatments and did not return to the worksite for intervention. When households were not relocated, treatments tended to be of a more limited nature. In addition, the vast majority (89%) of non-relocated households remained out of the work area and less than 20 households entered the work area while work was in progress. The sufficiency of the grantee's protective measures seems to be supported by respondent's opinions about the adequacy of the occupant protection.

While the results were generally positive, six percent (59) of all households reported that they did not feel adequately protected. Over 20 percent of the households returned to the dwelling during intervention and another five percent did not relocate from the dwelling prior to the start of work. Data from the households that did not relocate or relocated late were combined and compared with data from households that fully relocated as part of the analysis of the effects of various factors on increases in children's blood lead levels. These findings are discussed in Section 7.4.3.1.

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[8] The interior strategy was not reported for seven of the dwellings where non-relocated households lived.
[9] This analysis does not include responses from households living in New York City. The rationale for excluding these responses is found on Table 7-10.

Table 7-10: Number and Percent of Households Who Reported that They Were Adequately Protected by Occupant Protection Activities by Interior Strategy (Households from New York City Excluded)[a]

Interior Strategy	Total Households[b]	Number and Percent of Households Who Reported that They Were Adequately Protected		
		Relocated Households	Non-Relocated Households	All Households
01/02	127	31 94%	89 95%	120 94%
03	105	38 86%	48 79%	86 82%
04	193	109 87%	53 78%	162 84%
05	565	441 88%	54 84%	495 88%
06/07	11	9 82%	-	9 82%
All	1,001	628 88%	244 85%	872 87%

[a]One hundred, thirty two responses from New York City was excluded from this table because the responses of its residents deviated substantially from the other grantees. Seven percent of all respondents outside of New York City had no opinion or did not know whether they were adequately protected, while 34 percent of respondents in New York City had no opinion/did not know. The next highest rate of this response by any other grantee was 11 percent. Five percent of all respondents outside of New York City felt they were not adequately protected, while 28 percent of respondents in New York City felt that they were not.
[b]In addition to the 132 responses excluded from New York City, 12 households did not respond to this question and 133 households lived in treated dwellings for which strategy forms were not approved.

Data from: Form 06
Data as of: June 1, 2000
Source of Data: NCLSH Table (Revision of McL-027 and McL-036)

7.4.3 Findings for All Children with Blood Lead Increases of 5 µg/dL or More

Eighty-one (81) of the 869 children (9.3%) who had both pre-intervention and immediate post-intervention blood lead samples had blood lead increases equal to or greater than 5 µg/dL between the two measurements. Blood lead increases ranged from 5 to 25 µg/dL with an average increase of 8.4 µg/dL. The 81 children resided at ten grantee sites. Alameda County, the State of California and New York City reported no children with increases of 5 µg/dL or more. New Jersey did not report any children with serial blood lead tests.

Upon request from the Evaluation team, the ten grantee sites where the 81 children resided provided additional information about possible reasons for these blood lead increases. A checklist of nine potential reasons was developed to assist grantees in this process. Table 7-11 presents the grantee responses. Grantees were given the option of writing in additional reasons, so the table includes two additional responses that were frequently reported by the grantees: hand-to-mouth activity and unabated exterior lead source. Often more than one explanatory category was selected, yielding a total of 163 responses for the 81 children.

Table 7-11: Grantee Responses to Survey of Potential Reasons for Blood Lead Increases Equal to or Greater than 5 µg/dL from Pre-Intervention to Immediate Post-Intervention

Reason for Blood Lead Increase	Frequency
Expected Seasonal Variation	29
Sources of Lead in Other House(s) (sitter, relative, neighborhood, etc.)	28
Household Activities[1]	21
Hand-to-Mouth Activity (excessive)	14*
Expected Increase Due to Child's Age	10
Job Exposures of Household Member	7
Unabated Exterior Lead Source	7*
Activities in Neighborhood (demolition, industrial or other)	1
Use of Traditional or Folk Remedies or Food/Beverage Containers Containing Lead	0
Other	28
Unknown	18

*Responses written-in by grantees
[1]Household Activities include home repairs or other hobbies that involve the use or disturbance of lead.

Data from: UC Survey of Grantees – Reasons by Blood Lead Increases
Data as of: June 1, 2000
Source of Data: UC Table

To verify these responses, other data reported by the grantees were examined to determine their consistency with the responses. Responses were compared to available data related to the child's age, month of blood lead collection, neighborhood point sources of lead, and possible occupational or recreational exposures to lead. Most of the responses were consistent with the other available data. For example, child's age appeared to be a viable reason for each of the ten cases when grantees provided this response.

Information provided by grantees, including responses noted in the "other" category, indicated that elevated blood lead levels in nine children (9%) may have been related to the lead hazard control work conducted: four cases in Minnesota, three cases in Massachusetts, and one case each in Vermont and Wisconsin. For each of these nine children, one of the following situations reportedly occurred:

- the family did not relocate during the intervention,
- the family was present during at least part of the intervention, or
- one or more family members visited the home while the intervention was underway.

7.4.3.1 Findings for Children Fitting Evaluation Criteria. As described in Section 7.4.1.2, the Evaluation team conducted a multivariate analysis of factors associated with increases in blood lead levels of 5 µg/dL or more. Prior to running this analysis, however, data for the 869 children having pre-intervention and immediate post-intervention blood lead samples were studied in order to identify the subset of children whose data met specific study requirements and therefore could be included in the analysis. The 869 children described above included 216 children who:

- Lived in dwellings that were missing other pre- or immediate post-intervention data,
- Did not fall within the Evaluation protocols for age eligibility (6 months to 72 months of ages at pre-intervention),
- Did not fall within the blood sampling time restrictions of sixteen weeks prior to the start of the intervention to four weeks after work started.[10]
- Lived in dwellings that were treated with rarely conducted Interior Strategies (i.e., 01, 06 or 07)

Because these 216 children did not meet the basic study requirements or lived in dwellings where a Strategy effect would not be evident (i.e., because the Strategy was used in less than 10 of the dwellings), they were ineligible for multivariate analyses of factors associated with increases in blood lead levels of 5 µg/dL or more. Among the children excluded were 12 children (6%) with blood lead increases of 5 µg/dL or more. This percentage was significantly different from the 11 percent of children (69) within the group of 653 children who met the Evaluation criteria ($p=0.03$).

Unlike the other statistical analyses contained in this report, evidence of the dwelling passing clearance was not required for inclusion in this model. The Evaluation team determined that the power of the analysis could be adversely affected by limiting eligibility with the clearance requirement. Eight-one (81) children in the analysis, including 13 children (16%) with blood lead increases of 5 µg/dL or more, lived in dwellings that did not have evidence of clearance. Evidence of clearance was not a variable tested in the full logistic regression analysis of factors associated with blood lead increases, but when tested in a bivariate analysis, the percentage of children with 5 µg/dL or greater blood lead increases was not significantly different in the subset of dwellings that passed clearance than in the subset that did not have evidence of clearance ($p=0.08$).

In the full logistic regression analysis, four factors were significantly associated with blood lead increases of 5 µg/dL or more: child's age at pre-intervention, female caregiver's education, general exterior building condition and season of blood sample collection (immediate post-intervention).

[10] The time restriction is more lenient than was originally stated in the Evaluation protocols, which called for pre-intervention blood sampling to be conducted between 6 weeks prior to the intervention and the start of the intervention. In addition, time restrictions were removed from the immediate post-intervention sample. The Evaluation team believes that the original restrictions could be relaxed to expand the analysis population, without compromising the integrity of the analysis.

Table 7-12: Predicted Odds Ratios for a Child Having a Blood Lead Increase Equal to or Greater than 5 µg/dL for various Pre-Intervention Ages Compared to a Child of Median Pre-Intervention Age (40Months) and Predicted Probabilities of a Child Having a Blood Lead Increase Equal to or Greater than 5 µg/dL by Child's Age (Pre-Intervention)

Child's Age (Months)	Odds Ratio of a Child Having a Blood Lead Increase of 5 µg/dL or More[a]	Predicted Probability of a Child Having a Blood Lead Increase of 5 µg/dL or More[b]
6	17.13	34.0%
12	4.89	12.8%
18	2.14	6.0%
24	1.31	3.8%
30	1.04	3.0%
36	0.98	2.9%
42	1.02	3.0%
48	1.06	3.1%
54	1.02	3.0%
60	0.83	2.4%
66	0.53	1.6%
72	0.25	0.7%

[a]Odds Ratio compared to a child of age 40 months, pre-intervention (median age child)
[b]Model predicted values based on child living in home with:

1. no exterior deterioration (modal value for all children),
2. a female caregiver with more than high school education,
3. window paint lead loading at the GM (1.3 mg/cm^2)
4. post-intervention blood lead collected April 1

Data from: Forms 01, 04, 05, 09 and 10
Data as of: June 1, 2000
Source of Data: Model Results for Blood "Spike" Model (#77d)

7.4.3.1.1 Child's Age at Pre-Intervention

The youngest children in the Evaluation had the highest risk of a blood lead increase of 5 µg/dL or more. When compared to the median age child in the analysis (a 40-month old child), the odds ratio was above 2 through age 18 months and primarily above 1 through age 54 months. Table 7-12 presents these odds ratios. The table also presents the predicted probabilities for children of different ages with average educational attainment by the female caregiver (12 years), and no exterior building components that were deteriorated.

7.4.3.1.2 Female Caregiver's Education[11]

In the statistical model, years of education were examined as a categorical variable, after preliminary analysis of the unadjusted data suggests that the effect of education should be split between caregivers who received less than 12 years of education, those who received 12 years or more, and those where the level of caregivers education was unknown (17 children) Children with a female caregiver who received 12 or more years of education had a lower risk of a blood lead increase of 5 µg/dL or more than children with a female caregiver who received less than 12 years of education. Sixteen percent of children whose female caregiver had less than a high school education had an increase of 5 µg/dL or more; just seven percent of children whose female caregiver had a high school education or more had such an increase.

7.4.3.1.3 General Exterior Building Condition

Exterior building condition, as defined by the number of exterior building components broken or obviously deteriorated prior to intervention, was examined as a continuous variable in the statistical model. A child living in a building with more components exhibiting exterior building deterioration was more likely to have blood lead increases of 5 µg/dL or more. A more detailed analysis of the unadjusted data suggests that the effect of the general exterior building condition may be dichotomous. Children living in a dwelling with at least one exterior components with obvious deterioration had a higher risk of having a blood lead increase than children living in dwellings with no exterior deterioration. Sixteen percent of children living in a dwelling with one or two exterior components with obvious deterioration had an increase of 5 µg/dL or more; just eight percent of children living in dwellings with no exterior deterioration had such an increase.

7.4.3.1.4 Season

The leading response on the grantee surveys (seasonal differences) was also a significant factor in the model. When blood lead samples were collected during early summer, the incidence of blood lead increases was greater. The odds of a child having a blood lead increase of 5 ug/dL or higher in the summer were 146% higher than in the spring or fall and 434% higher than in the winter.

In a subsequent examination of the effect of season on the change in blood lead levels, children were more likely to have increases in blood lead levels of 5 µg/dL or more when tested between winter and spring and spring and summer than when tested between summer and fall ($p=0.03$ and $p<0.01$, respectively) (Table 7-13). Children tested between winter and spring and spring and summer were not significantly more likely to have an increase of 5 µg/dL or more than when tested between fall and winter: ($p=0.49$) and ($p=0.27$), respectively.

[11] The male caregivers' educational attainment was not examined because the data were frequently unavailable. Male caregivers were either not present or respondents did not provide these data on over half of the interview forms. Female caregivers were missing education data on just 5 percent of the forms.

Table 7-13: Number and Percent of Children with Blood Lead Increase Equal to or Greater than 5 µg/dL between Pre-Intervention and Immediate Post-Intervention By Season

Months when Pre-Intervention Blood Lead Sample Collected	Number of Children Tested and Percent with Increase Equal to or Greater than 5 µg/dL	Months when Immediate Post-Intervention Blood Lead Sample Collected			
		Winter (Jan-Mar)	Spring (Apr-Jun)	Summer (Jul-Sep)	Fall (Oct-Dec)
Winter (Jan-Mar)	Number of Children Percent >= 5 µg/dL	41 12%	112 13%	26 15%	1 0%
Spring (Apr-Jun)	Number of Children Percent >= 5 µg/dL	8 25%	33 15%	116 16%	34 9%
Summer (Jul-Sep)	Number of Children Percent >= 5 µg/dL	14 0%	0 0%	48 13%	97 4%
Fall (Oct-Dec)	Number of Children Percent >= 5 µg/dL	76 9%	8 0%	2 0%	37 0%
All	Number of Children Percent >= 5 µg/dL	139 10%	153 13%	192 15%	169 4%

Data from: Forms 05 and 09
Data as of: June 1, 2000
Source of Data: NCLSH Table (using Model #77d dataset)

7.4.3.2 Discussion of Findings about Blood Lead Increases. In a previous study of children whose homes had undergone the "traditional" form of lead abatement that was common in the early 1980s and earlier, over one-half of the children exhibited significant increases in blood lead probably related to the dust lead levels that also increased (Farfel 1990). In the current study, less than 10 percent of the children with reported pre-intervention and immediate post-intervention blood lead samples experienced an increase of 5 µg/dL or more between those sampling periods.

The children in the Evaluation lived in at-risk housing and may have been exposed to untreated lead-hazards for a number of months between the time of the initial blood lead test and the beginning of the lead hazard control intervention. Furthermore, these children may have been exposed to lead outside of the housing environment being evaluated. Yet one cannot discount the fact that these children lived in dwellings that were undergoing interventions that potentially could have exposed them to additional hazards.

The investigation suggests that on a case-by-case basis, some children may have been put at increased risk because of breakdowns in the occupant protection system. Grantees reported nine of the 81 children may have experienced increases in blood lead levels of 5 µg/dL or more because their family did not relocate, their family was present for at least part of the work period, or the family returned to the home. As individual cases, these reports cannot be discounted. Yet, overall, the statistical analysis did not find evidence that children living in households that either did not relocate or relocated for less than the full work period had a significantly different likelihood of having a blood lead increase greater than or equal to 5 µg/dL than children living in households that fully relocated.

This finding should not be misinterpreted to suggest that relocation was no more beneficial than not relocating, but instead suggests that the grantees' occupant protection decisions were appropriate. When grantees felt that households did not need to be relocated or could be partially relocated, the children were as protected (when measured by chance of blood lead increases) as when grantees felt that the households had to be relocated.

The statistical model did not identify any interior strategy that had a significantly different effect on the likelihood of a child having an increase in blood lead levels of 5 µg/dL or more. Effects of Interior Strategy 02, 03, 04, and 05 were compared to each other. The lack of significant effects does not prove that the lead hazard control interventions did or did not result in an increased exposure risk, but the available data did not reveal that any single interior strategy was any more or less risky than the others.

Finally, some limitations to the modeling may explain why results of investigation by grantees are not fully supported by the analysis of blood lead increases. Of the top five reasons reported by grantees, two (Child's Age and Season) were found to be significant in the model. The second most common reason identified by the grantees, exposure at other people's homes, was not a question asked of the families during any Evaluation questionnaires so it could not be tested. Two other responses, exposure to lead from home activities and exposure to lead from work-related activities, were harder to characterize in the analyses. Responses on household questionnaires indicated that although enrolled households were involved with over two dozen different home- and work-related lead activities, generally less than five percent of households were involved in any one lead activity. For the analyses in this report, the Evaluation team defined the home and work activities by the number of home- or work-related lead activities reported by a household member under the assumption that more activities would increase a child's exposure. If this assumption is not correct, it is possible that an alternative method of measuring home- or work-related lead exposures could have been significantly related to the blood lead increases as the grantees suggested.

7.5 Summary of the Observed outcomes Immediately Post-Intervention

7.5.1 Clearance Dust Lead Findings

Seventy-six percent of all 2,842 dwellings *treated* by grantees passed the initial clearance examination using the local dust lead standards applicable at the time. For the 2,682 dwelling units with data available to demonstrate final clearance, 80 percent passed the initial clearance examination. For the dwellings that initially failed, an average of 1.13 recleanings and follow-up clearance tests were required to achieve final clearance. The findings offer strong evidence that clearance was achievable on the first attempt for the vast majority of interventions. When dwellings failed initial clearance, final clearance was generally successful after only one additional recleaning and retest.

The interventions were most successful reducing dust lead levels below the clearance standards on window sills (6% of dwellings failed based on at least one sample, 3% failed based on dwelling mean), followed by window troughs (7%, 6%) and floors (20%, 8%). The intensity of treatments as characterized by interior strategy had a significant effect on clearance failure rates and immediate post-intervention dust lead loadings. The effects varied by the sample type. Interior Strategy 05, the strategy that included window replacement, was correlated with lower initial clearance dust lead loadings and lower failure rates on both window sills and window troughs than other interior strategies. Low-intensity lead hazard control activities (Interior Strategies 02 and 03) generally performed as well or better than other strategies based on floor dust lead loadings and failures.

Any conclusions to be drawn from this report's findings on clearance failures must be tempered somewhat by the fact that the clearance standards in place today are at least half those used during the Evaluation. The differential effects identified between interior strategies may not be the same using the new standards as those reported here.

Even though statistically significant differences could be identified between interior strategies, on average, all strategies performed well. The highest geometric mean dust lead loadings by strategy for floors, window sills and troughs were: 19 $\mu g/ft^2$, 43 $\mu g/ft^2$, and 76 $\mu g/ft^2$, respectively. These dust lead loadings were each at least one-tenth of the respective clearance standards (200, 500, and 800 $\mu g/ft^2$) used during the Evaluation. Furthermore, the number of clearance retests was not related to the interior strategy applied. While some strategies performed better than others, no strategy could be considered ineffective at clearance.

7.5.2 Occupant Protection

Seventy-one percent of households were relocated during the intervention. Twenty-two percent of those households reported that they returned to the dwellings during intervention, although in most cases the return visits were less than one hour and did not include a child. Eighty-eight percent of the relocated households felt that they were adequately protected during the intervention.

For the households that did not relocate, 92 percent of the households remained out of the work area during the time that work was being done. When households were not relocated, treatments tended to be of a more limited nature. Eighty percent of non-relocated households reported that all dust and debris were cleaned up each day. Eighty-five percent of non-relocated households felt that they were adequately protected during the intervention.

Taken as a whole, the findings suggest that grantees followed HUD guidance and occupants were adequately protected. Analyses of children's blood lead levels immediately post-intervention did not identify a difference in the probably that a child would experience a blood lead increase of 5 µg/dl or more from pre-intervention based on whether the child was relocated or not. The analyses also did not identify a differential effect by interior strategy.

At the same time, the cases where households were possibly exposed to an on-going lead hazard control worksite are of concern. Approximately 10 percent of the children with pre-intervention and immediate post-intervention blood lead samples experienced an increase of 5 µg/dl or more between the sampling periods. Grantees reported that for 9 of the 81 children who experienced such blood lead increases, the increase may have been related to no family relocation, relocation during only part of the intervention, or a family's return to the home during the intervention. Grantees must remain vigilant to offer households the necessary support and incentives to stay out of the work areas and be properly protected.

Exhibit 7-1: List of Variables Used in Clearance Dust Lead Models: Logistic Models of Clearance Failure and Nested Models of Dust Lead Loadings (Initial Clearance Dust Lead Data Used)

Variables Used in Both Sets of Models

Seasonality of Dust Sample Collected (at Clearance)
Paint Lead on Interior Doors/Trims (mg/cm^2) (A.M. of log(XRF))
Paint Lead on Interior and Exterior Windows (mg/cm^2) (A.M. of log(XRF))
Paint Lead on Other Exterior Components (mg/cm^2) (A.M. of log(XRF))
Number of Interior Elements with Deterioration (Pre-Intervention)
Roof Leak (Yes/No)
Plumbing Leak (Yes/No)
Number of Exterior Elements with Deterioration (Pre-Intervention)
Entry Height in Stories
Occupancy Status (Pre-Intervention)
Interior LHC Strategy Level
Exterior LHC Work (Yes/No)
Site LHC Work (Yes/No)
Number Units Abated by Each Contractor
Interaction of No. Interior Elements with Deterioration and Interior LHC Strategy
Interaction of No. Exterior Elements with Deterioration and Interior LHC Strategy
Interaction of Paint Lead on Interior Doors/Trims and Interior LHC Strategy
Interaction of Paint Lead on Interior and Exterior Windows and Interior LHC Strategy
Interaction of Paint Lead on Exterior Other and Exterior LHC work
Interaction of Surface Type and Condition of Entry Floor (Pre-Intervention) [4]
Interaction of No. Interior Elements with Deterioration and Exterior LHC Work

Variables Used Only in Nested (Loading) Models

Dust Lead Loading on the Appropriate Surface[1] (Pre-Intervention)
Surface Condition for the Appropriate Surface[1] (Pre-Intervention)
Surface Type (Pre-Intervention) [7]
Interaction of Surface Type and Condition for the Appropriate Surface (Pre-Intervention) [7]
Indicator for Entry vs. Non-entry (Yes/No)[2]
Interaction of Dust Lead on the Appropriate Surface[1] (Pre-Intervention) and Interior LHC Strategy
Interaction of Condition for the Appropriate Surface[1] (Pre-Intervention) and Interior LHC Strategy

Variables Used Only in Secondary Analysis of Nested (Loading) Models

Surface Condition for the Appropriate Surface[1] (at Clearance)
Surface Type (at Clearance) [7]

Exhibit 7-1- continued: List of Variables Used in Clearance Dust Lead Models: Logistic Model of Clearance Failure and Nested Model of Dust Lead Loadings (Initial Clearance Dust Lead Data Used)

Variables Used Only in Logistic (Failure) Models

Average Dust Lead Loading on the Appropriate Surface[1] (Pre-Intervention)
Number Samples Taken on Surface (at Clearance)
Average Surface Condition for the Appropriate Surface[1] (Pre-Intervention)[3]
Percent Painted for Appropriate Surface[1,3]
Surface Type (Hard, Painted or Carpet) of Entry Floor (Pre-Intervention)[4]
Percent of Painted Floors[5]
Percent of Hard Floors[5]
Percent of Carpeted Floors[2]
Percent of Painted Floors*Average Surface Condition[5] of Painted Floors
Percent of Carpeted Floors* Average Surface Condition[2] of Carpeted Floors
Percent of Hard (Unpainted) Floors* Average Surface Condition[5] of Hard (Unpainted) Floors
Interaction of Average Surface Condition of Appropriate surface (Pre-Intervention) and Interior LHC Strategy[1,8]
Interaction of Average Dust Lead on the Appropriate Surface[1] (Pre-Intervention) and Interior LHC Strategy

Variables Used Only in Secondary Analysis of Logistic (Failure) Models

Average Surface Condition for the Appropriate Surface[1] (at Clearance)[3,6]
Surface Type (Hard, Painted or Carpet) of Entry Floor (at Clearance)[4]

[1]For floor models ("entry", "bare floors" and "all floors"), floor surface used;
For "window sill" model, window sill surface used;
For "window trough" model, window trough surface used.
[2]Tested only in "all floors" model.
[3]Tested only in "window sill" and "window trough" models.
[4]Tested only in "entry floor" model.
[5]Tested only in interior floor models ("bare floors" and "all floors").
[6]For "all floor" model, two variables used – one for bare floors and one for carpets.
[7]For "all floors" and entry floor models, surface type is carpeted, painted or bare. For window models and "bare floor" model, surface type is painted or unpainted.
[8] In all models except the "entry floor" model.

Exhibit 7-2: List of Variables Used in Generalized Estimating Equations (GEE)/Blood Spike Model

Lead Hazards

Pre-intervention Variables:

Entryway Dust Lead Loading
Surface Type of Entry Floor (Hard, Painted or Carpet)
Surface Condition of Entry Floor
Average Interior Floor Dust Lead Loading
Percent of Painted Floors
Percent of Hard Floors
Percent of Carpeted Floors
Percent of Painted Floors * Average Surface Condition
Percent of Carpeted Floors * Average Surface Condition
Percent of Hard Floors * Average Surface Condition
Average Window Sill Dust Lead Loading
Average Surface Condition of Window Sills
Percent Painted Window Sills
Average Window Trough Dust Lead Loading
Average Surface Condition of Window Troughs
Percent Painted Window Troughs
Percent Dust Collected in Same Room for Each Component
(Entries, Floors, Window Sills, Window Troughs)
Average Paint Lead on Interior Doors/Trim (Mean of Log(XRF))
Average Paint Lead on Windows (Mean of Log(XRF))
Average Paint Lead on Exterior Components (Mean of Log(XRF))
Average Paint Condition of Interior Doors/Trims
Average Paint Condition of Windows
Average Paint Condition of Exterior Components
Interaction between Paint Lead Loading and Paint Condition for Each Component
(Interior Doors/Trim, Windows, Exterior components)
Interaction between % Dust Collected in Same Room and Dust Lead Loading (Pre-Intervention) for Each Component (Entries, Floors, Window Sills, Window Troughs)
Interaction of Surface Type and Condition of Entry Floor

Exhibit 7-2-continued: List of Variables Used in Generalized Estimating Equations (GEE)/Blood Spike Model

Immediate Post-intervention (Clearance) Variables:

Entryway Dust Lead Loading
Surface Type of Entry Floor (Hard, Painted or Carpet)
Surface Condition of Entry Floor
Average Interior Floor Dust Lead Loading
Percent of Painted Floors
Percent of Hard Floors
Percent of Carpeted Floors
Percent of Painted Floors *Average Surface Condition
Percent of Carpeted Floors * Average Surface Condition
Percent of Hard Floors * Average Surface Condition
Average Window Sill Dust Lead Loading
Average Window Trough Dust Lead Loading
Average Surface Condition of Window Sills
Average Surface Condition of Window Troughs
Interaction of Surface Type and Condition of Entry Floor

Pre-Intervention Building/Dwelling Condition

Number of Interior Elements with Deterioration
Roof Leak (Yes/No)
Plumbing Leak (Yes/No)
Number of Exterior Elements with Deterioration
Living Space of Dwelling at Pre-intervention (sq. ft)
Entry Height in Stories

Household Characteristics

Pre-intervention Variables:

Was Home Renovated (Yes/No)
Years of Education of Female Parent
Presence of Cleaning Equipment (Percent)
Frequency of Cleaning the House
Frequency of Washing Exterior Window Sills
Cleanliness of the Home
(1=Appears clean, 2=Some evidence of cleaning, 3=No evidence of cleaning)
Household Income ($)
Number of Children Less than 6 Years
Number of People between 6-18 Years
Number of People in Home

Exhibit 7-2-continued: List of Variables Used in Generalized Estimating Equations (GEE)/Blood Spike Model

Immediate Post-intervention (Clearance) Variables:

Cleanliness of the Home
(1=Appears clean, 2=Some evidence of cleaning, 3=No evidence of cleaning)
Frequency Change of Cleaning House (between Pre-Intervention-Clearance)
Frequency Change of Washing Exterior Window Sills (between Pre-Intervention-Clearance)

Child Characteristics (Pre-Intervention unless noted)

Child's Blood Lead Level (Pre-Intervention)
Child's Blood Lead Level (at Clearance)
Indicator of Pre-Intervention Blood Samples Collected after Start of Intervention
(Yes = after start of intervention, No = Up to 16 wks prior to start of intervention)
Child's Age, Age Square, Age Cubic
Race of Child
Sex of Child
Frequency of Putting Fingers into Mouth
Frequency of Putting Toys into Mouth
Number of Hours Awake per Week
Number of Hours Away from Home per Week
Number of Hours inside the House per Week
Number of Hours outside the House per Week
Parent Report Previous Child Lead Poisoning (Yes/No)
Child Received WIC Benefit (Yes/No)
Fully Relocated during Intervention (Yes/No)
Interaction between Entry Dust Lead and Mouthing Behavior
Interaction between Interior Floor Dust Lead and Mouthing Behavior
Interaction between Mouthing Behavior and Age, Age^2, Age^3
Interaction between Blood Lead and Age, Age^2, Age^3

Other Characteristics

Season of Blood Sample Collection (Pre-Intervention)
Season of Blood Sample Collection (at Clearance)
Season of Dust Sample Collection (Pre-Intervention)
Season of Dust Sample Collection (at Clearance)
Building Type (Single unit, 2-4 units, >4 units)
House Age (by decade)
Occupancy Status (Pre-Intervention)
Ownership (1=Rented, 2=Owner occupied, 3=Other)
Market Value

Exhibit 7-2-continued: List of Variables Used in Generalized Estimating Equations (GEE)/Blood Spike Model

Intervention (These variables only used in alternative models)

Interior LHC Work (by Strategy)
Exterior LHC Work (Yes/No)
Site LHC Work (Yes/No)
Interaction between Interior LHC Work and Exterior LHC Work
Interaction between Interior LHC Work and Site LHC Work
Interaction between Blood Lead and Interior Strategy
Interaction between No. of Exterior Elements with Deterioration and Interior Strategy
Interaction between No. of Interior Elements with Deterioration and Interior Strategy
Interaction between Floor Dust Lead (Pre-Intervention) and Interior Strategy
Interaction between Entry Dust Lead (Pre-Intervention) and Interior Strategy
Interaction between Window Sill Dust Lead (Pre-Intervention) and Interior Strategy
Interaction between Window Trough Dust Lead (Pre-Intervention) and Interior Strategy
Interaction of Average Floor Surface Condition (Pre-Intervention) and Interior Strategy
Interaction between Average Surface Condition of Window Sills and Interior Strategy
Interaction between Average Surface Condition of Window Troughs and Interior Strategy
Interaction between Paint Lead on Interior Doors/Trim and Interior Strategy
Interaction between Paint Lead on Windows and Interior Strategy
Interaction between Paint Lead on Exterior Components and Exterior Strategy

8.0 EFFECTS OF INTERVENTIONS ON DUST LEAD LOADINGS

8.1 INTRODUCTION

The purpose of the HUD Lead Hazard Control Grant Program was to implement lead hazard control interventions that would reduce a child's exposure to lead-based paint, dust lead and possibly soil lead. Such reductions were expected to provide health benefits to children currently living in the treated dwellings (secondary prevention) and provide health benefits to very young children or children moving into or born into the dwelling in the future (primary prevention). Although a primary way to assess long-term treatment effects is to study post-intervention blood lead levels (see Chapter 9), it was recognized from the start of the Evaluation that confounding factors influencing children's blood lead levels would limit the use of blood lead as an outcome measure. In addition, while blood lead levels would be a lagging indicator of the effects of the intervention, the post-intervention dust lead loadings would serve as an immediate measure of how well interventions reduced lead exposures and maintained those levels. Thus, while improvements in children's health were the ultimate goal of the Lead Hazard Control Grant Program, the intermediate effects of interventions on post-intervention dust lead loadings proved to be the best measure of treatment effectiveness in the Evaluation.

Previous studies have established that interior dust lead loadings are important predictors of a child's blood lead level. (Lanphear 1996a and 1998) Treatments that would limit the creation of leaded dust in the future as well as directly reduce levels of leaded dust in the child's environment were expected to have beneficial effects on the child's blood lead level.

The lead hazard control interventions implemented through the Lead Hazard Control Grant Program were expected to have four main effects on dust lead loadings.

(1) Interventions would generate varying levels of leaded dust depending on how and how much lead-based paint was disturbed during work;
(2) Interventions would change surface conditions on the areas to be sampled that could influence the post-intervention "cleanability" of the surfaces by both the contractors and by residents;
(3) Interventions would require a final cleaning by the contractor that would reduce leaded dust and debris to levels that were at least below the clearance levels at immediate post-intervention; and
(4) Interventions were expected to have varying long-term influences on the potential generation of leaded dust.

The first three effects of interventions had an immediate influence on clearance dust lead loadings; those effects are discussed in Chapter 7. With respect to the fourth effect, treatments that abated lead through the removal of the lead-based paint either by removing the building component or the paint on the surface were expected to permanently prevent the generation of dust lead from that surface. Treatments that abated lead through the enclosure or encapsulation of lead-based paint were expected to prevent the generation of dust lead for at least 20 years (i.e., well beyond the duration of the evaluation). Treatments that made the lead-based paint intact were expected to stop dust lead from being generated for an undetermined period of time until the paint began to deteriorate. Finally, decisions to not treat lead-based painted surfaces that were intact or had only de minimus amounts of deterioration were expected to stop dust lead generation for an unknown period until the paint began to deteriorate.

This chapter will explore the long-term effects of interventions on dust lead loadings. The grantees generally selected a mixture of interim control treatments and abatements on various interior and exterior building components. At a limited percentage of buildings, grantees also treated the lead-contaminated soil, most commonly with interim controls. The effect of the interim controls was expected to change with time; as the interim controls of lead hazards lost their effectiveness and lead-based paint deteriorated, dust lead loadings were expected to rise. The Evaluation team planned to assess this effect by measuring the rate of reaccumulation of the dust lead loadings (Objective 4) and determining the longevity of different intervention strategies. The study design also called for an examination of factors that influenced post-intervention dust lead loadings (Objective 5) and the measurement of changes in dust lead loadings from pre-intervention to post-intervention (Objective 9).

For many reasons, the assessment of the effects of the different intervention strategies on post-intervention dust lead loadings turned out to be more complicated than originally expected. Grantees selected intervention strategies that were based on, among other factors, baseline environmental and building conditions. This presented a confounding relationship. Grantees that had more hazards in the dwellings they treated tended to select more intensive treatments, so that distinguishing the effects of interventions on post-intervention dust lead from the effects of baseline environmental conditions was hampered. Grantees also chose a mixture of intervention measures for the housing: applying a combination of strategies for housing components (e.g., replacing some windows and stabilizing paint on others). In addition, dust lead loadings did not always follow the expected pattern of declining at clearance and then rising at varying rates after clearance. For example, dust lead loadings on floors tended to decline further after clearance, not rise. As explained in Section 8.2, the methodology used to assess dust lead loadings in the study evolved as the constraints of the study became apparent, and hypotheses about changes in dust lead loadings were revised.

Midway through the collection of data, preliminary post-intervention dust lead findings suggested that there were unique grantee effects that could not be explained by the available data. The Evaluation team hypothesized that soil lead and exterior dust lead might help explain some of the observed differences in dust lead loadings. With support from HUD, a study involving a special one-time collection of exterior dust and soil samples was performed by the University of Cincinnati on a subset of 500 buildings in the Evaluation. These data were analyzed to determine the pathways of exterior lead sources into dwellings and the magnitude of effects of the lead on interior dust lead. These findings are presented in Section 8.5.

As explained in Section 8.6, examination of the relationship of treatment failures to dust lead loadings was not possible because the data on treatment failures was not considered to be of adequate quality. Instead, analyses of treatment failures are presented which offer inferential evidence of how the different treatment intensities may influence the observed dust lead outcomes.

The assessment of effects of interventions on dust lead loadings focused on the impact of interventions at the dwelling unit level. The interior intervention strategies defined in Chapter 5 were the primary focus of these comparative analyses (Table 8-2). These analyses also considered the effect of exterior and/or site work on the dust lead outcomes. In a separate set of analyses, the effects of individual lead hazard control treatments to specific housing components on dust lead loadings were also assessed (see Section 8.7). This assessment focused primarily on the difference in the intensity of window treatments (e.g., window replacement and window paint stabilization).

8.2 METHODOLOGY

During the first two funding rounds of the HUD Lead Hazard Control Grant Program, dust lead testing was conducted prior to intervention, at clearance and six and twelve months after intervention. These collection times were called phases. Dust lead samples were collected from interior floors, window sills and window troughs (previously known as window wells). Interior dust lead loadings were used as a measure of the safety and effectiveness of the lead hazard control interventions that the grantees selected.

8.2.1 Dust Collection Methodology

The Evaluation protocols further defined the dust lead testing requirements. Dust lead samples were collected from floors at the interior entry to the dwelling, the child's playroom (or a living area), the kitchen, and the two youngest children's bedrooms during each sampling phase of the study. Floor dust lead samples were collected near the primary doorway to the room. Dust lead samples were also collected at each phase from window sills in the kitchen and youngest child's bedroom and from window troughs in the playroom and the next youngest child's bedroom.

Because dust lead sampling is in practice a "disruptive" sampling method that removes leaded dust from the surface, efforts were made to reduce the effect of sampling of a prior phase on the sampling of a later phase. Therefore at each successive sampling phase, samples were taken from half of the window sill and trough with the location of the sample alternating from phase to phase. Likewise, floor samples were taken from alternate sides of the doorway.

The Evaluation protocols required the collection of the pre-intervention dust lead samples to occur within six weeks prior to the lead hazard control intervention[1]. This sampling would serve as a baseline dust lead level for the dwelling. The specific locations of the windows and doorways that were sampled were recorded so that data collectors could return to a location adjacent to the same spot during subsequent sampling phases. The Massachusetts and Wisconsin grantees collected two pre-intervention dust lead samples from a majority of their dwellings. A second sample was collected either because the first sample was taken too early or because educational efforts of the grantee might have changed the baseline conditions of the dwelling. When two samples were collected, the pre-intervention dust sample that was closest to the intervention was used in the statistical analyses of the effectiveness of lead hazard controls.

Samples collected at clearance were used to represent the immediate post-intervention dust lead loadings at the dwelling. As described in Chapter 7, multiple clearance dust lead sampling events were sometimes required when the dwelling did not pass clearance on the initial or subsequent attempts. Unlike Chapter 7, which focused on the initial clearance results, this chapter used the final clearance sampling results.

[1] For statistical analysis, dust samples collected between 16 weeks before the start of intervention and 4 weeks after the start of intervention were accepted as eligible pre-intervention samples.

Dust lead samples were also collected at 6 and 12 months after the date of final clearance. When HUD approved the extension of the Evaluation, the protocols were amended to require additional dust lead samples to be collected two- and three years after the clearance date, for selected dwellings from grantees participating in the extension.

Dust lead samples were most commonly collected using a standard dust wipe sampling procedure described both in the Evaluation protocols and subsequently in the 1995 HUD *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing* (HUD 1995). All samples were collected by single-surface sampling; composite dust lead sampling was not permitted.

Originally, the protocols called for wipe sampling to be conducted only on uncarpeted surfaces of the floor; wipe sampling on carpets was not approved. However, one year after the protocols were issued, and before most Evaluation data were collected, the Evaluation team notified grantees that dust wipe samples from carpeting were acceptable if the floor by the doorway was carpeted. The Evaluation protocols allowed, and originally encouraged, grantees to collect carpeted floor samples using the University of Cincinnati DVM vacuum sampling method (Que Hee 1985). However, only one grantee routinely collected vacuum samples. Because the number of vacuum sample results was limited and because vacuum sample results are not comparable to wipe sample results, vacuum sample results are not included in this report.

Each grantee selected its own laboratory (or laboratories) to analyze the dust samples. Each laboratory was required to show evidence that it was proficient under the Environmental Lead Proficiency Analytical Testing Program. Laboratories were not required to be accredited under the EPA National Lead Laboratory Accreditation Program because the study began early in that program's existence and few laboratories were as yet recognized. Lead was measured by flame atomic absorption, graphite furnace atomic absorption spectrophotometry or inductively coupled plasma-atomic emission spectrometry. Grantees were required to submit double blind quality control samples provided through the Evaluation and blank samples at a specified rate. More details on QA/QC procedures for dust lead samples and the procedures for the substitution of dust lead values below the levels of detection are presented in Section 3.2.

8.2.2 Objectives of Data Analysis Methodology

As mentioned earlier the selection of intervention strategies was not made on a random basis and thus the distribution of pre-intervention conditions were not the same for each of the strategies. Since the impact of interventions frequently depends on the pre-intervention conditions, differences in pre-intervention must be taken into account in evaluating the impact of interventions on these three measures of intervention success. The Evaluation team considered three measures of intervention success:

- dust lead loadings at a point in time after intervention,
- changes (%) in dust lead loadings from baseline to a point in time after intervention, and
- percent of dust lead loadings above a given level at a point in time after intervention.

Each measure has advantages and disadvantages as an assessment tool. Before looking at the specific findings of the study, the relative benefits and drawbacks of each of the measures are first presented.

8.2.2.1 Post-Intervention Dust Lead Loadings as a Measure of Effectiveness. One measure of effectiveness tested whether the dust lead loadings at a point in time after intervention differed by the intervention strategy. Ultimately, the risk to the children is based on the amount of lead to which they are exposed in their residence. If, one year after treatment, the floor dust lead loadings associated with one strategy are significantly higher than the loadings associated with a second strategy other things being equal, then arguably the first strategy was less effective than the second. Similarly, if a year after intervention, there is no significant difference between the intervention strategies, then the interventions may be considered equally effective.

8.2.2.2 Changes (%) from Pre-Intervention to Post-Intervention Dust Lead Loadings as a Measure of Effectiveness. A second measure of effectiveness tested whether the percent change in dust lead loadings from baseline to a point in time after intervention differed by the intervention strategy. This measure has a potential advantage over the dust lead loading measure because it reduces the possibility of attributing success to an intervention when the pre-intervention conditions were a more likely cause. For example, if a particular strategy yielded an average post-intervention dust lead loading that was not significantly different from pre-intervention, then this strategy appears ineffective, regardless of its comparative post-intervention loading.

8.2.2.3 Percent of Dwellings with Dust Lead Loadings Above a Given Level as a Measure of Effectiveness. A third measure of effectiveness tested whether the percentage of dwellings with a maximum dust lead loading above a given level at a point in time after intervention differed by the intervention strategy. The previous measures provide information about the relative differences in the effects of interventions, but they may not answer the practical question: did the different interventions achieve levels that might be considered safe? The post-intervention dust lead loadings associated with one strategy might be significantly higher than all of the other strategies, but if few dwellings for any strategy were above the selected level, then all strategies would appear to meet a minimum criteria for effectiveness. This measure examined the actual outcomes and compared those outcomes across strategies.

Because the standards of lead safety changed since the Evaluation data were collected, this measure is not as easily interpretable as it once might have been. For example, window sill dust lead loadings should be less than 250 $\mu g/ft^2$ under current standards, but because the sills were only required to clear at 500 $\mu g/ft^2$ during the Evaluation period, it may be unfair to suggest that interventions could not achieve and maintain the current standard. As a result, both levels were examined. Likewise, the floor standard has changed from 200 to 100 to 40 $\mu g/ft^2$ since the Evaluation began. The association between the interior strategies performed and the probability that floor dust lead results in those dwellings were under the levels of 100 or 40 $\mu g/ft^2$ is presented in this report. Even though most grantees cleared at 200 $\mu g/ft^2$, the 1990 clearance standard specified in the HUD Grant agreements, this level was not examined because so few dwellings exceeded this level one-year post-intervention.

8.2.2.4 Discussion of the Use of these Measures. The choice of a treatment intervention was often largely dependent on the pre-intervention conditions of the dwelling and the funds available. During field visits, the Evaluation team observed that dwellings with multiple lead hazards and building components in poor condition were generally judged to need substantial lead interventions to achieve clearance. Therefore, lower intensity strategies were less commonly applied to dwellings that had many lead hazards, and were instead generally used in dwellings with lower dust lead loadings on floors and window sills. Conversely, grantees tended to use higher intensity strategies (i.e., those that included window replacement) in dwellings that had higher pre-intervention dust lead loadings. However, such higher intensity strategies were also used in dwellings with a limited number of lead hazards. Grantees may have determined that leaded components that were currently maintained might not be maintained in the future, so abatement was appropriate. Alternatively, grantees may have been required by local laws or local standards of care to abate leaded surfaces regardless of their condition.

As a result of the choices that grantees made, this Evaluation was able to look at the different effects of interventions when dwellings are in relatively good or fair condition compared to other older, grant eligible properties. The Evaluation had less power to examine the comparative effects of low intensity strategies in dwellings in relatively poor condition because such treatments were so rarely conducted.

8.2.3 Statistical Methodology

The 2,682 dwelling units that had dust samples collected at clearance and that had dust lead loadings below the grantee-specific clearance criteria were initially eligible for the statistical analyses on the effects of interventions on dust lead loadings through one-year post-intervention. Of the 2,682 dwellings that had evidence of clearance, 1,602 (60%) had pre-intervention and one-year post-intervention dust lead results available for all four dust lead sampling surfaces of interest (entry floors, interior floors, window sills and window troughs). Of the 826 dwellings enrolled in the extended Evaluation, 744 had evidence of passing clearance and were initially eligible for two-year and three-year post-intervention analyses. Of these 744 dwellings, 452 (61%) had pre-intervention and three-year post-intervention dust lead results available for all four dust lead sampling surfaces of interest.

Dust lead loadings were generally analyzed as the dwelling unit average of each type of component sampled (floors, window sills and window troughs). After preliminary analyses, an exception was made for floors. Entry floors were analyzed separately from other interior floor results because entry floor loadings were consistently higher than those of other interior floors and were likely indicative of the pathway of leaded dust from the building exterior or common areas into the dwelling.[2] On average, the interior floor result was the arithmetic mean of three samples, the window sill result was the mean of two samples and the window trough result represented a single sample[3].

[2] Carpeted floors and painted floors were both found to have significantly different dust lead loadings than uncarpeted and unpainted floors, but because they did not represent unique pathways, they were not treated separately. A variable for floor type was examined in all models with interior floor dust lead as an outcome measure.
[3] In less than a third of the dwellings, a second bedroom was sampled; thus, only three interior floors and one window trough sample was available for a majority of the dwellings.

Three principal methods of statistical modeling were employed to examine variables influencing post-intervention dust lead loadings. Repeat measures (RM) modeling was used to assess the trends in dust lead loadings across sampling phases. Multiple regression methods were used to investigate factors that influence post-intervention dust lead loadings. Structural equation models (SEMs) were fit to determine pathways and predictors of dust lead measures as well as examine how the interventions changed the pathways found in the pre-intervention SEM model.

The SAS procedure PROC SYSLIN was used to run the SEM models and PROC MIXED was used to run the multiple regression and RM models. All lead variables (i.e., dust lead and paint lead) were transformed to their natural logarithm to normalize their statistical distributions. All modeling is based on the log of the household arithmetic mean dust lead loading and tables present the geometric means of the appropriate groups of household arithmetic means. Volume I of the Compendium presents a detailed explanation of how each model was developed and run. Summaries are provided below for the repeated measures models, multiple regression models, and the SEM models.

8.2.3.1 Repeated Measures Models. The RM models are employed to analyze multiple phases of dust results per dwelling. The models examined trends in post-intervention dust lead loadings from clearance onward. The RM models analyzed entry floor, interior floor, window sill, and window trough dust lead outcomes at final clearance, six-months and one-year post-intervention for dwellings in the base Evaluation. The RM models also analyzed entry, interior floor, window sill, and window trough dust lead outcomes at clearance, six-months, one-, two- and three-years post-intervention for dwellings in the extended Evaluation. Overall four base Evaluation and four extended Evaluation RM models were run. Phase, interior strategy and interaction of phase and interior strategy were entered as possible predictors of post-intervention dust lead loading. A backward elimination of insignificant independent variables ($p>0.05$) was performed; the interior strategy was retained in each model regardless of statistical significance to allow for a test of its effects in the final model. The dependent variable in each RM model is the log of the household arithmetic mean dust lead loading for the sample type.

8.2.3.2 Multiple Regression Models. Multiple regression models were used to explore the predictors of dust lead loading at one post-intervention time. Multivariate models analyzed entry, interior floor, window sill, and window trough dust lead outcomes at one-year for dwellings in the base Evaluation and three years for dwellings in the extended evaluation. Possible predictors included environmental measures and housing characteristics and conditions. A backward elimination of insignificant independent variables ($p>0.05$) was performed; the interior strategy was retained in each model regardless of statistical significance to allow for a test of its effects in the final model. The dependent variable in each multiple regression model is the log of the household arithmetic mean dust lead loading for the sample type.

Dwellings were eligible for the base Evaluation dataset if they cleared and had pre-intervention and one-year post-intervention dust lead data from all four sample types (entry floor, interior floors, window sills and window troughs). Dwellings were also required to have complete data for all the variables identified in Exhibit 8-1 for the four one-year post-intervention multiple regression models for inclusion. Similar rules applied for the extended Evaluation dataset.

8.2.3.3 Post-Intervention Structural Equations Models. A Structural Equations Model (SEM) is a means of estimating direct and indirect effects within or on a set of interrelated variables. The effects of environmental and demographic data on entry floor, interior floor, window sill and window trough dust lead loading was assessed. The relationships between dust lead loadings on the four sample types was also explored. A pre-intervention dust SEM was developed to establish the baseline pathways of lead through the home environment. The predictors of the pre-intervention outcomes established in the pre-intervention model were included as predictors (see section 8.4.3.1) of pre-intervention outcomes in the post-intervention model. No step-wise inclusion or elimination of pathways was performed for pre-intervention outcomes. All variables specified in Exhibit 8-1 were included as possible predictors of post-intervention outcomes. Backward elimination of insignificant predictors of the post-intervention outcomes was performed, followed by forward inclusion steps to re-enter, as needed, previously excluded pathways. The variable *interior lead hazard control strategy* was forced into the one year post-intervention SEM model. However, if interior strategy was not a significant variable, it was not included in the final output figures.

8.3 Effectiveness of All Interventions on Longitudinal Dust Lead Loadings

This section presents information on the overall impact of the HUD LHC Grant Program on dust lead loadings post-intervention as measured by unadjusted results. One set of descriptive statistics is presented for the dwellings that had dust lead results for all four dust lead sampling surfaces of interest (entry floors, interior floors, window sills and window troughs) at both pre-intervention and one-year post-intervention and met the statistical model requirements for the one-year multiple regression analyses. A second set of descriptive statistics is presented for the dwellings that had dust lead results available on all four sampling locations at both pre-intervention and three years post-intervention and met the statistical model requirements for the three-year multiple regression analyses. These same datasets were used for the analyses of specific intervention effects discussed in Section 8.4 (with the exception of the SEM models).

8.3.1 Dwellings Meeting the Requirements in the Base Evaluation

The 1,034 dwellings available in this dataset were not a random sample of dwellings from the whole population, but were dependent on the willingness of residents and owners to participate in the longitudinal study as well as availability of data for all sampling locations in dwellings. Certain grantees and certain interventions were more likely to have a greater percentage of the dwellings in the dataset (Table 8-1).

The data in the one-year post-intervention dust lead analysis dataset also had somewhat different housing characteristics than the dwellings in the clearance dataset. Twenty-five percent were owner-occupied as compared to 20 percent in the clearance dataset. The dwellings were more likely to be in single-family buildings (41% v. 31%) and less likely to be in buildings with more than four units (21% v. 29%).

The overall dust lead findings were heavily influenced by dust lead results from dwellings treated with Interior Strategy 05 (see Table 8-2 for strategy definitions).[4] Dwellings treated with this strategy contributed 65 percent of the dwellings in the one-year longitudinal dataset

[4] See Section 5.2 for a more detailed description of dwelling unit interventions. Effects of Interior Strategy 01 (No Interior Work) are not presented in this chapter because less than 20 dwellings were treated with these interventions.

(compared with 55 percent in the clearance dataset). The data would have been even more heavily weighted toward higher intensity treatments, except that the reduction of dwellings from New York City dropped the percentage of results from Interior Strategy 06/07 dwellings from seven percent in the clearance dataset to three percent in the one-year post-intervention dataset.

8.3.2 Dwellings Meeting the Requirements in the Extended Evaluation

Like the base Evaluation dataset, the 278 dwellings available in the extended Evaluation dataset were not a random sample but were dependent on resident and owner participation, availability of needed data, and the grantees that participated in the extended Evaluation. In general, just over one quarter of the dwellings that had data available for the analysis of the base Evaluation dust lead data also had data available in the extended Evaluation (Table 8-1). With just 744 dwellings with evidence of clearance funded for participation in the extended Evaluation, these 278 dwellings include 37 percent of the available homes.

The three-year post-intervention dust lead dataset contained dwellings that were more likely to be owner-occupied and in single-family dwellings than those in the clearance dataset. Thirty-four percent were owner-occupied as compared to 20 percent in the clearance dataset. Fifty-three percent of dwellings were in single-family buildings (v. 31%) and just six percent were in buildings with more than four units (v. 29%). Dwellings treated with Interior Strategies 04 and 05 accounted for 21 and 63 percent, respectively, of the dwellings in extended Evaluation dust lead dataset (v. 16 and 55% in the clearance dataset).

Table 8-1: Number of Dwellings that Cleared and Number of Dwellings in One-Year and Three-Year Dust Lead Analysis Datasets by Grantee

Grantee	Number of Dwellings Cleared	Number of Dwellings in One-Year Dataset[a]	Number of Dwellings in Three-Year Dataset[b]
Alameda County	167 (6%)	6 (<1%)	1 (<1%)
Baltimore	393 (15%)	244 (24%)	68 (24%)
Boston	68 (3%)	36 (3%)	33 (12%)
California	103 (4%)	1 (<1%)	5 (2%)
Chicago	120 (4%)	84(8%)	-
Cleveland	152 (6%)	58 (6%)	-
Massachusetts	134 (5%)	84 (8%)	-
Milwaukee	223 (8%)	93 (9%)	59 (21%)
Minnesota	143 (5%)	66 (6%)	41 (15%)
New Jersey	27 (1%)	1 (<1%)	-
New York City	420 (16%)	132 (13%)	-
Rhode Island	160 (6%)	106 (10%)	26 (9%)
Vermont	391 (15%)	85 (8%)	27 (10%)
Wisconsin	181 (7%)	80 (8%)	18 (6%)
All Grantees	*2,682*	*1,034*	*278*

[a]Dwellings were eligible for the base Evaluation dataset if they cleared and had pre-intervention and one-year post-intervention dust lead data from all four sample types (entry floors, interior floors, window sills and window troughs). Dwellings were also required to have all the variables listed in Exhibit 8-1 for the four one-year post-intervention multiple regression models for inclusion.
[b]Dwellings were eligible for the extended Evaluation dataset if they cleared and had pre-intervention and three-year post-intervention dust lead data from all four sample types (entry floors, interior floors, window sills and window troughs). Dwellings were also required to have all the variables listed in Exhibit 8-1 for the four three-year post-intervention multiple regression models for inclusion.

NOTE: Alameda County, California and New Jersey had less than 5 percent of their cleared dwellings in either data set. Reasons for loss of one-year post-intervention data are presented below (as well as % of cleared units in each category):

	Ala.Co.	Calif.	N.J.	Others
Pre- or Post-Int. Dust Not Collected/Eligible*	36 (22%)	47 (46%)	2 (7%)	566 (24%)
Pre-Intervention Trough Samples Not Collected	54 (32%)	28 (27%)	23 (85%)	123 (5%)
Pre-Int. Entry Samples Not Collected/Eligible**	30 (18%)	0 (0%)	0 (0%)	30 (1%)
Other Dust Samples Missing/Not Eligible	24 (14%)	22 (21%)	1 (4%)	105 (4%)
Other Required Data Missing	17 (10%)	5 (5%)	0 (0%)	535 (22%)
Eligible	*6 (4%)*	*1 (1%)*	*1 (4%)*	*1,026 (43%)*

*When the lab quality for a set of dust lead samples did not meet study criteria, the dust lead samples were ineligible.
**Alameda County had a higher percentage of ineligible entry floor samples because the samples were taken from a small area (< 6” on a side) indicating that they were collected from the threshold instead of inside the doorway.

Table 8-2: Interior Strategy Code Definitions

Strategy		Definition
Interior	01	No Action
	02	Cleaning, Spot Paint Stabilization Only
	03	Level 02 plus Complete Paint Stabilization, Floor Treatments
	04	Level 03 plus Window Treatments
	05	Level 04 plus Window Replacement, Wall Enclosure/Encapsulation
	06	All Lead-Based Paint Enclosed, Encapsulated, or Removed (Meets Public Housing Abatement Standards)
	07	All Lead-Based Paint Removed

Glossary of Treatments

Encapsulation - The application of a covering or coating that acts as a barrier between lead-based paint and the environment, the durability of which relies on adhesion and which has an expected life of at least 20 years.

Enclosure - The application of rigid, durable construction materials that are mechanically fastened to the substrate to act as a barrier between lead-based paint and the environment.

Paint Stabilization - The process of repainting surfaces coated with lead-based paint, which includes the proper removal of deteriorated paint and priming.

Paint Removal - The complete removal of lead-based paint by wet scraping, chemical stripping, or contained abrasives.

Removal/Replacement - The removal/replacement of a building component that was coated with lead-based paint.

Window Treatments - The process of eliminating lead-containing surfaces on windows that are subject to friction or impact through the removal of paint or enclosure of certain window components.

8.3.3 Floor Dust Lead Findings

- One-year post-intervention, the geometric mean interior floor dust lead loading was 12 $\mu g/ft^2$. This represents a 70 percent decline from the pre-intervention levels (Table 8-3/Figure 8-1).
- One-year post-intervention, 18 percent of the dwellings had an interior floor dust lead loading at or above 100 $\mu g/ft^2$. This represents a 55 percent decline from the pre-intervention percentage (40%). Using the current standard of 40 $\mu g/ft^2$, the percentage of dwellings with a single floor dust lead loading at or above the standard declined 41% from pre-intervention to one-year post-intervention (56% to 33%, respectively) (Table 8-4/Figure 8-3).
- Geometric mean interior floor dust lead loadings did not increase from final clearance to one-year post-intervention (13 $\mu g/ft^2$ to 12 $\mu g/ft^2$). However, at one year post-intervention, the percentage of dwellings failing floor clearance standards of 100 $\mu g/ft^2$ increased from 11% at clearance to 18%.
- Three-years post-intervention, the geometric mean interior floor dust lead loading was 9 $\mu g/ft^2$ (Table 8-5). This represents a 78 percent decline from the pre-intervention levels. The percentage of dwellings with an interior floor dust lead loading at or above 100 $\mu g/ft^2$ remained at 18 percent, while the percentage of dwellings with an interior floor dust lead loading at or above 40 $\mu g/ft^2$ declined to 30 percent (Table 8-6).

The effect of interventions on dwelling unit entry floor dust lead loadings was similar to the effect on interior floors, but average entry floor dust lead levels were higher. Geometric mean entry floor dust lead loadings were generally 10 to 20 percent higher than interior floor dust lead loadings across all phases of the evaluation.

8.3.4 Window Dust Lead Findings

On windows, the overall reductions in geometric mean dust lead loadings were even more dramatic. The effects of interventions on window sill and window trough post-intervention dust lead loadings were similar to each other but window trough dust lead levels were higher. At pre-intervention, geometric mean window trough dust lead loadings were 8 to 12 times higher than window sill dust lead loadings, while post-intervention, the trough dust lead loadings were generally 4 to 6 times higher than sill dust lead loadings. (At clearance, the trough dust lead loadings remained higher than the sill dust lead loadings, but the relative difference was much smaller.)

- There was an overall reduction of 434 $\mu g/ft^2$ (88%) in geometric mean window sill lead loadings from pre-intervention to one-year post-intervention. Geometric mean window trough dust lead loadings declined 4,288 $\mu g/ft^2$ (93%) from pre-intervention to one-year post-intervention (Table 8-3/Figure 8-2).
- Window sill dust lead loadings rose 45 $\mu g/ft^2$ from clearance to six months post-intervention before declining 7 $\mu g/ft^2$ from six-months to one-year post-intervention. Geometric mean window trough dust lead loadings rose 367 $\mu g/ft^2$ from clearance to six months post-intervention before declining 75 $\mu g/ft^2$ at one-year post-intervention.

- One-year post-intervention, 14 percent of the dwellings had window sill dust lead loadings at or above 500 µg/ft^2. This represents a 75 percent decline from the pre-intervention percentage (55%). Using the current standard of 250 µg/ft^2, the percentage of dwellings with a single floor dust lead loading at or above the standard declined 63 percent from pre-intervention to one-year post-intervention (67% to 25%, respectively) (Table 8-4/Figure 8-3). Thirty-four percent of the dwellings had a one-year window trough dust lead loading at or above 800 µg/ft^2, a 56 percent decline from the pre-intervention percentage (77%). Using the current standard of 400 µg/ft^2, the percentage of dwellings with a single floor dust lead loading at or above the standard declined 42 percent from pre-intervention to one-year post-intervention (84% to 49%, respectively)
- Three-years post-intervention, the geometric mean window sill dust lead loading was 62 µg/ft^2, an 89 percent decline from pre-intervention and a 13 percent decline from one-year post-intervention (Table 8-5). The geometric mean window trough dust lead loading was 363 µg/ft^2, a 95 percent decline from the pre-intervention levels and a 28 percent decline from one-year post-intervention. The percentage of dwellings with a window sill dust lead loading at or above 500 µg/ft^2 declined to 12 percent, while the percentage of dwellings with a window trough dust lead loading at or above 800 µg/ft^2 declined to 24 percent (Table 8-6).

Discussion

Although the number of dwellings that met the extended Evaluation dust dataset criteria was about one quarter the size of the population that met the base Evaluation dust dataset criteria, the overall changes and observed trends were similar. It is of interest that the extended Evaluation pre-intervention geometric mean window sill and trough dust lead loadings were 14 and 67 percent *higher*, respectively, than those of the base Evaluation dataset, but percentage changes in window dust lead loadings between pre-intervention, six-months and one-year post-intervention were roughly equivalent.

The findings demonstrate that the lead hazard control activities undertaken by the grantees can dramatically reduce the floor dust lead loadings in treated dwellings and those levels can be maintained for at least three years. The fact that geometric mean floor dust lead loadings were 12 µg/ft^2 and 14 µg/ft^2 on interior floor and entry floors three years after clearance further suggests that in housing likely to receive this type of Federal lead-hazard control assistance, the interventions used in the Evaluation can reduce floor dust lead loadings below the current Federal hazard standard (40 µg/ft^2) for an extended period of time.

The interventions were equally effective on window dust lead loadings. Three years post-intervention, the geometric mean window sill dust lead loading was 62 µg/ft^2, or one quarter of the current Federal hazard standard (250 µg/ft^2) for sills. The interventions used in the Evaluation resulted in 95 percent reductions in window trough dust lead loadings one year post-intervention and 97 percent reductions in those loadings three years post-intervention. Although the federal government does not have a standard for window trough dust lead hazards, the geometric mean window trough dust lead loading at three-years post-intervention, 363 µg/ft^2, was below the current clearance standard for troughs (400 µg/ft^2).

Table 8-3: Geometric Mean Dust Lead Loading at Each Sampling Phase of the Evaluation by Surface Sampled: One- Year Post- Intervention Dataset

Sampling Phase	Entry Floor GM (GSD) µg/ft^2	Interior Floors GM (GSD) µg/ft^2	Window Sills GM (GSD) µg/ft^2	Window Troughs GM (GSD) µg/ft^2
Pre-Intervention	45 (7)	40 (6)	496 (7)	4,621 (11)
Clearance	13 (3)	13 (3)	24 (4)	41 (4)
Six-Months Post-Intervention	16 (4)	13 (4)	69 (4)	408 (6)
One-Year Post-Intervention	14 (4)	12 (4)	62 (4)	333 (6)

Table 8-4: Percent of Dwellings with at Least One Dust Lead Loading at or Above Given Standards at Each Sampling Phase of the Evaluation by Surface Sampled: One-Year Post-Intervention Dataset

Sampling Phase	Entry Floor Percent at or above Standard		Interior Floors Percent at or above Standard		Window Sills Percent at or above Standard		Window Troughs Percent at or above Standard	
	100 µg/ft^2	40 µg/ft^2	100 µg/ft^2	40 µg/ft^2	500 µg/ft^2	250 µg/ft^2	800 µg/ft^2	400 µg/ft^2
Pre-Intervention	32%	48%	40%	56%	55%	67%	77%	84%
Clearance	4%	21%	11%	34%	0%	7%	0%	7%
Six-Months Post-Intervention	10%	25%	23%	37%	16%	27%	37%	53%
One-Year Post-Intervention	8%	21%	18%	33%	14%	25%	34%	49%

Figure 8-1: Geometric Mean Entry Floor and Interior Floor Dust Lead Loading from Pre-Intervention to One-Year Post-Intervention

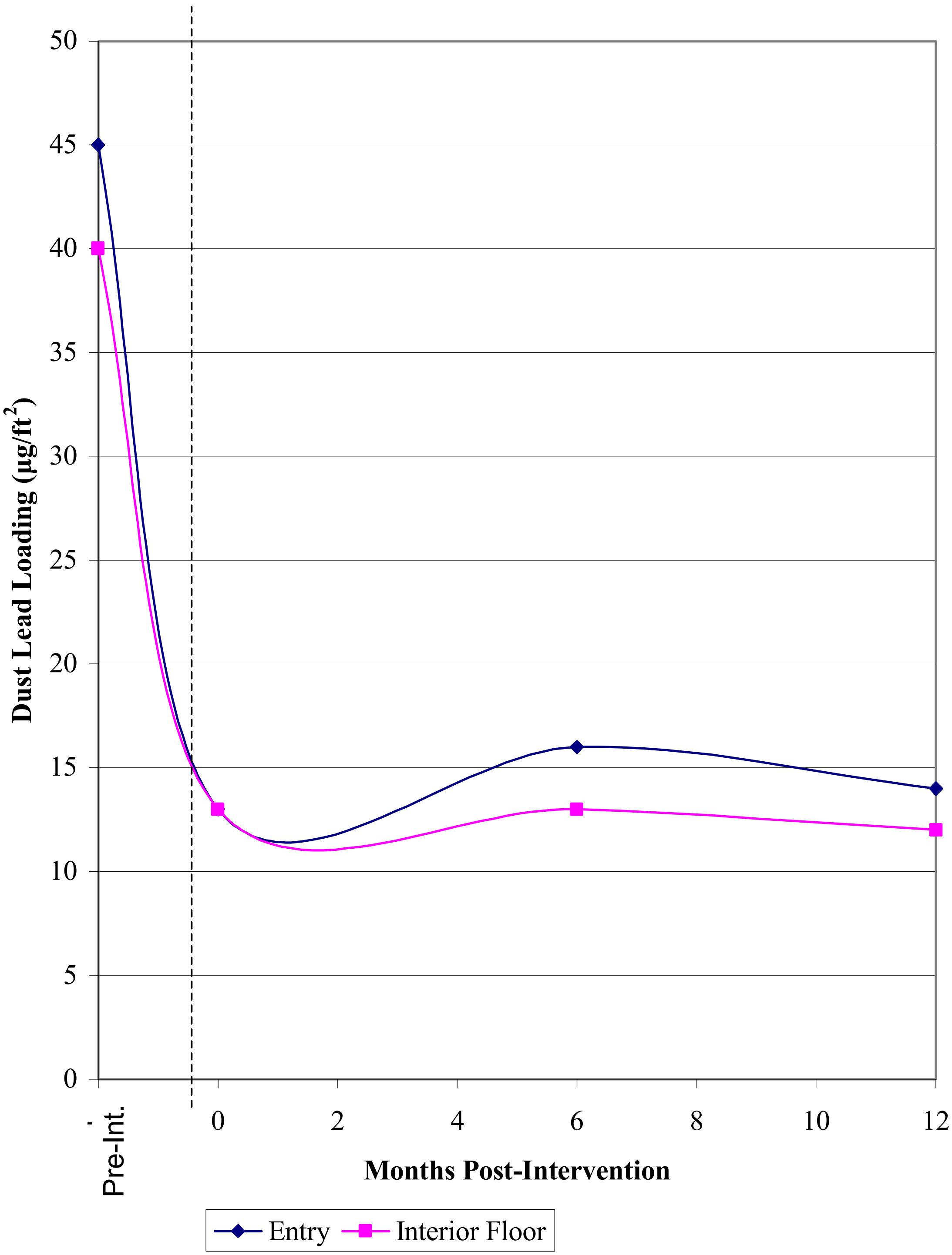


Figure 8-2: Geometric Mean Window Sill and Trough Dust Lead Loading from Pre-Intervention to One-Year Post-Intervention

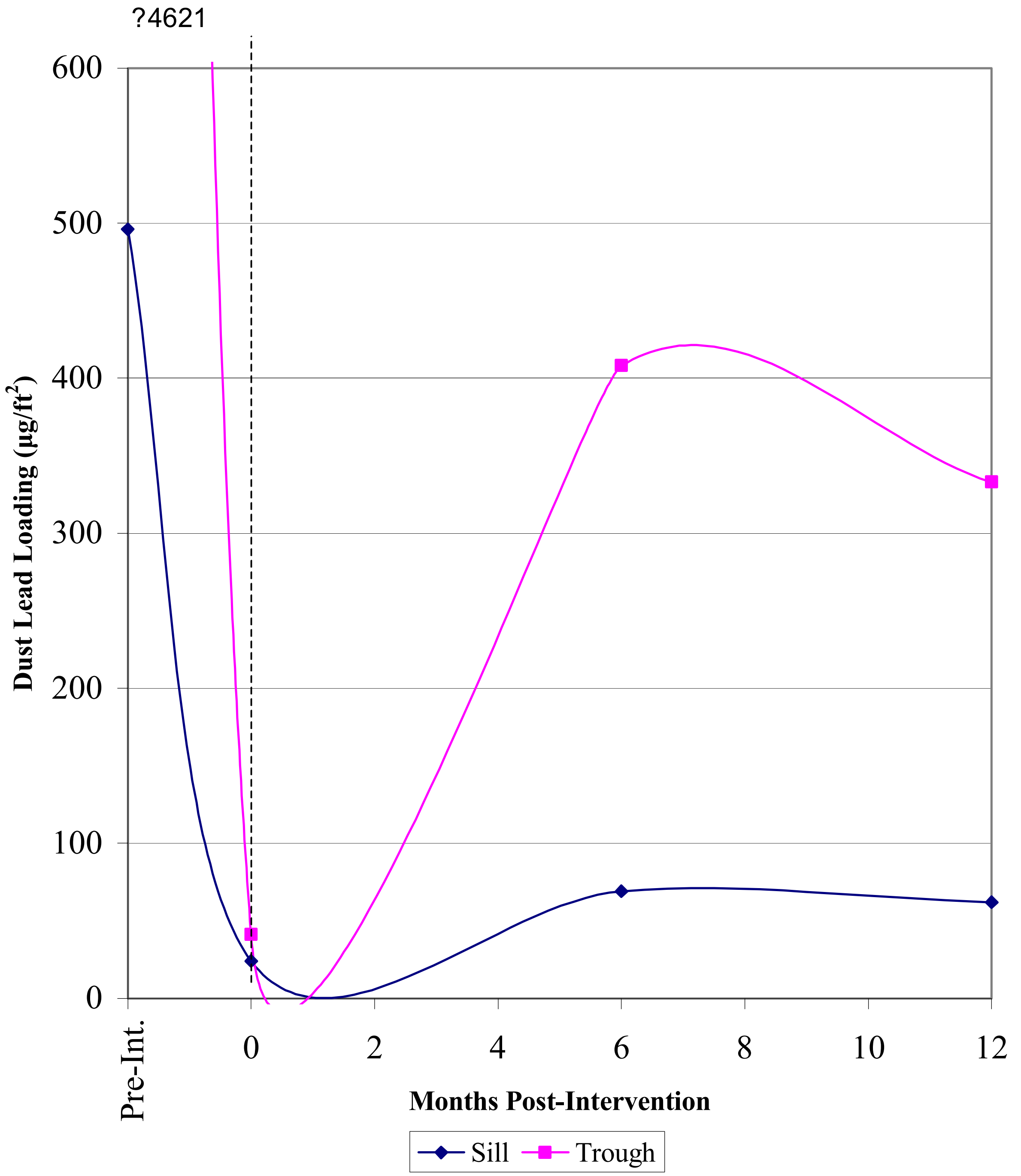


Figure 8-3: Percent of Dwellings with at Least One Dust Lead Loading at or Above 100 µg/ft² on Floors, 500µg/ft² on Window Sills or 800 µg/ft² on Window Troughs from Pre-Intervention to One-Year Post-Intervention

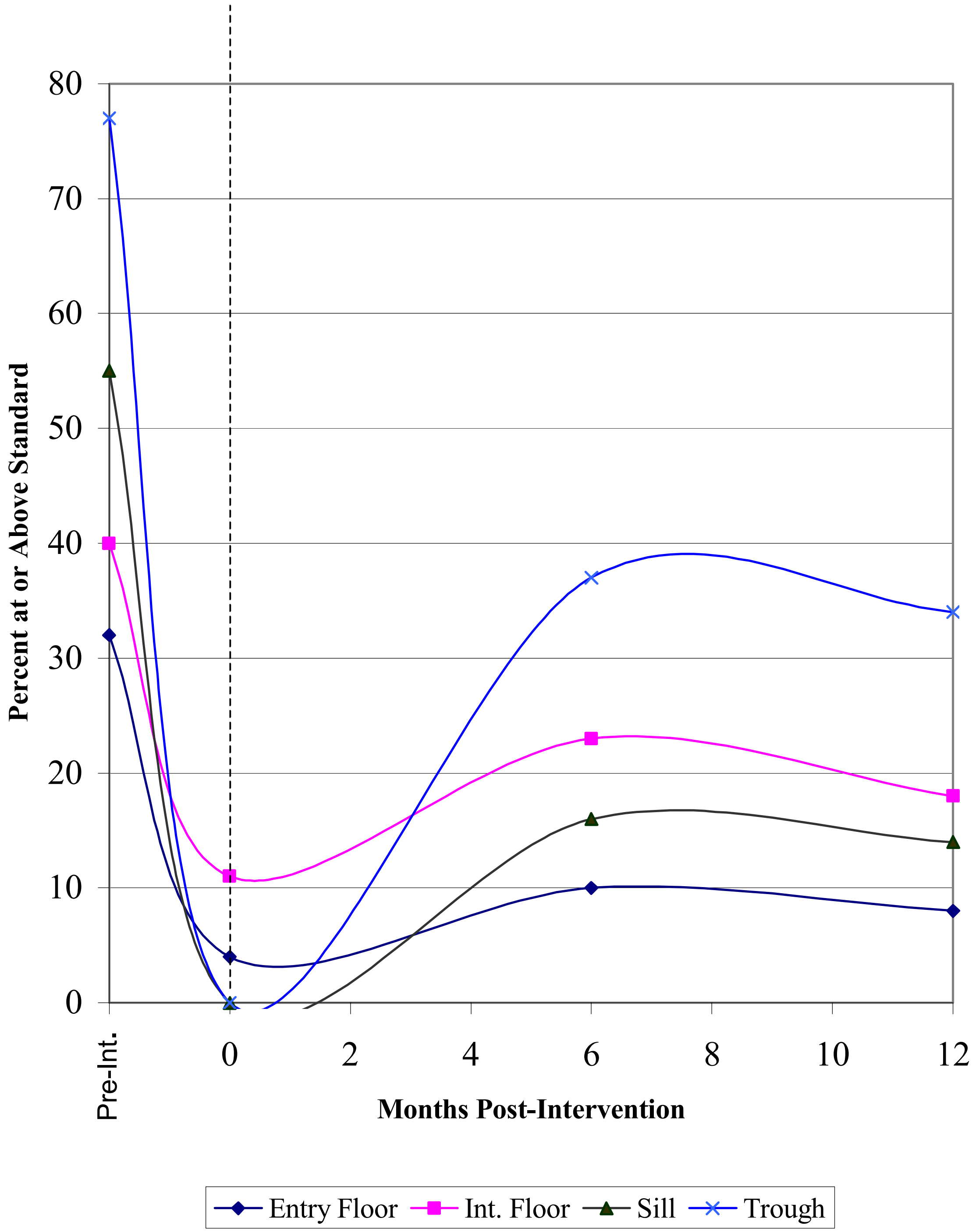


Table 8-5: Geometric Mean Dust Lead Loadings at Each Sampling Phase of the Evaluation by Surface Sampled: Three-Year Post-Intervention Dataset

Sampling Phase	Entry Floor GM (GSD) µg/ft^2	Interior Floors GM (GSD) µg/ft^2	Window Sills GM (GSD) µg/ft^2	Window Troughs GM (GSD) µg/ft^2
Pre-Intervention	48 (7)	40 (6)	576 (8)	7,725 (9)
Clearance	16 (4)	14 (3)	28 (3)	40 (4)
Six-Months Post-Intervention	16 (4)	11 (4)	86 (5)	560 (7)
One-Year Post-Intervention	14 (4)	12 (4)	71 (4)	503 (7)
Two-Years Post-Intervention	12 (4)	10 (5)	61 (5)	390 (9)
Three-Years Post-Intervention	10 (5)	9 (6)	62 (5)	363 (9)

Table 8-6: Percent of Dwellings with at Least One Dust Lead Loading at or Above Given Standards Each Sampling Phase of the Evaluation by Surface Sampled: Three-Year Post-Intervention Dataset

Sampling Phase	Entry Floor Percent at or above Standard		Interior Floors Percent at or above Standard		Window Sills Percent at or above Standard		Window Troughs Percent at or above Standard	
	100 µg/ft^2	40 µg/ft^2	100 µg/ft^2	40 µg/ft^2	500 µg/ft^2	250 µg/ft^2	800 µg/ft^2	400 µg/ft^2
Pre-Intervention	36%	51%	44%	59%	59%	69%	86%	91%
Clearance	8%	24%	13%	39%	0%	11%	0%	8%
Six-Months Post-Intervention	11%	25%	21%	32%	23%	35%	48%	63%
One-Year Post-Intervention	11%	25%	22%	35%	14%	29%	44%	58%
Two-Years Post-Intervention	11%	21%	18%	29%	16%	26%	41%	52%
Three-Years Post-Intervention	6%	19%	18%	30%	12%	24%	38%	51%

The lead hazard control interventions were not only effective in reducing household maximum dust lead loadings below the 1990 HUD Guidance levels (200 µg/ft^2 on floors, 500 µg/ft^{2}on window sills, and 800 µg/ft^2 on window troughs) at clearance, but they were able to maintain maximum dust lead loadings below those levels through three-years post-intervention. Although the grantees were not required to clear to a floor level of 40 µg/ft^2 or a window sill level of 250 µg/ft^2, the treatments were fairly successful in reaching and maintaining these levels through three-years post-intervention. The treatments were less successful in maintaining window trough dust lead loadings below the current standard of 400 µg/ft^2, with over half of the dwellings having exceeding the standard one to three years after clearance.

8.4 Relative Effectiveness of Intervention Strategies on Dust Lead Loadings

The overall statistics offer the reader a context to identify apparent trends in dust lead loadings across time. However, the focus of the objectives of the Evaluation was to determine whether the various lead hazard control treatments used by grantees had differential effects on dust lead loadings. This section of the report examines in detail the relative effectiveness of various interior and exterior lead hazard control treatments on post-intervention dust lead loadings.

This section is divided into three subsections. The first subsection uses the RM models described in Section 8.2.3 to look at the effect of interior strategies on post-intervention dust lead loadings without consideration of other variables. The second subsection examines the effects of interior strategies and other lead hazard control work on post-intervention dust lead loadings when other factors are considered with multiple regression models. The third subsection observes the pathways of paint and dust lead both pre-intervention and one-year post-intervention and considers how the lead hazard control interventions modified those pathways with SEMs.

8.4.1 Relationships Between Interior Strategy and Post-Intervention Dust Lead Loadings Without Consideration for Other Factors

This section presents the observed associations between interior strategy and dust lead loadings without consideration of other factors. As will be presented in Section 8.4.2, these bivariate associations are generally similar to the relationships between the two variables when other factors are considered. The multivariate models will demonstrate that other factors can influence the relationships between the interior interventions and dust lead loadings, but a presentation of the non-model adjusted findings offers important context for the later findings.

8.4.1.1 Floor Dust Lead Loadings: One-Year Post-Intervention. Findings for the geometric mean pre- and one-year post-intervention floor dust lead loadings by Interior Strategy are presented on Tables 8-7 and 8-8. These tables also present the percentage of dwellings at pre- and one-year post-intervention with the entry or at least one interior floor sample above[5] 100 or 40 µg/ft^2 by Interior Strategy.

[5] Even though most grantees cleared at 200 µg/ft^2, the 1990 clearance standard specified in the HUD Grant agreements, this level was not examined because so few dwellings exceeded this level one-year post-intervention. One hundred (100) µg/ft^2 represents the 1995 HUD interim guidance standard for floors while 40 µg/ft^2 represents the current Federal clearance standard.

Table 8-7: Geometric Mean Entry Dust Lead Loadings and Percent of Dwellings with Entry Floor Dust Lead Loadings at or Above 40 or 100 µg/ft^2 at Pre- and One-Year Post-Intervention by Interior Strategy

Interior Strategy	Number of Dwellings	Geometric Mean Entry Floor Dust Lead Loading (µg/ft^2) by Intervention Phase		Percent of Dwellings by Phase with the Entry Floor Sample at or Above:			
		Pre-	1 Yr Post-	100 µg/ft^2		40 µg/ft^2	
				Pre-	1 Yr	Pre	1 Yr
02	56	12	10	2%	5%	14%	13%
03	122	23	12	11%	7%	24%	16%
04	147	46	15	31%	14%	48%	31%
05	675	55	15	38%	8%	55%	22%
06/07	34	80	7	47%	0%	62%	3%
All	1,034	45	14	32%	9%	48%	21%

Table 8-8: Geometric Mean Interior Floor Dust Lead Loadings and Percent of Dwellings with at Least One Interior Floor at or Above 40 or 100 µg/ft^2 at Pre- and One-Year Post-Intervention by Interior Strategy

Interior Strategy	Number of Dwellings	Geometric Mean Interior Floor Dust Lead Loading (µg/ft^2) by Intervention Phase		Percent of Dwellings by Phase with at Least One Interior Floor Sample at or Above:			
		Pre-	1 Yr Post-	100 µg/ft^2		40 µg/ft^2	
				Pre-	1 Yr	Pre	1 Yr
02	56	10	6	11%	2%	23%	13%
03	122	17	9	13%	7%	31%	20%
04	147	38	9	31%	11%	53%	22%
05	675	50	15	48%	24%	64%	41%
06/07	34	95	6	56%	0%	71%	3%
All	1,034	40	12	40%	18%	56%	33%

Post-clearance trends of entry and interior floor dust lead loadings by strategy were also explored (Figures 8-4 and 8-5, respectively). The dust lead loadings displayed differing trends by intervention after the treatments were completed. At final clearance, the geometric mean dust lead loadings on floors treated with Interior Strategies 02 and 05 were lower than those of other strategies (see Section 7.3.2.3 for further discussion). In dwellings treated with Interior Strategy 05, geometric mean dust lead loadings on both entry floors and interior floors significantly *increased* until six months post-intervention. During the same time period, dust lead loadings of interior floors treated with Interior Strategies 03, 04 and 06/07 significantly *declined* from clearance to six months post-intervention. Entry floor dust lead loadings in dwellings treated with Interior Strategy 06/07 also significantly decreased until six months post-intervention. Between six months and one-year post-intervention, geometric mean entry floor and interior floor dust lead loadings generally remained constant or declined slightly (1-2 $\mu g/ft^2$) regardless of the intervention.

Discussion

The longitudinal finding of most interest is that across all strategies, there was no indication that dust lead loadings on floors increased between clearance and three-years post-intervention. Indeed, dust lead loadings *declined* between these two sampling phases. If any lead-based paint deteriorated and generated dust lead, it likely was removed from the floors through routine cleaning and use. Although the sample sizes for dwellings treated with Interior Strategies 02 and 03 are small (therefore limiting the significant differences that might have been observed between strategies), the trends of the different interior interventions on post-intervention dust lead loadings were comparable.

These longitudinal trends, especially the trends from clearance to six-months post-intervention, offer important insights into the changes in dust lead loadings following clearance. Although the study originally anticipated that the clearance dust lead loadings would be the lowest loadings observed during the course of the study, post-intervention dust lead loadings showed continuing declines for three out of five of the strategies. After occupants returned to dwellings treated with Interior Strategies 03, 04 and 06/07, additional dust lead was removed from these dwellings. These same interventions had the highest floor dust lead loadings at clearance, suggesting that worksite containment and cleaning were not as effective in these dwellings as in dwellings treated with Interior Strategy 02 or 05. In fact, for a small percentage of the dwellings, the treatment left more leaded dust in the home than existed prior to work (see Section 8.4.2.1.2).

Interestingly, dwellings treated with Interior Strategy 05 had significant increases in dust lead loadings between clearance and six-months post-intervention. Previous studies have observed that following final clearance, dust lead loadings can reaccumulate rapidly. Results from the Baltimore Repair and Maintenance Study identified an increase in dust lead loadings that occurred within two months of the intervention before loadings leveled off (EPA 1997a). The investigators in that study suggested that when families returned to their dwellings, leaded dust was brought into the dwelling from external sources.

Figure 8-4: Entry Floor Dust Lead Loading from Clearance to One-Year Post-Intervention by Interior Strategy

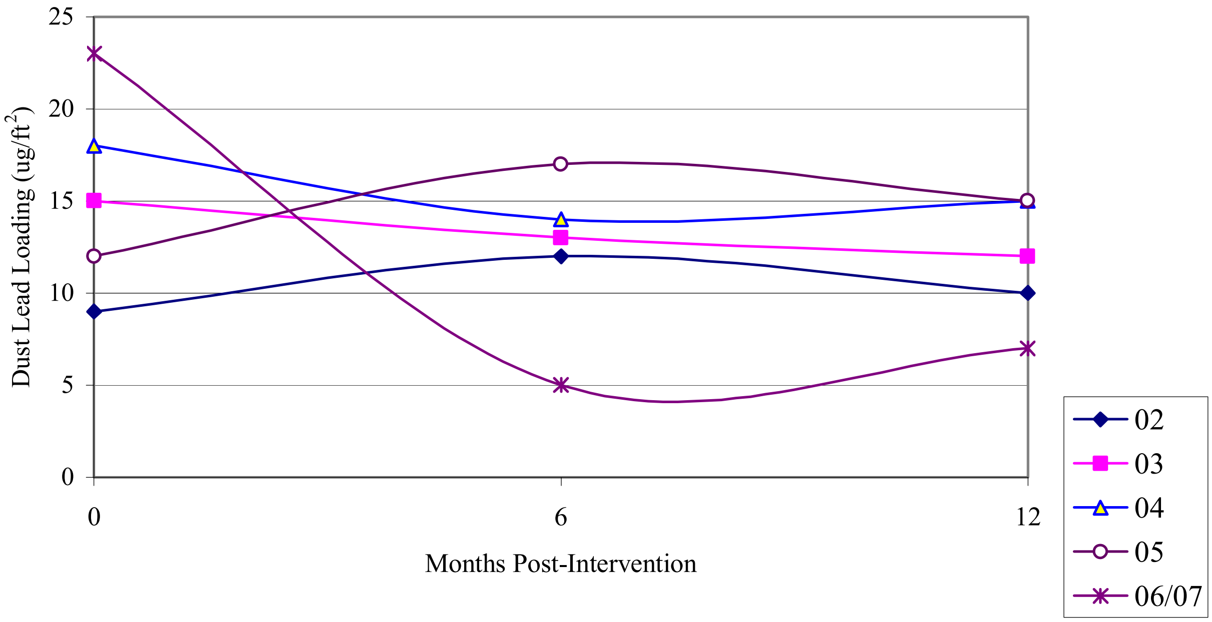
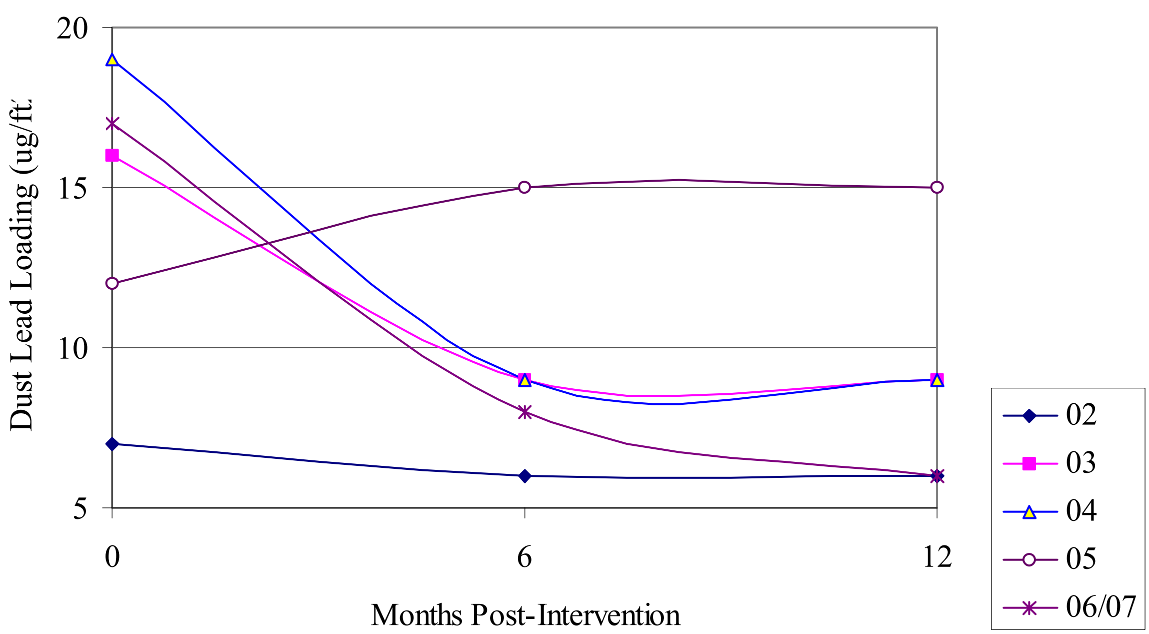


Figure 8-5: Interior Floor Dust Lead Loading from Clearance to One-Year Post-Intervention by Interior Strategy



These findings suggest that the measurement of dust reaccumulation as originally conceived by the Evaluation team did not consider other substantial factors. Beyond the effects of deteriorating interior paint lead adding to the leaded dust in the dwelling, the effects of occupancy and the effects of external sources of leaded dust appear to have affected changes in dust lead immediately after clearance. Therefore, the use of the clearance loadings as a "baseline" for reaccumulation of leaded dust from treatment failures would not be appropriate. Furthermore, the findings of the dwellings treated with Interior Strategy 06/07 suggest that after one year, dust lead loadings in these dwellings was still approaching, but had not reached equilibrium (i.e., a point where the removal of leaded dust by routine cleaning was balanced by the introduction of leaded dust from environmental sources).

8.4.1.2 Floor Dust Lead Loadings: Three-Years Post-Intervention. Three-year post-intervention dust lead data were examined to determine whether the trends observed in the base Evaluation continued for two additional years and whether any new trends emerged between one- and three-years post-intervention. Unfortunately, comparisons between strategies were less robust in the extended Evaluation because of low sample sizes. The number of available dwellings dropped from 1,034 dwellings in the base Evaluation to 278 in the extended Evaluation. Furthermore, the sample sizes for some of the intervention strategies were quite small. The main contributor of dwellings treated with Interior Strategy 03 or 06/07, New York City, did not participate in the extended Evaluation. Too few Interior Strategy 06/07 dwellings (7) were available in the extended Evaluation to draw meaningful conclusions, so this strategy was not analyzed. Just 20 dwellings were treated with Interior Strategy 02 and 23 dwellings treated with Interior Strategy 03. When other factors are considered, comparisons between strategies will likely be limited to the effects of Interior Strategy 05 versus Interior Strategy 04.

Findings for the geometric mean three-year post-intervention floor dust lead loadings and the percentage of dwellings with the entry or at least one interior floor sample above 100 or 40 µg/ft^2 by Interior Strategy are presented on Tables 8-9 and 8-10.

Table 8-9: Geometric Mean Entry Dust Lead Loadings and Percent of Dwellings with Entry Floor Dust Lead Loadings at or Above 40 or 100 µg/ft^2 at Pre- and Three-Years Post-Intervention by Interior Strategy

Interior Strategy	Number of Dwellings	Geometric Mean Entry Floor Dust Lead Loading (µg/ft^2) by Intervention Phase		Percent of Dwellings by Phase with the Entry Floor Sample at or Above:			
		Pre-	3 Yr Post-	100 µg/ft^2		40 µg/ft^2	
				Pre-	3 Yr	Pre	3 Yr
02	20	12	11	5%	0%	20%	5%
03	23	34	7	22%	4%	35%	13%
04	59	35	10	25%	7%	42%	14%
05	176	65	11	45%	7%	60%	23%
All	278	48	10	36%	6%	50%	19%

Table 8-10: Geometric Mean Interior Floor Dust Lead Loadings and Percent of Dwellings with at Least One Interior Floor at or Above 40 or 100 µg/ft² at Pre- and Three-Years Post-Intervention by Interior Strategy

Interior Strategy	Number of Dwellings	Geometric Mean Interior Floor Dust Lead Loading (µg/ft²) by Intervention Phase		Percent of Dwellings by Phase with the Interior Floor Sample at or Above:			
		Pre-	3 Yr Post-	100 µg/ft²		40 µg/ft²	
				Pre-	3 Yr	Pre	3 Yr
02	20	10	8	10%	0%	20%	10%
03	23	16	5	22%	0%	43%	4%
04	59	27	8	32%	12%	53%	25%
05	176	60	10	55%	24%	68%	37%
All	278	40	9	44%	18%	59%	30%

The trends for post-intervention entry floor and interior floor dust lead loadings by interior strategy in the extended Evaluation dataset (Figures 8-6 and 8-7) were similar to those in the base Evaluation dataset between clearance and one-year post-intervention. However, no significant differences between interior strategies were identified for entry floors in the extended Evaluation dataset.

Between one-year and three-years post-intervention, both entry floor and interior floor dust lead loadings in dwellings treated with Interior Strategies 03, 04 and 05 declined, while those in dwellings treated with Interior Strategy 02 increased. For those floor dust lead loadings that declined, the dust lead loadings generally decreased 3-4 µg/ft², or roughly 30 percent in the two years of the extension. The changes for Interior Strategies 04 and 05 were statistically significant.

Discussion

As discussed in the one-year findings, the changes immediately after clearance may reflect the influence of activities other than the deterioration of interior lead-based paint, such as the movement of external sources of lead into a dwelling following treatment[6] and the routine cleaning of a reoccupied dwelling. Furthermore, the results reinforce the observation made with the base Evaluation data that because it takes time for dust lead loadings to reach equilibrium, it is difficult to identify a post-intervention "baseline" from which to measure the potential reaccumulation of dust lead.

[6] A study by NCHH in Cambridge, Massachusetts observed that after dwellings were treated and cleared, work continued in the common areas and hallways and within one month of clearance entry dust lead loadings within the dwellings increased dramatically. The external sources may reflect sources at the property being treated as well as in the local environment.

Figure 8-6: Entry Floor Dust Lead Loading from Clearance to Three-Years Post-Intervention by Interior Strategy

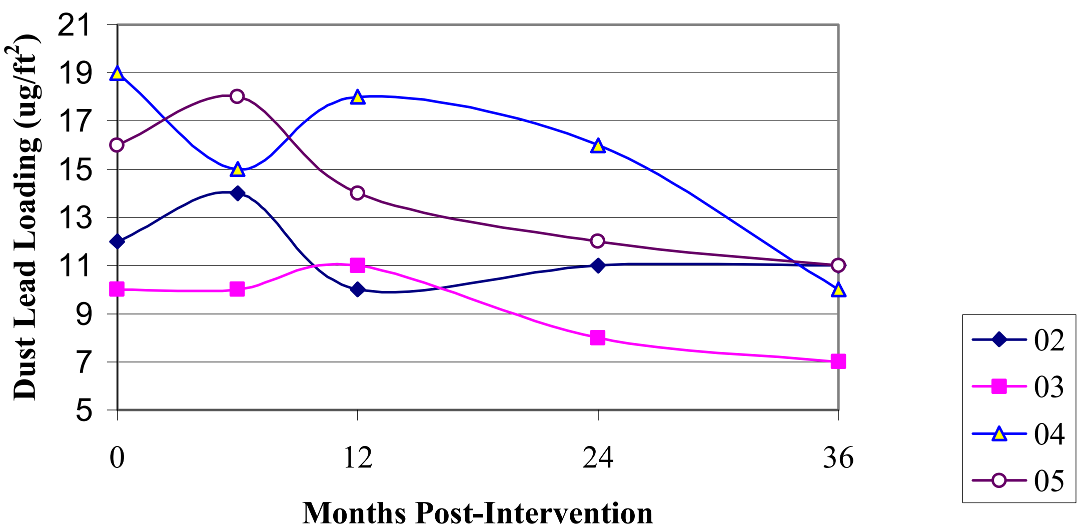
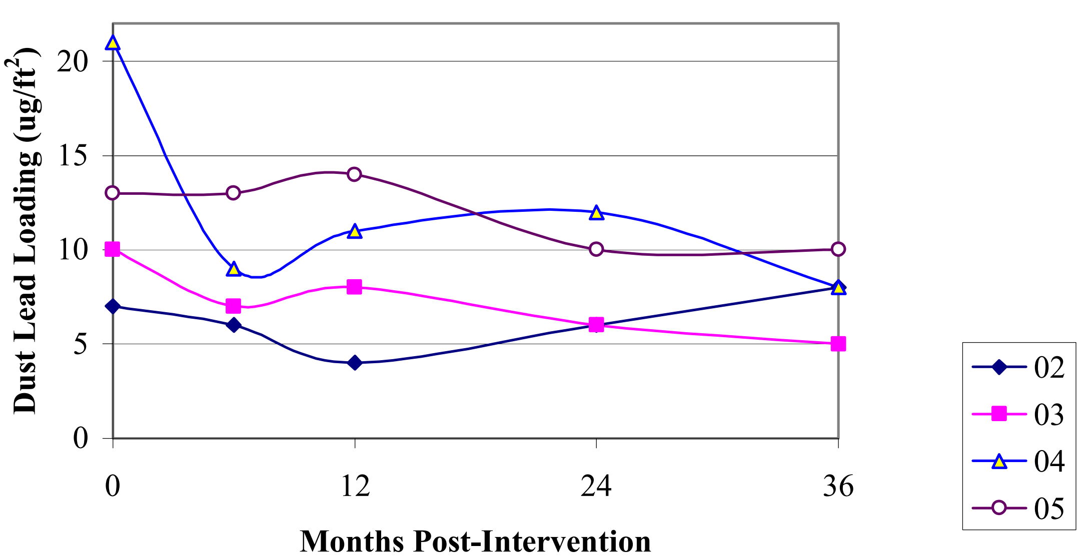


Figure 8-7: Interior Floor Dust Lead Loading from Clearance to Three-Years Post-Intervention by Interior Strategy



8.4.1.3 Window Dust Lead Loadings: One–Year Post-Intervention. Findings for the geometric mean pre- and one-year post-intervention window dust lead loadings by Interior Strategy are presented on Tables 8-11 and 8-12. These tables also present the percentage of dwellings at pre- and one-year post-intervention with at least one window sill sample above 500 or 250 µg/ft^2 or at least one window trough sample above 800 or 400 µg/ft^2 by Interior Strategy.

Table 8-11: Geometric Mean Window Sill Dust Lead Loadings and Percent of Dwellings with at Least One Window Sill Dust Lead Loading at or Above 250 or 500 µg/ft^2 at Pre- and One-Year Post-Intervention by Interior Strategy

Interior Strategy	Number of Dwellings	Geometric Mean Window Sill Dust Lead Loading (µg/ft^2) by Intervention Phase		Percent of Dwellings by Phase with the Window Sill Sample at or Above:			
		Pre-	1 Yr Post-	500 µg/ft^2		250 µg/ft^2	
				Pre-	1 Yr	Pre	1 Yr
02	56	117	91	25%	20%	43%	29%
03	122	168	102	27%	21%	41%	38%
04	147	479	84	52%	19%	64%	33%
05	675	685	53	63%	11%	75%	21%
06/07	34	518	30	59%	9%	71%	18%
All	1,034	496	62	55%	14%	67%	25%

Table 8-12: Geometric Mean Window Trough Dust Lead Loadings and Percent of Dwellings with at Least One Window Trough Dust Lead Loading at or Above 400 or 800 µg/ft^2 at Pre- and One-Year Post-Intervention by Interior Strategy

Interior Strategy	Number of Dwellings	Geometric Mean Window Trough Dust Lead Loading (µg/ft^2) by Intervention Phase		Percent of Dwellings by Phase with at Least One Window Trough Sample at or above:			
		Pre-	1 Yr Post-	800 µg/ft^2		400 µg/ft^2	
				Pre-	1 Yr	Pre	1 Yr
02	56	2,860	1,630	71%	63%	84%	73%
03	122	1,178	266	54%	28%	69%	40%
04	147	6,605	679	78%	51%	83%	61%
05	675	5,881	266	82%	28%	87%	46%
06/07	34	2,456	208	71%	35%	76%	47%
All	1,034	4,621	333	77%	34%	84%	49%

The window dust lead loadings displayed similar trends after clearance for all interior intervention groups except Interior Strategy 06/07 (Figures 8-8 and 8-9). The dust lead loadings on windows treated with Interior Strategies 02-05 all increased from clearance to six-months post-intervention on both window sills and window troughs. These changes were all significant. Between six-months and one-year post-intervention, however, window dust lead loadings stayed the same or declined slightly on all of these surfaces, except window troughs treated with interior Strategy 02. Only in dwellings treated with Interior Strategy 05 did dust lead loadings on window sills and troughs significantly change (decline) after six months post-intervention.

Window trough dust lead loadings in dwellings treated with Interior Strategy 06/07 also increased until six months post-intervention, but the magnitude of the change was much smaller and was not statistically significant. Dwellings treated with Interior Strategy 06/07 had the highest window trough dust lead loadings among the intervention groups at clearance; six months later it was the lowest. Yet, between six-months and one-year post-intervention, window trough dust lead loadings in dwellings treated with Interior Strategy 06/07 continued to increase, with this change being significant. By one-year post-intervention, the window trough dust lead loadings in these dwellings were comparable to those on troughs in dwellings treated with Interior Strategies 03 and 05.

Window sill dust lead loadings exhibited an opposite pattern in dwellings treated with Interior Strategy 06/07. Unlike all other strategies, between clearance and six-months post-intervention, the sill dust lead loadings *declined* slightly, though not significantly. After six-months post-intervention, window sill dust lead loadings in dwellings treated with Interior Strategy 06/07 displayed similar patterns to windows treated with other interventions: the dust lead loadings declined slightly, though not significantly. Window sills treated with Interior Strategy 06/07 had among the highest dust lead loadings at clearance, but by one-year post-intervention they were significantly different (lower) than all other strategies.

Figure 8-8: Window Sill Dust Lead Loading from Clearance to One-Year Post-Intervention by Interior Strategy

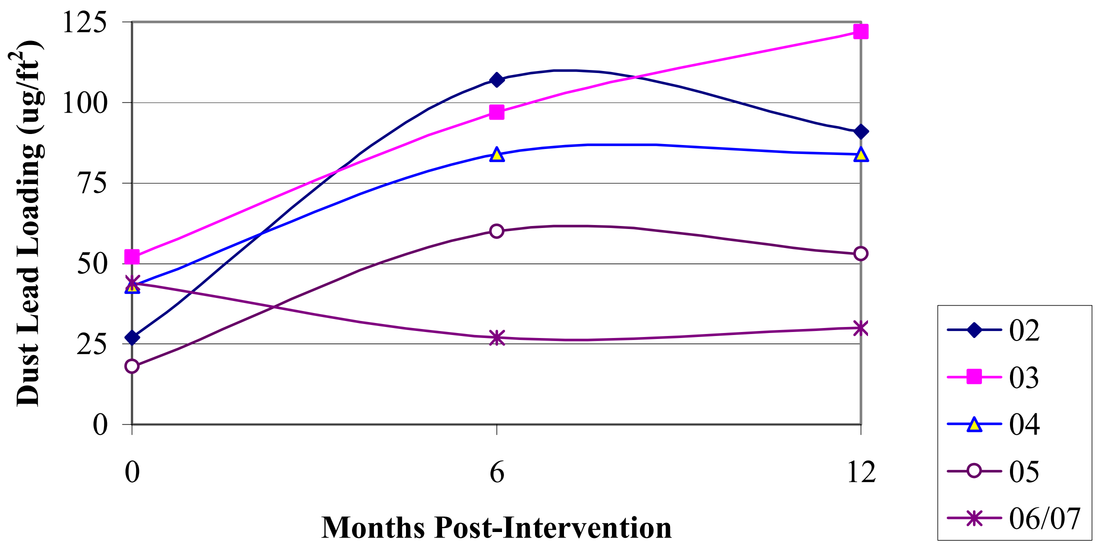
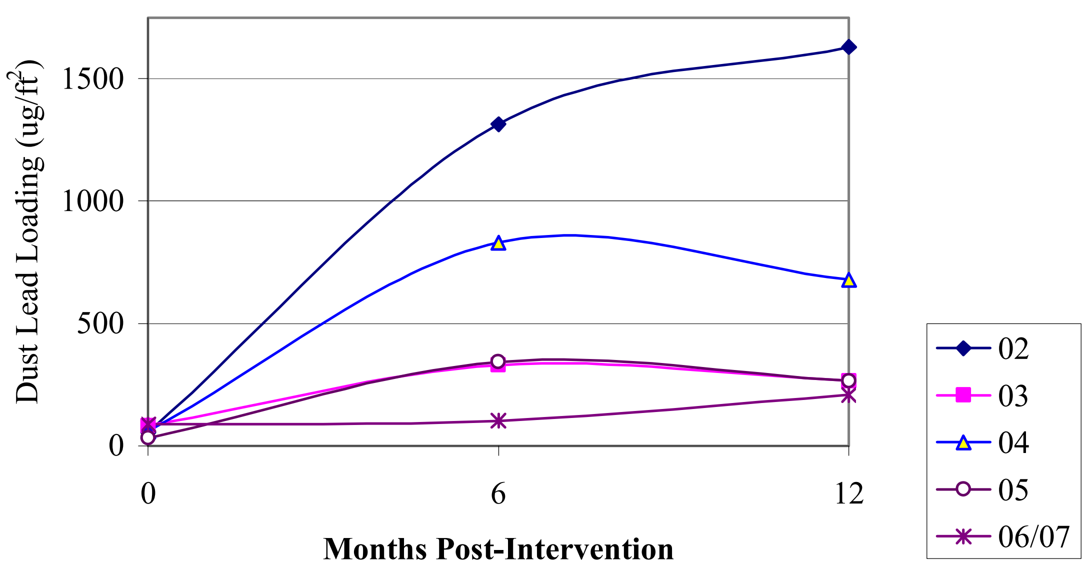


Figure 8-9: Window Trough Dust Lead Loading from Clearance to One-Year Post-Intervention by Interior Strategy



Discussion

Unlike floors, the longitudinal trends for window surfaces from clearance to six-months post-intervention generally followed expectations as dust lead loadings rose after clearance. However, when considered in conjunction with the floor results, the reaccumulation in window dust lead raises questions about the source of this lead. It is possible that the rise in dust lead loadings support the original hypothesis that the increases reflect the deterioration of lead-based paint immediately after treatment. Yet, this would suggest that there were a large number of paint lead failures around the window surfaces immediately after treatment, but those failures essentially stopped between six-months and one-year after intervention. Alternatively, the increases in window dust lead loadings after interventions may offer further support for the theory suggested by the authors of an abatement study in Baltimore that immediately after clearance, dust lead loadings rise from external sources (Farfel 1991). If the cleaning by the contractors reduced window dust lead loadings to levels below the ambient levels in the environment, then the increases could reflect the window dust lead loadings seeking an equilibrium with that environment. Either theory is supportable by the results of the dwellings treated by Interior Strategy 06/07. Since these dwellings were fully abated, dust lead loadings would not be expected to rise post-intervention. At the same time, most of the Interior Strategy 06/07 dwellings were in New York City where the limited amount of exterior lead on buildings and the taller buildings would be likely to introduce much less exterior leaded dust into a dwelling.

8.4.1.4 Window Dust Lead Loadings: Three-Years Post-Intervention. Findings for the geometric mean pre- and three-year post-intervention window dust lead loadings by Interior Strategy are presented on Tables 8-13 and 8-14. These tables also present the percentage of dwellings at pre- and three-year post-intervention with at least one window sill sample above 500 or 250 µg/ft^2 or at least one window trough sample above 800 or 400 µg/ft^2 by Interior Strategy.

Table 8-13: Geometric Mean Window Sill Dust Lead Loadings and Percent of Dwellings with at Least One Window Sill Dust Lead Loading at or Above 250 or 500 µg/ft^2 at Pre- and Three-Years Post-Intervention by Interior Strategy

Interior Strategy	Number of Dwellings	Geometric Mean Window Sill Dust Lead Loading (µg/ft^2) by Intervention Phase		Percent of Dwellings by Phase with the Window Sill Sample at or Above:			
		Pre-	3 Yr Post-	500 µg/ft^2		250 µg/ft^2	
				Pre-	3Yr	Pre	3 Yr
02	20	174	136	30%	20%	50%	35%
03	23	182	87	30%	17%	39%	35%
04	59	570	124	59%	29%	69%	44%
05	176	752	42	65%	5%	75%	15%
All	278	567	62	59%	12%	69%	24%

Table 8-14: Geometric Mean Window Trough Dust Lead Loadings and Percent of Dwellings with at Least One Window Trough Dust Lead Loading at or Above 400 or 800 µg/ft² at Pre- and Three-Years Post-Intervention by Interior Strategy

Interior Strategy	Number of Dwellings	Geometric Mean Window Trough Dust Lead Loading (µg/ft²) by Intervention Phase		Percent of Dwellings by Phase with at Least One Window Trough Sample at or Above:			
		Pre-	3 Yr Post-	800 µg/ft²		400 µg/ft²	
				Pre-	3 Yr	Pre	3 Yr
02	20	8,625	1,753	90%	60%	95%	75%
03	23	7,476	731	91%	48%	96%	52%
04	59	15,216	622	92%	54%	93%	59%
05	176	6,105	231	84%	28%	90%	45%
All	278	6,037	310	86%	38%	91%	51%

Window sill dust lead loadings in the extended Evaluation displayed similar trends across interior strategies (Figures 8-10). Between clearance and six-months post-intervention, window sill dust lead loadings increased dramatically. The geometric mean window sill dust lead loadings increased about three-fold from its clearance level (28 µg/ft²). But between six-months and three-years post-intervention, window sill dust lead loadings declined 28 percent. The change from clearance to six-months post-intervention was significantly different as was the change from six-months post-intervention to three-years post-intervention. The magnitude of the changes in dust lead loadings varied by strategy but the overall direction and significance of the changes were the same across interior strategies, with the exception of dwellings treated with Interior Strategy 04. (In this case, dust lead loadings increased from six months to three-years post-intervention.) At clearance, dwellings treated with Interior Strategy 05 had significantly different (lower) dust lead loading than other strategies and this remained true three-years post-intervention.

The trends for window trough dust lead loadings (Figure 8-11) were similar to window sills, although the magnitude of the change from clearance to six-months post-intervention was much larger: overall, the geometric mean window trough dust lead loadings increased approximately 14 times from its clearance level (40 µg/ft²). The increases were larger for dwellings treated with Interior Strategy 02 and smaller for those treated with Interior Strategy 05. The window trough dust lead loadings for all strategies declined from six-months post-intervention to three-years post-intervention. At three-years post-intervention, dwellings treated with Interior Strategy 05 had a significantly lower window trough dust lead loading than all other strategies, while dwellings treated with Interior Strategy 02 had significantly higher dust lead loadings than Interior Strategies 04 and 05.

Figure 8-10: Window Sill Dust Lead Loading from Clearance to Three-Years Post-Intervention by Interior Strategy

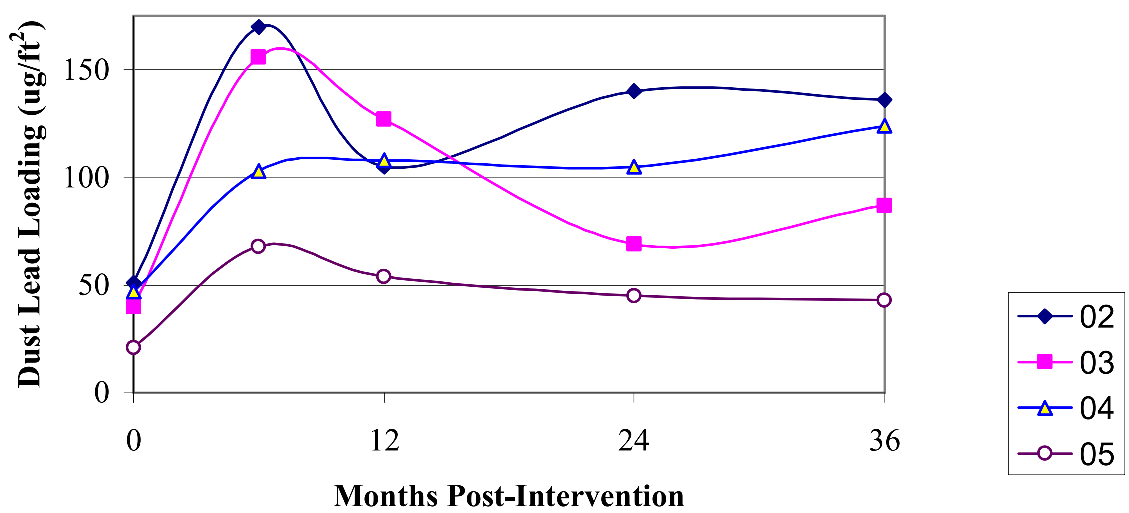
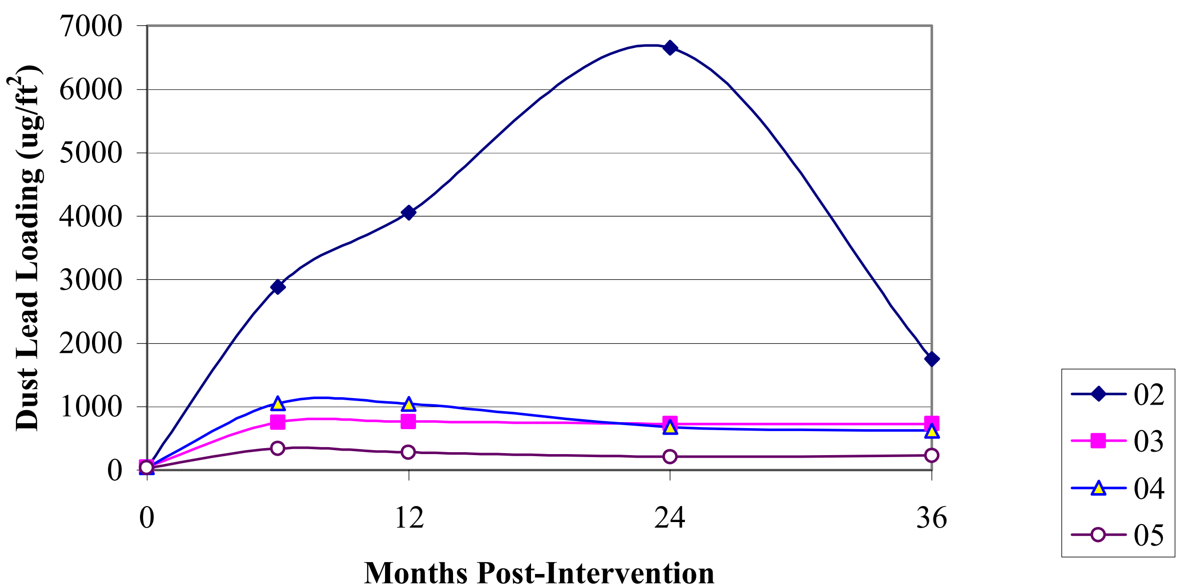


Figure 8-11: Window Trough Dust Lead Loading from Clearance to Three-Years Post-Intervention by Interior Strategy



Discussion

Between clearance and six-months post-intervention, something occurred around the windows that caused the dust lead loadings to dramatically rise. Because it occurred in dwellings where windows were abated as well as in dwellings where the window paint was treated with no more than limited paint stabilization, it does not appear as though the windows themselves are a likely source of the dust lead. However, observations presented in Section 8.6 suggest that other painted surfaces including exterior surfaces did experience substantial paint failure just in the first six months after interventions. It is also possible, as reported earlier, that the source was the ambient lead that settled on the windows sometime after clearance.

Once the window dust lead loadings reached equilibrium with its environment, there was no indication that these dust lead loadings increased between six-months post-intervention and three-years post-intervention. If any change occurred, dust lead loadings declined between these two sampling phases. As with floors, if any lead-based paint deteriorated and generated dust lead, it was generally removed from the windows through routine cleaning and use. The effects of the different interior interventions were fairly comparable after intervention.

8.4.2 Relationships Between Lead Hazard Control Interventions and Post-Intervention Dust Lead Loadings When Other Factors Are Considered

Four multiple regression analyses were developed exploring factors that significantly affected the one-year post-intervention dust lead loadings (see Section 8.4.2 for details). The analyses produced models that separately examined the factors influencing dust lead on entry floors, interior floors, window sills and window troughs. The findings for the two floor dust lead models were similar as were the findings for the two window dust lead models, so each set of findings is presented jointly.

8.4.2.1 <u>One-Year Post-Intervention Floor Dust Lead Loadings</u>

Factors that commonly influenced floor dust lead loadings were:

Pre-intervention dust lead loadings log-trans. (lower levels : less dust lead)
Pre-intervention door/trim paint lead log-trans. (lower levels : less dust lead)
Pre-intervention floor surface condition (better condition : less dust lead)
Pre-intervention floor surface type (see below)
Building type (multi-unit : less dust lead)
Building age (newer : less dust lead)
Occupancy at pre-intervention (vacant : less dust lead)
Ownership (owner-occupied : less dust lead)
Height of Dwelling from Bldg Entrance (higher floors: less dust lead)

Generally, these post-intervention findings were consistent with pre-intervention models that were developed (see Section 8.4.3.1). In two cases, the direction of the effect was reversed from pre-intervention. The direction of the effect of Occupancy Status changed for both entry floor and interior floor dust lead loadings and the direction of the effect of Floor Surface Type changed for entry floor dust lead loadings. These effects and changes in direction will be discussed in further detail in Section 8.4.2.1.3.

8.4.2.1.1 *Intervention Effects on One-Year Post-Intervention Floor Dust Lead Loadings*

One-year post-intervention, all three measures of the lead hazard control interventions (Interior Strategy, Exterior LHC Work, and Site LHC Work) were significantly related to interior floor dust lead loadings. Dwellings where exterior lead hazard control work was performed had lower interior floor dust lead loadings than dwellings without such work, after controlling for other factors. Likewise, dwellings with site work had lower interior floor dust lead loadings than dwellings without these treatments. Interior floor dust lead loadings in dwellings not receiving exterior or site work were predicted to be 32 percent and 45 percent higher, respectively, than the dwellings receiving treatments. For an average dwelling, interior floor dust lead loadings at one-year post-intervention were 3-4 $\mu g/ft^2$ higher in the dwellings that did not receive one of the interventions to the outside of the building or its immediate surroundings. (Similar effects of Exterior/Site Treatments are presented in Section 8.5.2.2).

Because interior lead hazard control work was conducted at almost all dwellings, the effect of not performing interior work could not be assessed. However, there was enough diversity in Interior Strategies to assess differences in the effectiveness of the Interior Strategies on one-year post-intervention dust lead loadings. The Interior Strategies were found to interact with the pre-intervention floor dust lead loadings. In other words, the effects of Interior Strategies on post-intervention dust lead loadings differed depending on the pre-intervention dust lead loading.[7] Figure 8-12 presents the estimated one-year post-intervention interior floor dust lead loadings by Interior Strategy and pre-intervention interior floor dust lead loadings when keeping all other variables constant. All significant factors except exterior and site work[8] were set to their mean values.

As displayed in the figure:

- The effect of different Interior Strategies varied by the pre-intervention floor dust lead loadings. Interior Strategies 06/7 (full abatement) and 04 (window treatments) were not effected by the pre-intervention dust lead loadings, while Interior Strategies 02, 03 and 05 had increasing dust lead loadings at one-year post-intervention as pre-intervention floor dust lead loadings increased.
- The percent reductions in interior floor dust lead loadings increased as pre-intervention dust lead loadings increased. As a correlate to the previous observation, as pre-intervention floor dust lead loadings increased, dwellings treated with Interior Strategies 06/07 and 04 displayed greater percent reductions than the other interior strategies.
- Dwellings treated with Interior Strategies 06/07 had the largest reductions in interior floor dust lead loadings when compared with the other interior strategies, while dwellings treated with Interior Strategy 05 (window abatement) and Interior Strategy 03 (full paint stabilization) had the smallest reductions. At the median and 75th percentile pre-

[7] Pre-intervention *interior floor* dust lead loadings also interacted with the percentage of same rooms that were sampled at both pre- and one-year post-intervention. In dwellings where the floor dust lead samples were collected from the same rooms at both phases, post-intervention floor dust lead loadings increased with higher pre-intervention floor dust lead loadings. In dwellings where a smaller percentage of samples were collected from the same rooms, the relationship between pre- and post-intervention dust lead loadings was not as apparent.
[8] For estimating purposes, exterior work was assumed to be performed, while site work was not. In this dataset, 76% of dwellings had exteriors treated and 13% of dwellings had the site treated.

intervention dust lead loadings, the reductions in interior floor dust lead loadings in dwellings treated with Interior Strategies 06/07 were significantly different than those in dwellings treated with Interior Strategy 03 or 05. Reductions in interior floor dust lead loadings when Interior Strategy 04 was used were also significantly different (greater) from those associated with Interior Strategy 03 or 05 in homes with pre-intervention floor dust lead loadings at or above the 75th percentile. At the median pre-intervention dust lead loading, post-intervention dust lead loadings in dwellings treated with Interior Strategy 05 were significantly different than those in dwellings treated with Interior Strategy 02 (cleaning/spot painting).

Of interest, one-year post-intervention *entry floor* dust lead loadings were not significantly related to either different interior strategies or exterior/site lead hazard control work in the multiple regression analysis. Although a significant relationship was not identified between Interior Strategy and post-intervention entry floor dust lead in the analysis, the dust lead outcomes on entry floors and interior floors were fairly similar (Table 8-15 and 8-16). The influence of interior interventions on entry floor dust lead is further discussed in Section 8.4.3.

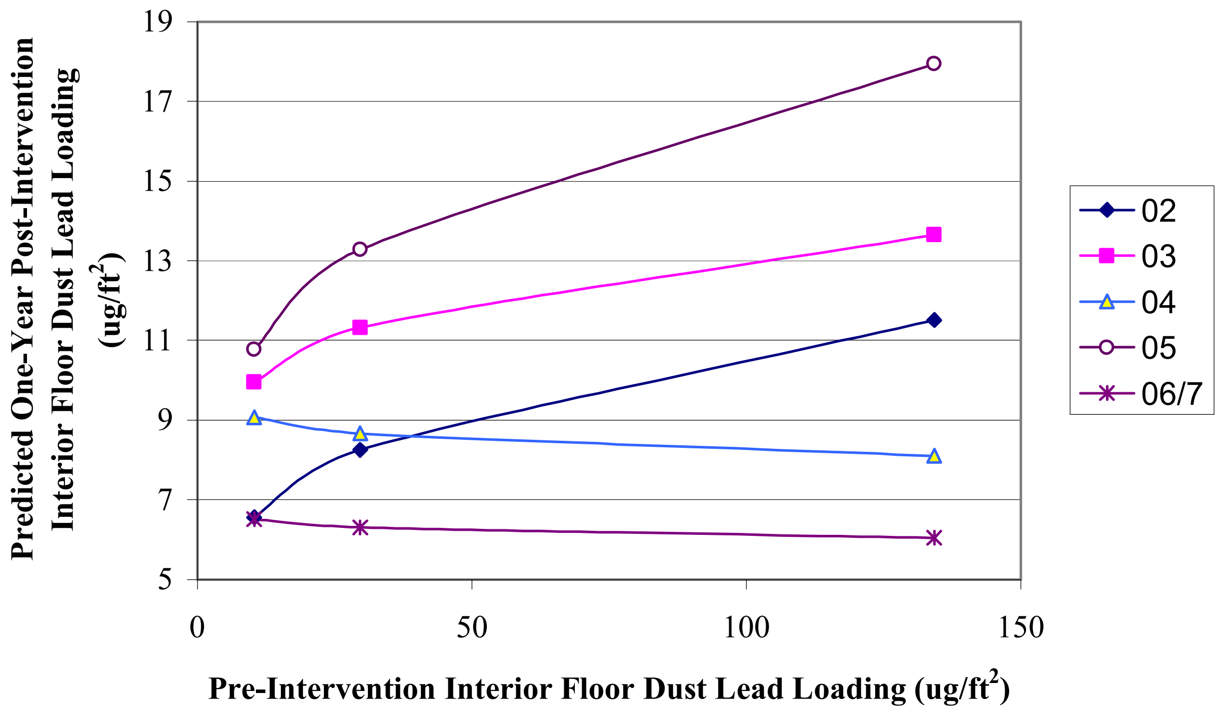
8.4.2.1.2 *Discussion of Intervention Effects*

Although all interior strategies resulted in average dust lead loadings at one-year post-intervention that were well below the current hazard standard of 40 µg/ft^2, different interior strategies resulted in significantly different post-intervention floor dust lead loadings. As an example, the multivariate modeling found that for dwellings with the median pre-intervention floor dust lead loading (30 µg/ft^2), full interior lead abatement (Interior Strategy 06/07) was associated with one-year post-intervention floor dust lead loadings that were 44 percent lower than loadings in homes treated with full paint stabilization (Interior Strategy 03). Such a finding matches expectations that the removal or permanent enclosure of all lead-based paint would eliminate most sources of lead dust in the home environment and result in lower dust lead loadings than lower intensity strategies. While some might debate whether these statistically significant differences are practically significant, previous studies demonstrating effects of floor dust lead on children's blood lead at levels below 40 µg/ft^2 would suggest that these "small" differences can have an impact on health outcomes. (Chapter 10 presents effect outcomes alongside the cost outcomes so that readers can assess cost-effectiveness.)

Surprisingly, the second most intensive strategy (window abatement combined with additional treatments (Interior Strategy 05)) was not as effective in reducing floor dust lead loadings as cleaning or limited paint stabilization (Interior Strategy 02) or less extensive window treatments (Interior Strategy 04) at the median pre-intervention dust lead loading. Although Interior Strategy 05 was as effective at reducing floor dust lead loadings as most other strategies at clearance, something occurred between clearance and one-year post-intervention that increased the geometric mean floor dust lead loadings in these homes. During the same period, dwellings treated with Interior Strategies 03, 04 and 06/7 experienced declines in floor dust lead loadings.

Evaluation researchers cannot account for the increase in floor dust lead loadings in the homes treated with Interior Strategy 05, but possible reasons include treatment failures, new interior lead-based paint deterioration, track-in or blow-in from exterior lead sources, or some other factor such as leaded dust on furnishings that had been stored during treatment. Section 8.4.2.2

Figure 8-12: Predicted One-Year Post-Intervention Interior Floor Dust Lead Loading by Pre-Intervention Floor Dust Lead Loading and Interior Strategy



will present findings that window dust lead loadings in dwellings treated with Interior Strategy 05 were lower than the loadings on windows treated with other less intensive strategies, yet these reductions did not correspond with lower floor dust lead loadings. Section 8.4.2.2 will also present findings that window sill and trough dust lead loadings in homes treated with Interior Strategy 05 more than tripled between clearance and six-months post-intervention suggesting that track-in and/or lead from furnishings were not the sole sources of the increases on floors.

One serious limitation to the one-year analyses is the unequal distribution of interior strategies by pre-intervention dust lead loading (or more broadly, by baseline housing condition). Only a small number of dwellings (<15) with pre-intervention entry floor and interior floor dust lead loadings above the 75th percentile (167 and 134 µg/ft^2, respectively) were treated with either Interior Strategy 02, 03 or 06/07 (Tables 8-15 and 8-16). Anecdotally, grantees had concerns about the ability to achieve clearance using the lower intensity strategies on dwellings in poor condition so they chose not to apply them in the worst homes. Additional research would be needed to determine whether the effects of the lower intensity strategies on floor dust lead loadings are truly equivalent to (or better than) the effects of Interior Strategy 05.

Although differential effects of interior lead hazard control strategies were observed in homes with higher pre-intervention dust lead loadings, for those dwellings where entry and interior floor dust lead loadings were initially low (<10 µg/ft^2), no intervention could be demonstrated to have a positive effect (Tables 8-15 and 8-16). This finding may be true for an assortment of reasons. Both the actual distribution of dust lead on a surface and the wipe sampling method are variable, so the selection of lower dust lead loadings as a baseline increases the chances that a second sample will be higher (i.e., regression to the mean). Furthermore, the objective of most contractors in the Evaluation was to pass floor clearance at a level of 100 or 200 µg/ft^2, so it would not be surprising if dust lead loadings on the "cleanest" surfaces increased slightly after treatment.

Table 8-15: Pre-Intervention and One-Year Post-Intervention Entry Floor Dust Lead Loadings by Interior Strategy and Pre-Intervention Entry Dust Lead Loading Quartile

Pre-Intervention Entry Dust Lead		Interior Strategy				
		02	03	04	05	06/07
1st Quartile (<12 µg/ft^2)	N	*33*	*29*	*33*	*159*	*5*
	GM Pre	6	5	5	4	1
	GM 1 Yr	6	8	6	8	5
	% Change	0%	60%	20%	100%	400%
2nd/3rd Quartile (12-167 µg/ft^2)	N	*22*	*85*	*78*	*317*	*15*
	GM Pre	26	28	39	44	37
	GM 1 Yr	22	13	17	16	6
	% Change	-15%	-54%	-56%	-64%	-84%
4th Quartile (>167 µg/ft^2)	N	*1*	*8*	*36*	*199*	*14*
	GM Pre	192	868	563	593	984
	GM 1 Yr	5	27	25	27	10
	% Change	-97%	-97%	-96%	-95%	-99%
All	N	*56*	*122*	*147*	*675*	*34*
	GM Pre	12	23	46	55	80
	GM 1 Yr	10	12	15	15	7
	% Change	-17%	-48%	-67%	-73%	-91%

Table 8-16: Pre-Intervention and One-Year Post-Intervention Interior Floor Dust Lead Loadings by Interior Strategy and Pre-Intervention Interior Floor Dust Lead Loading Quartile

Pre-Intervention Interior Floor Dust Lead		Interior Strategy 02	03	04	05	06/07
1st Quartile (<10 µg/ft²)	N	*35*	*36*	*27*	*158*	*4*
	GM Pre	5	5	4	5	3
	GM 1 Yr	4	6	6	6	6
	% Change	-20%	20%	50%	20%	100%
2nd/3rd Quartile (10-134 µg/ft²)	N	*19*	*82*	*91*	*308*	*16*
	GM Pre	24	26	28	38	28
	GM 1 Yr	8	10	12	13	6
	% Change	-67%	-62%	-57%	-66%	-79%
4th Quartile (>134 µg/ft²)	N	*2*	*4*	*29*	*209*	*14*
	GM Pre	389	562	806	449	1021
	GM 1 Yr	5	20	7	34	7
	% Change	-99%	-96%	-99%	-92%	-99%
All	N	*56*	*122*	*147*	*675*	*34*
	GM Pre	10	17	38	50	95
	GM 1 Yr	6	9	9	15	6
	% Change	-40%	-47%	-76%	-70%	-94%

8.4.2.1.3 *Discussion of Other Factors*

At pre-intervention, occupied dwellings had lower dust lead loadings than vacant dwellings, especially for floors. However, the predicted post-intervention dust lead loadings were higher in occupied dwellings after holding other factors constant. As discussed in Chapter 7, such a finding is likely a function of the dust loading (i.e., lack of cleaning) in the vacant dwelling (EPA 1996b). When vacant and occupied dwellings have a similar pre-intervention dust lead concentration and the vacant dwelling has a higher dust loading, then the vacant unit will have a higher dust lead loading. Simply cleaning the vacant dwelling so its dust loading was equivalent to the occupied dwelling, would result in a lower post-intervention dust lead loading in the vacant dwellings. As discussed in Chapter 7, when pre-intervention dust lead loadings were not held constant for the occupancy groups, little difference in post-intervention dust lead loadings was observed between the two groups.

For entry floors, floors that were painted prior to intervention and in better condition had lower dust lead loadings one-year post-intervention than unpainted or carpeted surfaces. At pre-intervention, painted entry and interior floors had higher dust lead loadings than the other surfaces. The finding may reflect an indirect influence of the intervention, since 43 percent of the painted entry surfaces changed to a different surface type post-intervention (as compared to 24% of carpeted entries and 13% of unpainted entries). Interestingly for interior floors, the outcomes post-intervention were similar to those pre-intervention with carpeted floors having the lowest predicted dust lead loadings and painted floors having the highest dust lead loadings. This may reflect the fact that Interior Strategy was a significant variable in this model.

8.4.2.2 One-Year Post-Intervention Window Dust Lead Loadings

Factors that commonly influenced window dust lead loadings were:

Pre-intervention dust lead loadings log-trans. (lower levels : less dust lead)
Pre-intervention paint lead log-trans. (lower levels : less dust lead)
Building age (newer : less dust lead)
Ownership (owner-occupied : less dust lead)

The occupancy of the dwelling prior to intervention also influenced window sill dust lead loadings at one-year post-intervention, while the season of dust collection influenced window trough dust lead loadings. The condition of the exterior paint was related to window sill dust lead, while the exterior paint lead level was related to window trough dust lead.

8.4.2.2.1 *Intervention Effects on One-Year Post-Intervention Window Dust Lead Loadings*

Interior Strategies were significantly related to one-year post-intervention dust lead loadings on both window sills and window troughs. As with interior floors, the Interior Strategies were found to interact with the pre-intervention dust lead loadings for each of the respective sample types. Figures 8-13 and 8-14 present the estimated one-year post-intervention window sill and window trough dust lead loadings by Interior Strategy and pre-intervention dust lead loadings when setting all variables to their mean values.

Figure 8-13: Predicted One-Year Post-Intervention Window Sill Dust Lead Loading by Pre-Intervention Sill Dust Lead Loading and Interior Strategy

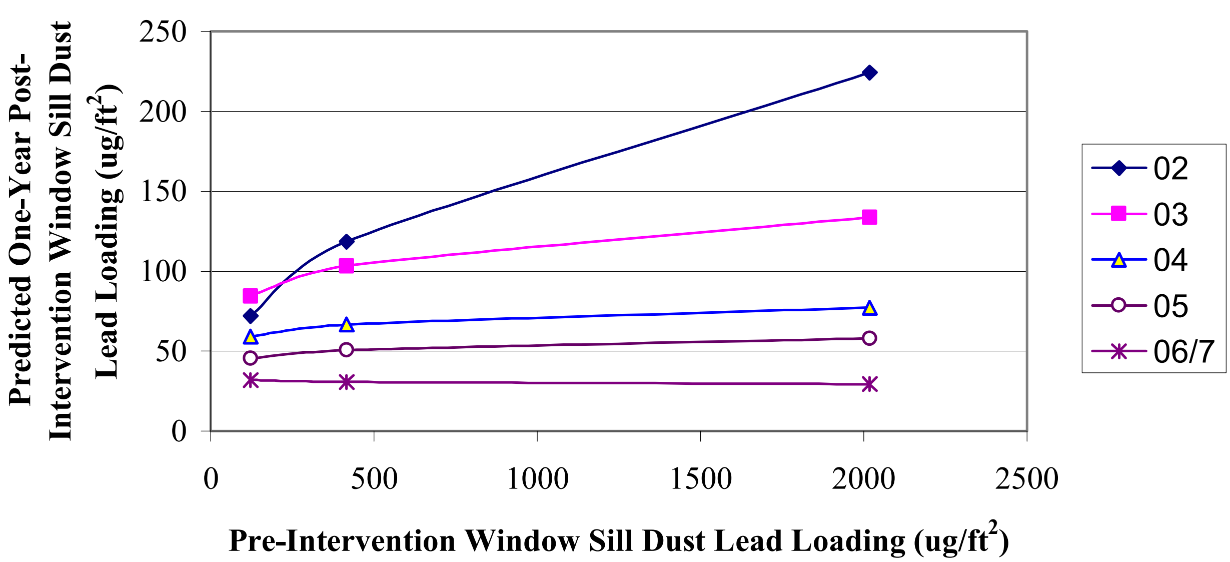
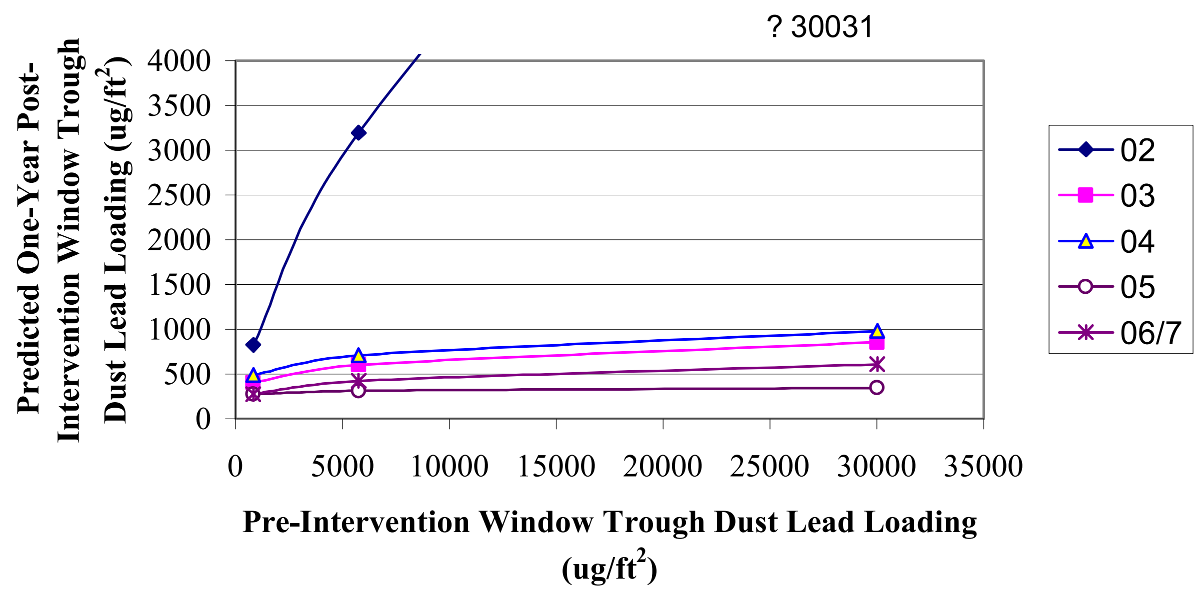


Figure 8-14: Predicted One-Year Post-Intervention Window Trough Dust Lead Loading by Pre-Intervention Trough Dust Lead Loading and Interior Strategy



As displayed in the figures:

- The percent reductions in window dust lead loadings increased as pre-intervention dust lead loadings increased.
- Dwellings treated with window abatement including both Interior Strategy 05 and 06/07 were associated with the largest percent reductions in window dust lead loadings. Dwellings treated with cleaning or limited spot painting (Interior Strategy 02) were associated with the smallest percent reductions in window dust lead loadings.
- As the intensity of the Interior Strategy increased, the percent reductions in one-year post-intervention dust lead loadings on *window sills* increased. At the median and 75th percentile pre-intervention dust lead loadings, all Interior Strategies were significantly (or marginally significantly) different from each other except Interior Strategies 02 and 03.
- On window troughs, one-year post-intervention dust lead loadings were almost always significantly different (higher) in dwellings treated with Interior Strategy 02 than all other Interior Strategies across the interquartile range[9]. Dwellings treated with Interior Strategy 05 had significantly different (lower) one-year post-intervention window trough dust lead loadings than all other Interior Strategies except Interior Strategies 06/07.

In addition to the differential effects of Interior Strategies, the regression models also identified a significant relationship between exterior lead hazard control treatments and one-year post-intervention window sill dust lead loadings. Exterior work was associated with lower window sill

[9] At the 25th percentile, Interior Strategies 02 and 04 were marginally significantly different.

dust lead loadings. Window sill dust lead loadings in dwellings not receiving exterior treatments were predicted to be 33 percent higher than the dwellings receiving treatments.

8.4.2.2.2 *Discussion of Intervention Effects on Window Dust Lead*

The effect of interior interventions on post-intervention window dust lead loadings more closely matched expectations than their effects on floor dust lead loadings. Especially on window sills, as the intensity of the interior strategy increased, the reductions of the window dust lead loadings from pre-intervention to one-year post-intervention increased as well. Although window trough dust lead results did not follow in rank order, windows that were abated (Interior Strategies 05 and 06/07) exhibited the largest reductions while windows that were only cleaned (Interior Strategy 02) displayed the smallest reductions.

These findings may be a logical result of the Interior Strategies being defined more by their treatments to windows than to the other components in the dwelling. Although results presented in Chapter 5, as well as anecdotal evidence, suggest that dwellings treated with more intensive window treatments also had more intensive treatments to other components, the strategy definitions did not require this. Thus, it is reasonable that higher intensity interior strategies were more effective in reducing window dust lead loading than floor dust lead loading.

As with the floor results, some might debate whether the statistically significant differences in window sill outcomes are practically significant, since the geometric mean dust lead loadings for individual strategies were all below the current Federal hazard standard. Although cleaning only (Interior Strategy 02) in dwellings with average baseline conditions was associated with one-year post-intervention floor dust lead loadings that were four times higher than loadings in similar homes treated with full interior lead abatement (Interior Strategy 06/07), the estimated geometric mean loading for a dwelling with a median pre-intervention dust lead loading was well below 200 $\mu g/ft^2$. However, the findings suggest in the "worst" quartile of housing, as measured by baseline dust lead loadings, the choice of strategy appears to have made a difference in whether window sill dust lead hazards would have existed one-year post-intervention.

As previously discussed, a limitation to the one-year analyses is the unequal distribution of interior strategies by pre-intervention dust lead loading . Less than 15 dwellings treated with either Interior Strategy 02, 03 or 06/07 had pre-intervention interior window dust lead loadings above the 75th percentile (Tables 8-17 and 8-18). However, unlike floors, the tendency for windows treated with window abatement (Interior Strategies 05 and 06/07) to be associated with greater reductions in window dust lead loadings than windows treated with cleaning (Interior Strategy 02) is just as clear between the middle two quartiles as it is in the upper quartile.

Similar to the findings for entry floors and interior floors, for those dwellings where window sill dust lead loadings were initially low (<122 $\mu g/ft^2$), no intervention except Interior Strategy 05 had a positive effect (Table 8-17). The increases in dust lead loadings between pre-intervention and one-year post-intervention could be related to a variety of factors. For example, contractors in the Evaluation had to pass window sill clearance at 500 $\mu g/ft^2$, so it was acceptable to have increases in dust lead loadings when pre-intervention dust lead loadings were well below the clearance standards.

Table 8-17: Pre-Intervention and One-Year Post-Intervention Window Sill Dust Lead Loadings by Interior Strategy and Pre-Intervention Entry Dust Lead Loading Quartile

Pre-Intervention Window Sill Dust Lead		Interior Strategy				
		02	03	04	05	06/07
1st Quartile (<122 µg/ft^2)	N	*28*	*52*	*38*	*132*	*9*
	GM Pre	27	43	46	46	36
	GM 1 Yr	51	87	51	39	36
	% Change	89%	102%	11%	-15%	0%
2nd/3rd Quartile (122-2,106 µg/ft^2)	N	*24*	*59*	*75*	*343*	*16*
	GM Pre	347	282	406	494	632
	GM 1 Yr	118	108	92	51	23
	% Change	-66%	-62%	-77%	-90%	-96%
4th Quartile (>2,106 µg/ft^2)	N	*4*	*11*	*34*	*200*	*9*
	GM Pre	5,023	6,303	9,565	7,079	5,198
	GM 1 Yr	1,147	163	120	71	42
	% Change	-77%	-97%	-99%	-99%	-99%
All	N	*56*	*122*	*147*	*675*	*34*
	GM Pre	117	168	479	685	518
	GM 1 Yr	91	102	84	53	30
	% Change	-22%	-39%	-82%	-92%	-94%

Table 8-18: Pre-Intervention and One-Year Post-Intervention Window Trough Dust Lead Loadings by Interior Strategy and Pre-Intervention Interior Floor Dust Lead Loading Quartile

Pre-Intervention Window Trough Dust Lead		Interior Strategy				
		02	03	04	05	06/07
1st Quartile (<846 µg/ft^2)	N	*18*	*63*	*35*	*133*	*10*
	GM Pre	208	230	216	179	193
	GM 1 Yr	249	145	203	210	64
	% Change	20%	-37%	-6%	17%	-67%
2nd/3rd Quartile (846-30,000 µg/ft^2)	N	*30*	*46*	*68*	*354*	*19*
	GM Pre	4,074	3,092	6,082	5,688	4,084
	GM 1 Yr	2,020	366	736	259	380
	% Change	-50%	-88%	-88%	-95%	-91%
4th Quartile (>30,000 µg/ft^2)	N	*8*	*13*	*44*	*188*	*5*
	GM Pre	276,482	105,430	113,829	73,953	57,406
	GM 1 Yr	50,113	1,605	1,559	331	228
	% Change	-82%	-98%	-99%	-100%	-100%
All	N	*56*	*122*	*147*	*675*	*34*
	GM Pre	2,860	1,178	6,605	5,881	2,456
	GM 1 Yr	1,630	266	679	266	208
	% Change	-43%	-47%	-90%	-95%	-92%

8.4.3 Pathways of Dust Lead and the Effect of Interventions on Those Pathways

A Structural Equations Model (SEM) is a means of estimating direct and indirect effects within or on a set of interrelated variables. A pre-intervention dust SEM was developed to establish the baseline pathways of lead through the home environment. Once the baseline pathways were established, a one-year post-intervention dust SEM was created to examine the effects of the lead hazard control interventions on the pathways. These analyses help better explain how the interventions influenced the changes in dust lead outcomes that were observed.[10]

8.4.3.1 Pre-intervention Structural Equation Model. The effects of all available pre-intervention environmental and demographic data on entry floor, interior floor, window sill and window trough dust lead loadings were assessed. Over 70 potential variables were identified (Exhibit 8-1). Complete data were available to run the pre-intervention dust SEM for 1,401 dwellings.

The model was developed based on *a priori* judgments of the likely pathways of lead in the home environment. Window trough dust lead was assumed to be able to affect the three other surfaces sampled, while window sill dust lead was assumed to be able to affect only the entry floor and/or the interior floors. Because entry floors had higher dust lead loadings than interior floors and entry floors were assumed to be an intermediate source of leaded dust being tracked in from the exterior, entry floors were postulated to be able to affect interior floors. Since the SEM allows pathways to move in only one direction, interior floors were not expected to affect any other surfaces sampled.

As displayed in Figure 8-15, all of these expected pathways proved to be significant with one exception. Window trough dust lead loadings did not have a direct effect on interior floor dust lead loadings. However, because window trough dust lead did directly affect window sill and entry floor dust lead loadings, the window trough lead loadings had an indirect effect on the interior floor dust lead outcomes.

At least one of the grantees has argued that because window troughs tend to be physically below window sills, the pathway between sills and troughs should be in the opposite direction. The Evaluation team considered this argument but felt that because wind currents at a window would tend to blow in, because those currents could move dust from the trough up to the sill, and because trough lead loadings were much higher than window sill loadings, the pathway as originally conceived was appropriate. Likewise, questions were raised about how window sill dust lead loadings could directly affect entry floor lead loadings which were sometimes in rooms without windows. The pathway may represent interior floor dust lead that is tracked out to the entry.

Several additional environmental factors directly influenced dust lead loadings (Figure 8-15). Five factors influenced both entry floor and interior floor dust lead loadings: 1) the surface type of the floor (i.e., carpeted, painted or other); 2) surface condition of the floor; 3) the paint lead level of interior trim and doors; 4) the interior building condition; and 5) the occupancy status of the dwelling. Additional factors that directly influenced interior floor dust lead loadings included

[10] A three-year post-intervention SEM was also created but because only a small number of dwellings in the model were treated with Interior Strategies other than 05, comparisons between Interior Strategies were not very informative.

the season of dust collection, the market value of the dwelling, and the number of people in the dwelling. An additional factor that directly influenced entry floor lead loadings was the size of the dwelling living space.

Seven factors influenced both window sill and window trough dust lead loadings: 1) surface condition, 2) paint lead level on windows, 3) building type (e.g., single-unit, 2-3 units, other), 4) the exterior building condition, 5) season of dust lead collection, 6) the market value of the dwelling, and 7) the occupancy status of the dwelling. Other factors that directly influenced window sill dust lead loadings included paint lead level of interior trim and doors and evidence of a prior roof leak. Other factors that directly influenced window trough lead loadings included: paint lead level of exterior components, frequency of cleaning the troughs and ownership of dwelling (e.g., rental v. owner-occupied).

8.4.3.2 One-Year Post-Intervention Structural Equation Model. A second SEM was created using data available at one-year post-intervention. Analysis of the one-year post-intervention data focused on the relationship between pre-intervention environmental measures and one-year intervention dust lead loadings, as mediated by the lead hazard control. The methodology for preparing the model is described in Section 8.2.3.3.

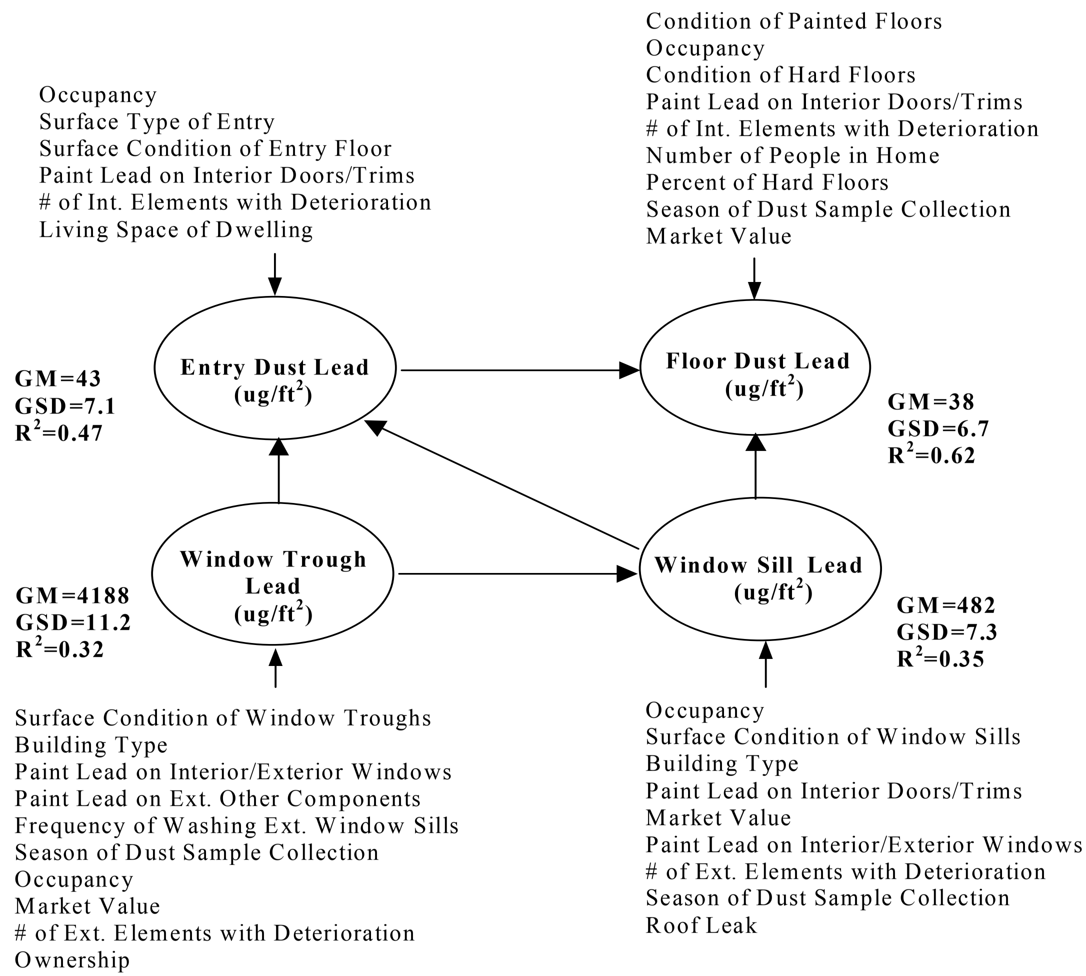
In addition to the pre-intervention variables, variables representing the intervention (i.e., interior strategy levels, any exterior lead hazard control work and any site lead hazard control work) and the post-intervention dust lead levels and conditions (e.g., surface condition and surface type of surfaces sampled for dust lead and season of dust lead collection at one-year post-intervention) were included in the model as possible modifiers of the dust lead pathways (Exhibit 8-1). The results of the one-year post-intervention dust SEM are presented in Figure 8-16. Because the final variables in the model differed somewhat from those in the multiple regression models in Section 8.4.2, the sample size was slightly larger (1,040 dwellings).

The pathways between dust lead sample types that were observed at pre-intervention were again significant predictors for the one-year post-intervention dust lead outcomes. The variable, Interior Strategy, had significant effects on one-year post-intervention dust lead loadings for all sample types. For window sills and window troughs, Interior Strategy interacted with pre-intervention dust lead loadings of those sample types. The interactions were similar to the interactions presented in Section 8.4.2.2.1. In general, the effects of the interior strategies on post-intervention dust lead loadings that were observed using SEM modeling corresponded well with the outcomes observed using the multiple regression models.

Exterior lead hazard control work had a significant effect on the one-year post-intervention window sill dust lead loadings, while site lead hazard control work had a significant effect on the one-year post-intervention dust lead loadings on both entry floors and interior floors. In all cases, the implementation of lead hazard controls was associated with lower post-intervention dust lead loadings.

Figure 8-15: Pre-Intervention Dust Lead Exposure Pathway

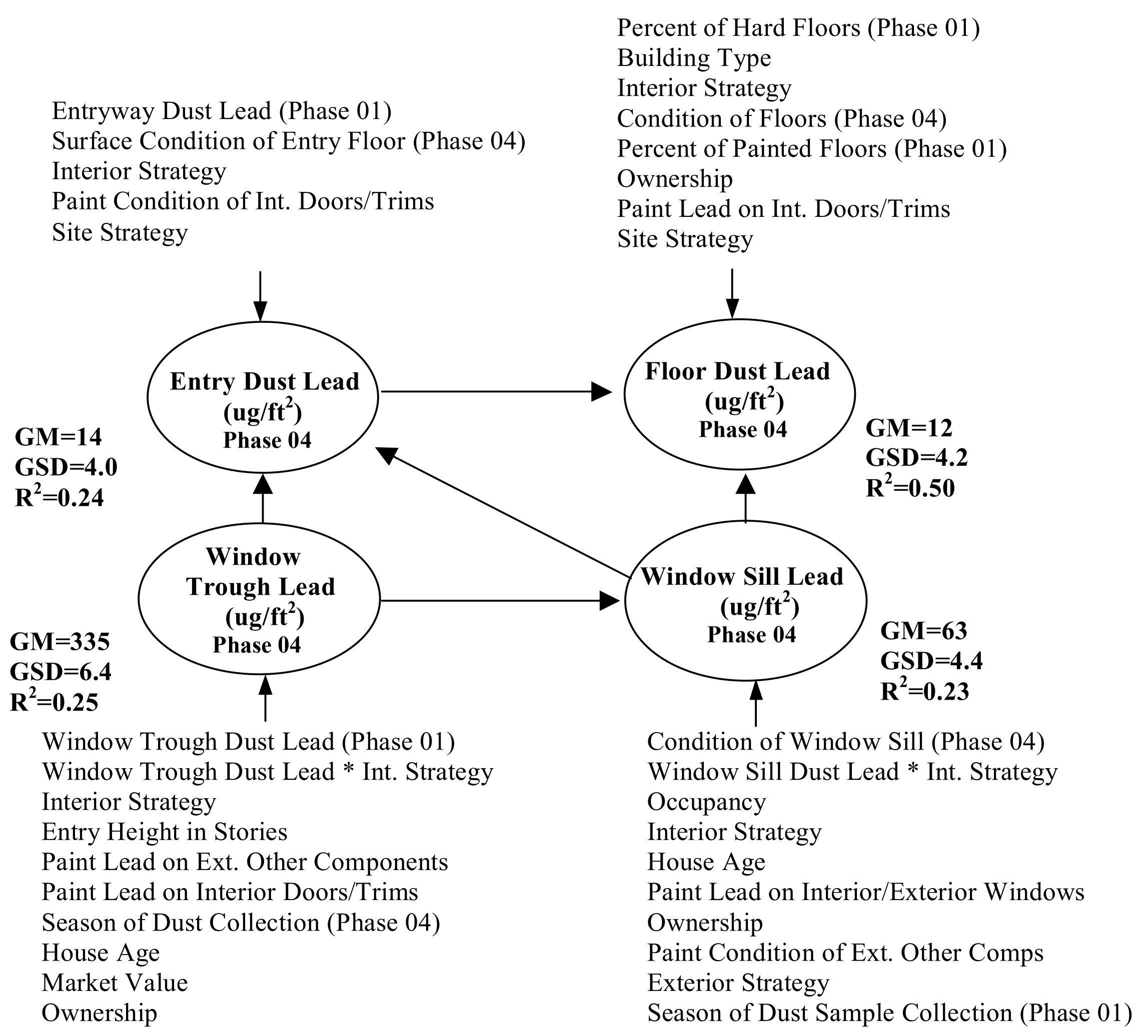
(Data as of: June 1, 2000)
(N=1401)



Note: Solid line indicates that a statistically significant coefficient was found.
All coefficients are significant at $P<0.05$

Figure 8-16: One Year Post-Intervention Dust Lead Exposure Pathway

(Data as of: June 1, 2000)
(N=1040)



Note: All coefficients are significant at $P<0.05$

In addition to the direct influence of the intervention variables on the dust lead loadings, the surface condition of the surfaces sampled post-intervention was a significant predictor of dust lead loadings for all four sample types. Further analysis of surface condition on windows demonstrated that the findings reflect both a direct effect of condition and an indirect effect of the Interior Strategies. Treatments and surface condition were intercorrelated; higher level Interior Strategies tended to result in better surface conditions. Thus, replacement windows resulted in lower dust lead loadings in part because the immediate lead exposure source was removed and in part because the surfaces were in good (smooth and cleanable) condition.

Although the findings of the one-year post-intervention dust SEM closely match the findings of the four multiple regression models of one-year dust lead loadings, one area of disagreement was observed. The multiple regression model for entry floor dust lead identified no significant relationship between interior strategy, exterior work or site work and the one-year post-intervention dust lead loadings on entry floors. The one-year post-intervention dust SEM identified direct associations with Interior Strategies and site work and indirect associations with Interior Strategies and exterior work (through window sill and trough dust lead). Estimates of entry floor dust lead loadings in dwellings that were treated with Interior Strategy 05 were higher than those in dwellings treated with other strategies, controlling for other factors. Interior Strategy 05 was significantly different than Interior Strategies 02, 04 and 06/07 and marginally significantly different than Interior Strategy 03.

Discussion

The advantage to structural equations analyses is their ability to suggest causal chains by simultaneously examining outcomes of interest. The one-year post-intervention dust SEM suggests that not only are all four dust lead sample types directly influenced by the differential effects of the five levels of Interior Strategies, but Interior Strategies indirectly influenced dust lead loadings along the dust lead pathways. For example, interior floor dust lead loadings at one-year post-intervention were both directly influenced by Interior Strategies and indirectly influenced by the effect of Interior Strategies on window trough, window sill and entry floor post-intervention dust lead loadings.

The pathway analysis suggests that exterior lead hazard control work has a direct influence on window sill dust lead loadings and an indirect effect on floor dust lead loadings. Site lead hazard control work directly influenced floor dust lead loadings, but did not affect window dust lead loadings. These findings correspond to the results of the multiple regression model for interior floors, which identified significant relationships between both exterior and site work and one-year post-intervention dust lead loadings.

Because the two multivariate analyses had two different goals and the SEM included certain post-intervention variables, the similarity of the predicted effects of the lead interventions in the two models offers support to the strength of the findings. At the same time, differences between the two models were expected and they should not be seen as exposing problems about either analysis. Rather, they point to areas where the conclusions that can be drawn from the findings must be viewed with more caution. Specifically, the entry floor findings suggest that because these samples are collected from a point where interior, exterior and site treatments all may have a significant effect, the ability to discern the exact variables exerting the primary effect is not as strong as on other surfaces.

A central premise of the structural equations analyses is that there are causal links between the four dust sample types. It is assumed that dust lead loadings on floors are correlated with dust lead loadings on windows because the dust on the windows moves from the windows to the floors. The results of both the pre-intervention and one-year post-intervention dust SEMs offer support to this hypothesis. Both before and after intensive lead hazard remediation, similar pathways of dust lead were observed suggesting that a strong relationship exists between the four sample types. A practical conclusion from these results would be that the lead exposure sources in a dwelling unit must be looked at as a whole system and to reduce floor dust lead loadings, lead exposure sources on windows must be addressed.

An alternative hypothesis should also be recognized. The dust lead loadings on all four sample types may be associated post-intervention because the clearance requirements caused contractors to clean the dust on all surfaces with a similar intensity. The model results clearly show that the dust lead loadings on the four sample types were correlated, but the assumption of causation is not a certainty. As presented in Section 8.4.1.3, across the different Interior Strategies, geometric mean dust lead loadings on window troughs increased at least ten-fold and geometric mean dust lead loadings on window sills doubled and tripled between clearance and six-months post-intervention, but entry floor and interior floor dust lead loadings remained fairly constant during the same period. Furthermore, no lagging effects on floors was observed, as floor dust lead loadings remained stable or declined in the succeeding phases of the study. These data would suggest that dust lead loadings on windows could rise significantly without influencing the floors.

Ultimately, whether the reader accepts the pathways presented in the model or not, it must be recognized that the pathways from windows to floors contributed just a small percentage of the dust lead down the causal chain. Treating all surfaces of concern is important, because only treating the “up-stream” hazards would not result in substantial “down-stream” dust lead reductions. Consider the Interior Strategy that was most commonly selected by grantees: Interior Strategy 05 (window abatement). This strategy was generally associated with the lowest dust lead loadings on windows, yet compared with dwellings treated with other strategies, these same dwellings had the highest geometric mean one-year post-intervention floor dust lead loadings. While window abatement was demonstrated to be the most effective measure to reduce dust lead loadings on windows, this treatment would need to be performed in conjunction with treatments that influence predictors of floor dust lead (e.g., floor surface type and condition, door and trim paint and general interior building condition, as well as exterior dust/soil lead) in order to most effectively control that exposure source.

8.5 Effect of Exterior Dust and Soil on Post-intervention Dust Lead Loadings

As part of a supplemental project to the Evaluation, members of the Evaluation team collected post-intervention exterior dust lead and soil lead samples from 503 buildings to assess the relationship between these sources of lead and post-intervention interior dust lead loadings. These data were analyzed to determine the pathways of exterior dust lead and soil lead into a dwelling and to estimate the magnitude of their effects on interior dust lead loadings.

The sampling of soil lead and exterior dust lead was not required under the NOFA for the HUD LHC Grant Program, but grantees were given the option of collecting soil samples as part of a routine lead risk assessment. Recognizing that soil lead levels might influence the interior dust lead loadings and ultimately, the observed effects of the intervention, the Evaluation protocols encouraged grantees to collect soil samples in a systematic manner at each sampling phase. The Evaluation protocols did not include methods for collecting or analyzing exterior dust samples.

After most pre-intervention data were collected, it became apparent that most grantees had not taken the opportunity to test soil. In addition, preliminary post-intervention findings suggested that there were unique grantee effects that could not be explained by the available variables. The Evaluation team hypothesized that soil lead and exterior dust lead might help explain regional effects as well as effects at individual dwellings. HUD agreed to support the collection of both soil and exterior dust samples from a subset of buildings enrolled in the Evaluation. Grantees that were participating in the extended Evaluation or that still had a significant number of one-year inspections to be completed as of 1998 were approached about participating in the this supplemental project. Sampling teams from UC collected samples from 12 of the 14 grantees; Massachusetts and New Jersey did not participate. The exterior dust and soil samples were analyzed at the University of Cincinnati.

8.5.1 Methodology

8.5.1.1 Sample Collection. Exterior sample collection occurred during the summer and fall of 1998 for all grantees except Alameda County and California. At these two sites, sampling occurred during February 1999. For most of the housing included in the supplemental project, the exterior samples were collected in close proximity to the two- or three-year post-intervention sampling visit made by the grantee. For Chicago, Cleveland and New York City, which did not participate in the extended Evaluation, exterior samples were collected in close proximity to the one-year post-intervention sampling phase.

Two composite exterior dust samples were collected: an exterior entry sample and a street sample. The exterior entry sample was a composite of two to three subsamples from the primary entrances to the building. Each subsample was collected from an area that was expected to have the heaviest dust lead loading, but not more than six feet from the door. Most commonly, this area was the sidewalk immediately adjacent to the doorway or the porch step. The street sample was a composite of two subsamples from the street curb in front of the dwelling. These samples were generally taken where the front walkway and driveway intersected with the street.

The exterior dust subsamples were collected by first collecting dust from a one square foot area, as outlined by a template of 24 inches by 6 inches in size, using a small scoop and brush. Any remaining dust was removed using three passes by a portable hand-held vacuum sampler. All collected exterior dust was deposited in a plastic sampling bag for analysis. The exterior dust collection method is described in more detail in Clark et al (Clark 2004).

One composite soil sample was collected from the perimeter of each building.[11] The sample included a total of 10 subsamples from all sides of the building where soil was present. Optimally, subsamples were collected at least two feet away from each other and from the foundation of the building. The top half-inch of soil was collected in a core sampling device and placed in a plastic sampling bag. When possible, bare soil was collected.

[11] A play area or mid-yard soil sample that is commonly collected during lead risk assessments was not collected as part of this study because of financial constraints.

UC's Hematology and Environmental Laboratory analyzed all samples. Both exterior dust samples and soil samples were prepared for analysis by oven drying each sample to a constant weight and then passing it through a 250 µm sieve. Particles less than 250 µm were homogenized, and an aliquot was taken for analysis. Analysis was conducted using flame atomic absorption. Exterior lead dust results were expressed in terms of both lead loading (i.e., the amount of lead by area, or $\mu g/ft^2$) and mass concentration of lead (i.e., the amount of lead by weight of sample or parts per million- ppm). Soil lead results were expressed in terms of concentration (ppm).

8.5.1.2 Statistical Methodology. A structural equations model (SEM) was fit to the longitudinal dust lead data to determine pathways between interior and exterior dust lead loadings and soil lead levels. Exhibit 8-1 presents the possible predictors examined in the model. This model is referred to as the Exterior Dust/Soil SEM. The Exterior Dust/Soil SEM was developed so that the outcome measures from the closest available post-intervention Grantee sampling phase to the collection of exterior dust and soil were used as primary outcomes. Forty (40) percent of the exterior dust and soil samples were collected closest to the one-year post-intervention sampling phase; 32 percent were collected closest to the three-year post-intervention sampling phase and 16 percent were collected closest to the two-year post-intervention sampling phase. Other sampling phases associated with the exterior dust and soil samples were clearance (7%) and six-months post-intervention (5%).[12]

The SEM developed for the pre-intervention dust data was used as a starting point for the Exterior Dust/Soil SEM. The predictors of the pre-intervention outcomes established in the pre-intervention model (see Section 8.4.3.1) were included as predictors of pre-intervention outcomes in this post-intervention model. No stepwise inclusion or elimination of variables was performed for pre-intervention outcomes. All variables presented in Exhibit 8-1 were included as possible predictors of post-intervention dust and soil measures. Backward elimination of insignificant predictors of the post-intervention outcomes was performed, followed by forward inclusion steps to re-enter, as needed, previously excluded variables.

Descriptive statistics of the results by grantee are presented below. The findings include both loading and concentration results for exterior dust lead. In the statistical model, loading was used as the measure of exterior and interior dust lead.

Both the exterior dust lead variables and the soil lead variables were transformed to their natural logarithm in the model to normalize their statistical distributions. For 48 percent of the dwellings (26% of the buildings) in the model, it was not possible to collect soil samples because of the absence of soil on the property. For those buildings, the soil concentration was assigned a value of one ppm. (A value of zero could not be used because it could not be transformed into its natural logarithm.)

Because exterior dust and soil sampling was done on a building basis, not a dwelling basis, the addition of the exterior dust and soil pathways necessitated accounting for multiple dwellings within a building having the same exterior entry dust, exterior street dust and soil lead levels.

[12] Although exterior dust and soil samples were collected one year or more after clearance, at 17 percent of the dwellings, interior dust samples were not available from that sampling phase. At those dwellings, interior dust lead data from the closest available post-intervention sampling phase was used as the outcome measure.

Furthermore, unlike the report's other SEMs, which were cross-sectional at one point in time after intervention, the exterior dust and soil model included data from various sampling phases from clearance to three-years post-intervention.

8.5.2 Findings

8.5.2.1 General Descriptive Statistics. A total of 503 buildings were sampled as part this supplemental project. All buildings had exterior entry dust samples collected, 494 buildings had exterior street dust samples collected and 418 buildings had perimeter soil samples collected. The geometric mean exterior entry and street dust lead loadings were 807 µg/ft^2 and 1,833 µg/ft^2, respectively. The geometric mean exterior entry and street dust lead concentrations were 1,397 ppm and 295 ppm, respectively. The geometric mean perimeter soil lead concentration for buildings with soil samples was 1,017 ppm.

Table 8-19 presents the median and 10th and 90th percentiles for the exterior dust and soil lead measurements. The exterior dust lead levels are presented as both concentrations and as loadings. The median dust lead loadings for exterior dust lead were similar to the geometric mean values presented above: 1,030 µg/ft^2 at the exterior entry and 1,890 µg/ft^2 at the street. For nine of the twelve grantees, the median exterior dust loading at the street was higher than at the entry to the building. Only Baltimore, Milwaukee and Minnesota had median exterior entry dust lead loadings that were higher than their median street dust lead loadings.

Median exterior dust lead as measured by concentration displayed a different pattern than the levels as measured by loading. The median exterior dust lead concentration at streets (308 ppm) was *lower* than the concentration at building entries (1,500 ppm). This pattern was true for all twelve of the grantees participating in the Exterior Dust and Soil Project. The median concentration value at the street was *six times lower* than the median loading value (308 v. 1,890 ppm), while the median concentration value at the building entry was almost *50 percent higher* than the median loading value (1,500 v. 1,050 µg/ft^2). The findings show that the amount of non-leaded dust was much higher at the street than at the building exterior.

The exterior dust lead findings played an important role in the development of the Exterior Dust/Soil SEM. The higher exterior dust lead *loadings* at the street relative to the exterior building entry initially suggested that the leaded dust from the street was carried by foot or by the air to the building entry. However, the finding that median exterior dust lead *concentrations* at the street were lower than those at the exterior building entry raised questions about that assumption. Under the principle that particles move from a level of higher concentration to lower concentration, the Evaluation team concluded that the most likely pathway of lead in the exterior was from the entry of the building to the street. The Exterior Dust/Soil SEM was developed based on this determination.

8.5.2.2 Model Results. Of the 503 buildings sampled, 289 buildings (and 541 dwellings) had all necessary data available to be included in the Exterior Dust/Soil SEM. As reported earlier, these buildings included 76 buildings (and 250 dwellings) where soil was not present so no soil could be collected. To include these dwellings in the model, each was assigned a soil lead concentration of 1 ppm. Table 8-20 presents the number of buildings and dwellings included in the model by grantee.

Table 8-19: Exterior Dust and Soil Lead Concentrations and Exterior Dust Lead Loadings

		Exterior Entry Dust						Street Dust						House Perimeter Soil		
Grantee	No. of Bldgs	Concentration (ppm)			Loading (µg/sq ft)			Concentration (ppm)			Loading (µg/sq ft)			Concentration (ppm)		
		10th %tile	Median	90th %tile	10th %tile	Median	90th %tile	10th %tile	Median	90th %tile	10th %tile	Median	90th %tile	10th %tile	Median	90th %tile
Alameda County	20	274	539	1,450	12	101	540	101	271	596	96	718	3,620	180	501	1,600
Baltimore	54	644	2,600	9,580	334	2,240	11,100	298	703	2,010	327	1,790	5,900	484	1,040	2,140
Boston	30	821	2,590	7,280	244	1,570	4,960	316	762	1,780	633	5,100	33,700	1,060	2,830	6,470
California	29	211	846	1,570	13	315	2,560	119	323	680	69	532	3,080	205	613	1,380
Chicago	53	487	2,330	11,800	159	1,170	10,800	155	279	494	915	2,680	12,700	480	1,480	3,250
Cleveland	51	764	2,250	5,950	106	2,490	18,000	240	477	1,220	1,420	12,700	48,000	749	1,760	3,930
Milwaukee	50	857	3,160	16,000	213	4,000	29,900	231	439	913	409	2,350	9,790	500	1,550	4,160
Minnesota	56	136	802	5,570	19	881	5,900	35	111	247	115	761	4,940	243	924	2,320
New York City	31	613	2,190	10,500	86	729	4,970	440	941	1,740	368	1,290	4,040	52	73	4,310
Rhode Island	34	178	1,370	5,230	55	645	6,230	32	286	1,240	432	2,000	17,400	185	812	2,220
Vermont	46	51	317	1,330	13	226	3,620	19	70	255	150	1,220	6,520	203	920	1,940
Wisconsin	47	185	627	5,370	26	674	4,990	34	88	402	110	839	5,850	87	753	2,660
All Grantees	503	2,530	1,500	7,520	43	1,030	10,600	52	308	1,100	230	1,890	13,600	270	1,190	3,330

June 2000 Dataset

The geometric mean soil lead concentration for all buildings in the model was 1,003 ppm at the building perimeter (Table 8-20). This average represents the level for all properties where soil was present and does not include properties without soil. Geometric mean soil lead concentrations in Boston were more than twice the all-grantee geometric mean, while Alameda County, California and Wisconsin had geometric mean soil lead concentrations that were less than half of the all-grantee level.

The geometric mean exterior dust lead loadings for all buildings in the model were 1,633 $\mu g/ft^2$ at the street and 954 $\mu g/ft^2$ at the primary building entries. Exterior dust lead loadings varied among grantees. In Cleveland, geometric mean exterior dust lead loadings for both sampling locations were twice as high as the loadings for all grantees combined. Boston and Chicago also tended to have higher street dust lead loadings, while Milwaukee and Baltimore tended to have higher exterior entry dust lead loadings. Conversely, Alameda County and California had geometric mean exterior dust lead loadings at both locations that were half those for all grantees together. Vermont and Minnesota also tended to have lower exterior entry dust lead loadings.

The geometric mean exterior dust lead loadings were higher than the geometric mean dust lead loading (11 $\mu g/ft^2$) measured at the interior entry of the dwelling unit closest to the building entry. This finding supports previous evidence that dust lead loadings on building exteriors tend to be higher than those on interior entryways (Lanphear 1995). However, the magnitude of the percent difference between the loadings (>8500%) is expected to be an overestimate. Because the sampling methodologies were different for the two locations (i.e., vacuum sampling versus wipe sampling), a more precise comparison between the loadings is not possible.

Figure 8-17 presents the significant endogenous and exogenous variables that influenced dust and soil lead outcomes in the Exterior Dust/Soil SEM. Of interest, exterior entry dust loading had a direct effect on both exterior street dust lead loading and interior entry dust loading. Through both direct and indirect pathways, exterior entry dust lead also influenced dust lead loadings on interior floors. Soil lead concentrations were a predictor of exterior street dust lead loadings.

No variables other than soil lead concentration and exterior entry dust lead loading were predictors of exterior street lead loading. Exterior entry dust had three predictors: window paint lead levels, exterior paint lead levels and the use of a site/soil intervention. Buildings with higher exterior paint lead levels and buildings with no soil treatments had higher exterior entry dust lead loadings. Soil lead concentration had one predictor: the use of an exterior intervention. Buildings with no treatments to the building exterior were associated with higher soil lead concentrations.

The exterior entry dust lead loadings had significant yet varying direct and indirect effects on dust lead loadings on the interior entry and the other interior floors. Table 8-21 presents the effect of increases in exterior dust lead loadings on the "downstream" dust lead loadings. For example, a 930 percent increase in exterior dust lead loadings was associated with a 20 percent increase in interior entry floor dust lead loadings and a 26 percent increase in other interior floor dust lead loadings. As addressed earlier, dust lead loadings on exterior entries were measured using a substantially different sampling method than loadings on interior surfaces, so the difference in magnitudes of effects may be somewhat misleading. Exterior entry dust lead

Table 8-20: Geometric Mean Exterior and Interior Dust Lead Loadings (µg/ft²) and Soil Lead Concentration (ppm) for Dust SEM-Exterior Dust and Soil

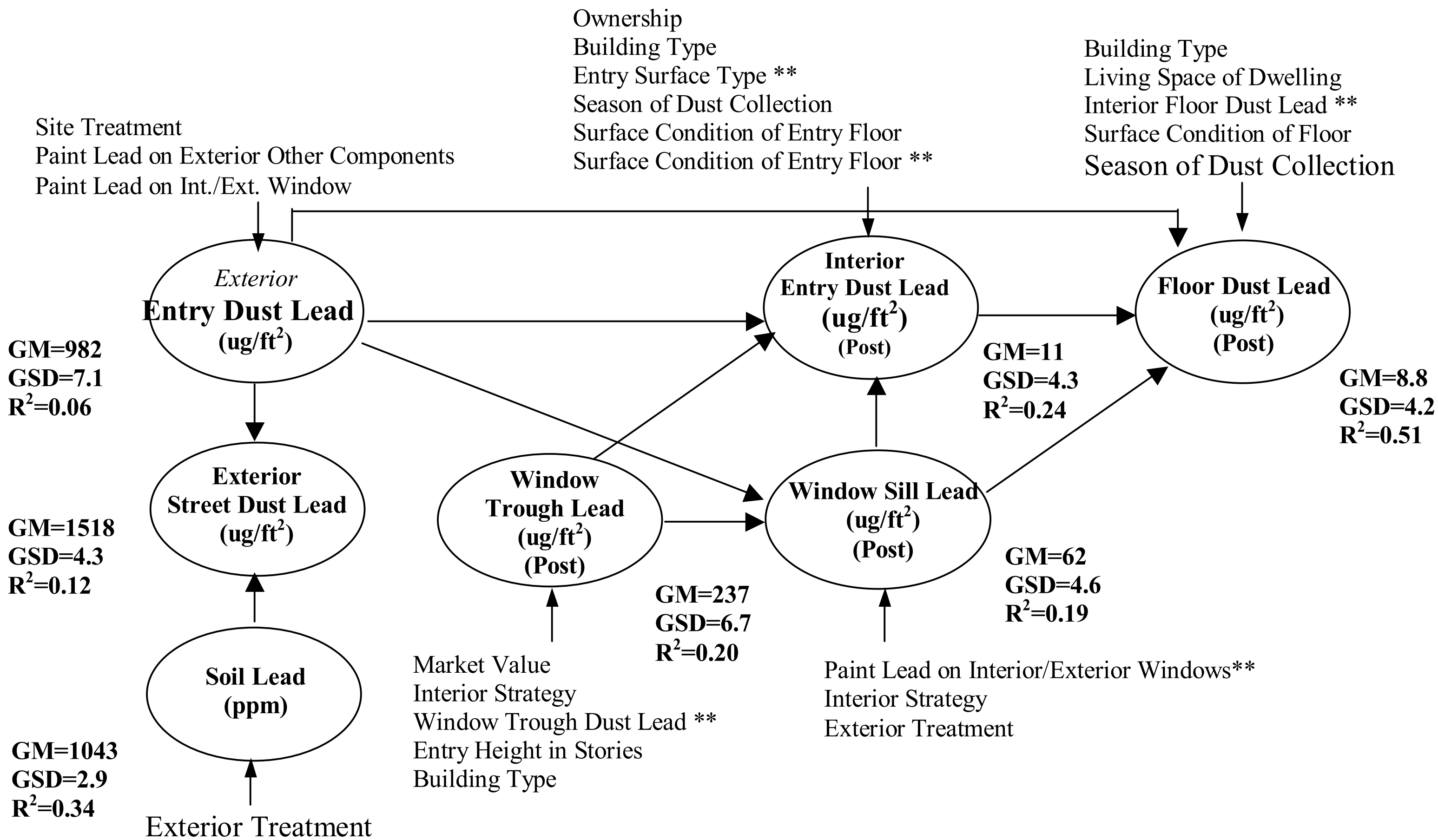
Grantee	Num. of Buildings / Dwellings	Exterior Entry GM (GSD)	Exterior Street GM (GSD)	Soil[1] GM (GSD)	Interior Entry GM (GSD)	Interior Floor GM (GSD)	Window Sill GM (GSD)	Window Trough GM (GSD)
Alameda County	6 / 6	126 (4)	325 (5)	383 (2) *n=6*	8 (3)	3 (3)	29 (9)	81 (17)
Baltimore	54 / 54	2,282(4)	1,570 (4)	1,084 (2) *n=6*	44 (3)	56 (4)	76 (3)	527 (4)
Boston	30 / 40	1,373 (4)	4,895 (5)	2,758 (2) *n=29*	8 (3)	5 (2)	62 (4)	46 (5)
California	9 / 11	178 (8)	946 (4)	496 (3) *n=9*	8 (3)	7 (3)	32 (5)	112 (10)
Chicago	21 / 25	1,494 (6)	3,854 (3)	1,476 (2) *n=20*	23 (3)	22 (3)	144 (6)	374 (13)
Cleveland	10 / 43	3,766 (6)	4,049 (4)	1,636 (3) *n=9*	19 (4)	13 (3)	86 (4)	159 (7)
Milwaukee	28 / 41	1,821 (9)	2,278 (3)	1,278 (2) *n=28*	13 (4)	9 (3)	161 (4)	1430 (8)
Minnesota	37 / 38	537 (11)	786 (4)	773 (2) *n=36*	8 (4)	8 (3)	50 (3)	772 (5)
New York City	25 / 185	844 (5)	1,052 (3)	1,011 (10) *n=3*	11 (3)	9 (3)	65 (5)	189 (4)
Rhode Island	24 / 37	518 (8)	2274 (5)	747 (3) *n=21*	6 (2)	5 (3)	36 (5)	118 (4)
Vermont	18 / 29	281 (8)	1,031 (5)	1,057 (2) *n=18*	6 (5)	2 (10)	33 (5)	618 (5)
Wisconsin	27 / 32	636 (6)	803(4)	459 (4) *n=27*	3 (9)	2 (4)	18 (3)	77 (5)
All Grantees	289 / 500	954 (7)	1,633 (5)	1,003 (3) *n=213*	11 (4)	9 (4)	62 (5)	237 (7)

[1] Excluding Buildings without soil

Figure 8-17

Post-clearance* Lead Exposure Pathway Including Exterior Dust and Soil Lead

(Data as of: June 1, 2000)
(N=541)



Note: Solid line indicates that a statistically significant coefficient was found.
All coefficients are significant at $P<0.05$.
Soil, exterior street dust, entry dust samples were collected by University of Cincinnati.
Other data were collected by Grantees.
* The housing data that were closest to the exterior dust collection were used.
** Pre-intervention variable

loadings collected by vacuum sampling ranged from 1 to 151,999 µg/ft^2, with 10th and 90th percentiles of 70 and 10,147 µg/ft^2, respectively. Interior entry dust lead loadings collected by wipe sampling ranged from 0 to 2,053 µg/ft^2, with 10th and 90th percentiles of 2 and 65 µg/ft^2, respectively.

Table 8-21: Percent Increase in Interior Entry and Other Interior Floor Dust Lead Loadings by Percent Increase in Exterior Entry Dust Lead Loadings

Exterior Entry Dust Lead Loading Percent Increase	Interior Entry Dust Lead Loading Percent Increase	Other Interior Floor Dust Lead Loading Percent Increase
14,400%[1]	47%	60%
930%[2]	20%	26%
500%	15%	20%
100%	6%	8%

[1]Percent Increase from 10th to 90th percentile (70 to 10,147 µg/ft^2)
[2]Percent Increase from 25th to 75th percentile (310 to 3,197 µg/ft^2)

Discussion

The model identifies two significant relationships between lead hazard interventions and soil concentrations and exterior entry dust lead loadings: 1) the use of site/soil interventions was associated with lower exterior entry dust lead, and 2) the use of exterior building interventions was associated with lower soil lead concentrations. Any interpretation of these findings must be made with caution, since the causal relationships may be misconstrued. For example, it would appear to be incorrect to infer from the model that the use of the exterior building treatments caused the lower soil lead concentrations. Masonry multi-unit buildings in Cleveland and New York City and masonry rowhouses in Baltimore generally did not have soil at their perimeter and these buildings often did not receive exterior lead hazard control interventions because lead hazards were not present. Because few other buildings lacked soil, a relationship was identified between the buildings having soil or not and the use of exterior lead hazard control treatments. When buildings without soil were removed from the model, there was no significant relationship between soil lead levels and the use of exterior treatments on the building.

Further exploration of the relationship between the use of site/soil interventions and exterior entry dust samples did not identify anything that would question a causal relationship. At the 28 buildings with soil interventions, the geometric mean exterior entry dust lead loading (467 µg/ft^2) that was less than half those of the other buildings. The exploration found that all of these buildings also had exterior building interventions conducted, raising questions about whether the exterior interventions were an important contributor. However, when the 231 buildings without soil lead interventions were examined, these buildings had comparable geometric mean exterior entry dust lead loadings regardless of whether or not exterior lead interventions were conducted (1011 $\mu g/ft^2$ v. 1137 $\mu g/ft^2$, respectively). The model estimated that the use of site interventions reduced exterior dust lead loadings by 69 percent and consequently reduced interior entry dust lead loadings by 3 percent.

It may appear contradictory that site/soil interventions would be associated with exterior entry and interior dust lead loadings, but that perimeter soil lead concentrations would not be associated with either outcome. This could be related to the fact that the soil interventions often treated areas other than, or in addition to, the building perimeter. Furthermore, the treatments selected often did not remove or otherwise significantly change the soil lead content; the predominant treatments were the introduction of ground cover (see Section 5.3.2).

8.5.3 Summary of Findings

A direct relationship between exterior entry dust lead loading and interior entry dust lead loading was identified. Based on past studies that have demonstrated that dust lead loadings on exterior locations are higher than interior locations, it was assumed that exterior leaded dust is tracked into the dwelling from the exterior. Because the sampling methodologies for interior and exterior dust lead sampling were different, this hypothesis could not be confirmed with the Exterior Dust and Soil Project data. However, the fact that exterior entry dust lead loadings were more than 85 times the interior entry dust lead loadings does not appear to challenge the hypothesis.

The higher exterior dust lead concentrations at the exterior entry sample locations relative to those at the exterior street sample locations suggested that leaded dust migrated from the building perimeter to the street. With this pathway predefined, the models did not identify exterior street dust as a source of lead for the leaded dust in the dwellings. A pathway where exterior street dust lead moves onto the window sill or window trough was not significant. In other words, evidence of blown-in lead from the street was not present from these data.

The analyses highlight the influence of exterior paint on exterior dust lead loadings and the subsequent migration of this lead into the building. Exterior paint lead both from the exterior cladding and trim and from the windows contributed to the exterior entry dust lead loadings. These leaded particles then migrated out to the street or into the building. This finding suggests that the deterioration of exterior leaded paint is a significant contributor to both interior and neighborhood dust lead loadings.

The analyses did not identify a significant relationship between perimeter soil lead concentrations and exterior entry or interior dust lead loadings. A significant relationship was identified between the use of a site/soil lead intervention and the exterior entry dust lead loading. Buildings where a site/soil lead intervention was conducted to some area of the property had lower post-intervention dust lead loadings on exterior and interior entries and other interior floors than those that had no site/soil lead intervention.

8.6 Treatment Longevity

A principal objective of the Evaluation (Objective 6) was to estimate the durability of lead hazard control treatments. The Evaluation designers were especially interested in the durability of treatments that left lead-based paint in a dwelling following treatment, such as paint stabilization. Although the Residential Lead-Based Paint Hazard Reduction Act (Title X of the Housing and Community Development Act of 1992) allowed interim controls such as paint stabilization to be used in Federally assisted housing, questions remained about the longevity of these treatments. The Evaluation offered HUD an opportunity to monitor the durability of these treatments for up to three years. The Evaluation also offered an opportunity to compare the longevity of encapsulants with non-encapsulating coatings (i.e., paints) and enclosures (i.e., materials applied to a lead-based painted surface with mechanical fasteners).

The longevity of treatments was considered a potential modifier for the effects of treatments on dust lead loadings. Dwellings in which interim control treatments failed (i.e., lead-based paint became a hazard) were expected to have higher dust lead loadings than dwellings without failures, given similar pre-intervention conditions and similar treatments. The Evaluation designers were interested in the magnitude of the differences in dust lead loadings.

During data collection, the Evaluation team recognized that part of the objective could not be fulfilled. Data collectors frequently did not follow the protocols for the assessment of treatment failures. The types of treatments applied and the components affected were frequently not listed during the follow-up inspections. In addition, data collectors used inconsistent standards to determine treatment failures. The Evaluation team informed grantees of these issues, conducted retrainings, and in some extreme cases, required reinspections of dwellings. On final review, however, the treatment longevity data were considered to have too much variability to reliably test the effect of treatment failures on longitudinal dust lead loadings.

Even though the effect of treatment longevity on dust lead could not be assessed, the Evaluation team was able to screen out the most questionable data and use the remaining information to characterize trends in the longevity of treatments. The differences in assessment standards of data collectors may limit this report's ability to quantify failure rates precisely, but these data remain valuable for comparative purposes. This section presents comparisons of failure rates by study phase, by type of component and by treatment category.

8.6.1 Methodology

When the Evaluation protocols were developed, the assessment of treatment failures after clearance was not a common practice in either a research or operational setting. Unlike most other study protocols, the development of a reporting form and procedures for the follow-up treatment assessments was done without the benefit of examples from prior field or research experience. This section reports not only the field assessment methods but also the operational issues that were encountered when these procedures were implemented.

8.6.1.1 Field Assessment Procedures. Post-intervention inspections of treatment durability were conducted at each post-intervention phase (i.e., 6-months, 1-, 2- and 3-years post-intervention). Because all grantees used Specmaster® software to report their treatments (see Section 5.1.2), the data collectors had the ability to print out the list of treatment specifications used in each room of the dwelling prior to conducting the inspection. Data collectors were instructed to take this list to the dwelling and systematically review the integrity of the treatments. The data collector was to identify each treatment that failed, its location, the magnitude of failure (e.g., 2 square feet), the reason for the failure, and any follow-up treatment that was performed by the grantee.

During training, data collectors were instructed to report all treatments where the physical integrity of the lead hazard control measure failed. Data collectors were not asked to assess whether the failure created a lead-based paint hazard. This decision was intended to improve the analysis of treatment cost-effectiveness. For example, the failure of new replacement windows would not be expected to generate a lead-based paint hazard, but it could have an impact on the relative cost-effectiveness of the treatment. If a low-cost replacement window was selected that was of comparable initial cost to a less effective treatment such as paint stabilization, the window replacement would be clearly considered more cost-effective. However, if a significant proportion of these low-cost windows were inoperable shortly after installation and repair or replacement was necessary at additional cost, then the cost-effectiveness equation would not be so obviously favorable to the replacement window.

Data collectors were asked to record the reasons for treatment failure in order to better evaluate the effectiveness of the various treatments. Reasons for treatment failure were characterized using the following list of options:

* Adhesion failure	* Failure of replaced component	* Unknown
* Physical damage	* Inadequate installation/application	
* Substrate failure	* Other	

8.6.1.2 Operational Issues. Certain problems were encountered during the follow-up inspections that impacted the final data quality. For example, the original form lacked fields to record the magnitude of the treatment failure. This information was later deemed critical if treatment failures were to be correlated with dust lead loadings. Therefore, a major revision to the follow-up inspection form was released to the grantees in August 1996, two years into the Evaluation. Additional trainings were provided to grantees about the final protocols, but the changes likely confused some of the data collectors.

Beyond protocol issues, local constraints created barriers for the successful collection of treatment failure data. Because data collectors did not have prior experience assessing treatment failures, they lacked a frame of reference that would have been helpful to both the Evaluation team and the data collectors as they tried to establish common definitions of treatment failures. Data collectors also had limited encouragement from the occupants of dwellings to devote the time required for a comprehensive inspection.

These operational issues may help explain why the Evaluation team, during scheduled quality control visits, observed data collectors frequently arriving at the dwelling units without a list of treatments conducted; moving rapidly through rooms of the dwelling; and ultimately, reporting fewer failures than the observer identified. The operational issues may also help explain why 10 percent of the treatments that failed were not on the list of treatments for the dwelling or why 37 percent of the units of quantity that failed were not comparable with the units of quantity treated (e.g., square feet versus linear feet).

Due to these problems, the Evaluation team decided that the use of these data to explain dust lead loadings was inappropriate. The imprecise documentation of results as well as the variability across data collectors was likely to introduce too much error for the treatment failure rate variable to be a reliable indicator.

At the same time, there was no indication that data collectors were systematically reporting biased results within a dwelling. For example, data collectors were not looking for failures on walls preferentially to trim. They were also not looking for paint failures preferentially to failure of replaced components. The lack of bias within a dwelling offered support for a decision to present the descriptive statistics for treatment failures. Acknowledging the imprecision of failure rates, these data still provide comparative information about treatment failures that should prove useful to understanding other results of the Evaluation and conducting future research on treatment failures.

The analysis examined failures to the 25 most commonly used treatment equivalent categories[13] (Table 8-22). These treatment categories included the 21 most commonly used interior treatments and the four most commonly used exterior treatments. The analysis was restricted to 25 categories since they would be most representative of treatments of interest. The categories represented 96 percent of all lead hazard control treatments (roughly 66,000 of 69,000 treatments).

8.6.2 Treatment Failures

Of the 10,613 treatment failures reported on follow-up inspection forms from six-months to three years post-intervention, 1,056 treatments (10%) were not on the associated list of treatments for the inspected dwelling. These unmatched treatments were excluded from further analysis. The remaining 9,577 treatment failures are further examined in this report. Overall, out of 73,046 treatments in dwellings with six-month follow-up inspections, 3.4% of the treatments failed. Failure rates for other phases were 5.1%, 7.4% and 7.6% for one, two, and three-years post-intervention, respectively.

[13] As explained in Section 5.1.2, similar lead hazard control specifications were collapsed into categories that were expected to have equivalent effects on dust lead generation.

Table 8-22: Top 25 Most Commonly Used Individual Lead Hazard Control Treatments

Rank	Treatment	Number of Times Used*
1	Trim – Stabilize Paint	10,025
2	Window – Replace	9,002
3	Wall/Ceiling – Stabilize Paint	7,949
4	Door – Stabilize Paint	6,198
5	Trim – Replace/Remove	4,619
6	Trim – Remove Paint	3,798
7	Wall/Ceiling – Enclose	3,149
8	Window – Wrap Sill/Trough	2,721
9	Door – Replace	2,543
10	Floor/Stair – Enclose (wood/vinyl)	2,382
11	Window – Stabilize Paint	2,323
12	Exterior – Stabilize Paint	2,082
13	Floor/Stair – Stabilize Paint	1,245
14	Window – Remove Component	1,171
15	Window – Replace Sash Only	883
16	Window – Install Jamb Liner	814
17	Window – Remove Paint	788
18	Exterior – Remove Paint	707
19	Window – Repair	673
20	Exterior – Enclose	654
21	Floor/Stair – Refinish	612
22	Exterior – Replace Component	497
23	Door – Remove Paint	496
24	Door – Remove Component	475
25	Trim – Encapsulate	358

*Number of Times Used (Per Room) During Interventions. Because not all dwellings were followed throughout the course of the study, the number of treatments that were monitored during any one phase were less than those reported here.

Data from: Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Tables C2 and C3

8.6.2.1 Treatment Failures by Time after Clearance. The treatment failures increased with time after clearance. On average, a dwelling had one treatment failure six months after intervention, two failures one and two years after intervention and three failures three years after intervention. The median number of failures per dwelling was zero at six months and one year after clearance and one at two and three years after clearance, suggesting an unequal distribution of failures. The percentage of treatments with a failure increased at each of the four post-clearance phases (6 months, 1 year, 2 years and 3 years post-intervention): 4%, 6%, 9% and 10%, respectively. The [14]percentage of treatment failures appeared to level off between two years and three years post-intervention.

Interpretation of this trend is somewhat clouded because unlike classic "survival" analyses, the observation of a failure was not a permanent result. If either the grantee or the property owner corrected the failure, a treatment failure would not be present at a subsequent phase unless it failed again. At each phase of data collection, the treatment was examined without regard to previous results. The number of treatment failures reported at each phase after 6 months post-intervention included treatments that failed previously and were not corrected,[15] plus any treatments that failed since the last visit.

It is important to emphasize that the grantees had no obligations under their LHC Grant agreements to conduct any follow-up treatments because maintenance is the duty of the property owner. Of the 9,577 failures identified by the inspections, less than 100 (1%) received additional treatment from the grantee. While data were not collected about whether specific treatments were conducted by the property owners without knowledge of the grantees, anecdotal evidence suggests additional work was not often completed. Based on this information, the trends suggest that most new failures occurred within the first six months after treatment and the rate of new failures declined at each subsequent phase until there was less than a ten percent increase from two to three years post-intervention.

8.6.2.2 Treatment Failures by Component Treated. The components on which treatments were most likely to fail were (in order): 1) doors, 2) exterior cladding/porches, 3) floors/stairs, 4) windows, 5) interior trim and 6) interior walls/ceilings. These findings support expectations that treatments to components that are subject to routine impact, abrasion or weather are more likely to fail. Treatments to doors were two to two and a half times more likely to fail than treatments to interior trim or interior walls/ceilings. On doors, eight percent of treatments had a failure at six months post-intervention and the percentage increased to 18 percent at three years post-intervention (Figure 8-18). The percentage of interior wall and ceiling treatments with a

[14] The average number of failures at six months and one-year post-intervention was the same in the base Evaluation and the extended Evaluation even though the sets of data differed. Therefore, results are not separated by dataset.

[15] Grantees were not required to correct treatment failures under their HUD LHC Grant agreement, although in some cases treatments were done. Property owners were expected to be notified of any lead-based hazards that existed at the property, but further action was dependant on the responsiveness of the property owner and/or the local enforcement agencies.

Figure 8-18: Percentage of Treatments Where at Least One Use of Treatment In a Room Failed by Component and Month of Post-Intervention Data Collection

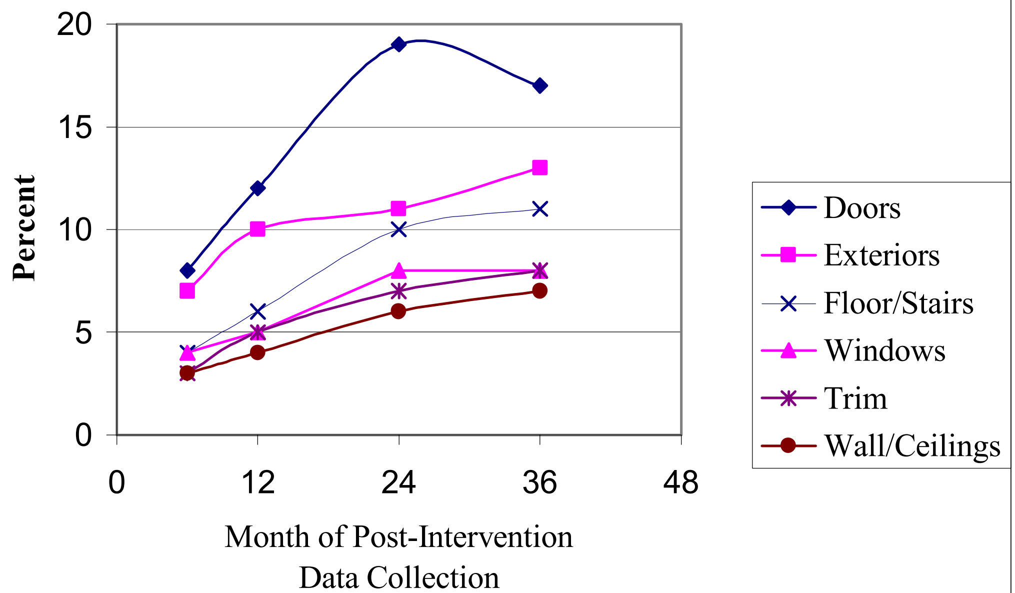
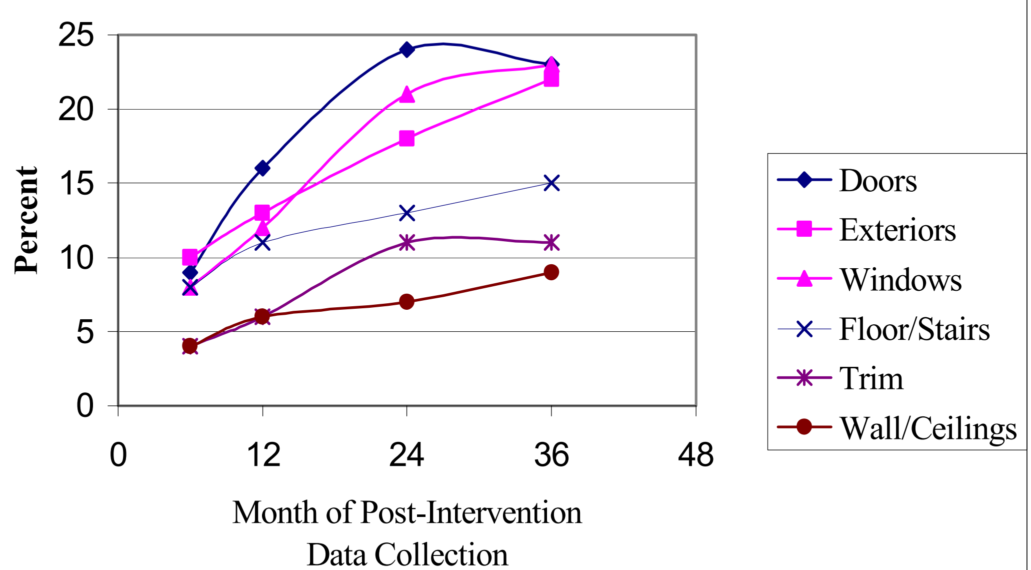


Figure 8-19: Percentage of Paint Stabilization Treatments Where at Least One Use Of Treatment Failed by Component and Month of Post-Intervention Data Collection



failure increased from three percent at six months post-intervention to seven percent at three years post-intervention.

The results for treatments to windows and floor/stairs were influenced by the types of treatments that were applied to these components. The majority of treatments applied to windows and floor/stairs either replaced the component or enclosed it. All other components were more likely to be treated with paint stabilization. Because paint stabilization treatments were more likely to fail (see Section 8.6.2.3), the failure rates for windows, and to a lesser extent for floor/stairs, are closer to those of doors and exteriors when only the failures of paint stabilization treatments are considered (Figure 8-19). Three years after intervention, paint stabilization treatments to doors, windows or exteriors were each more than twice as likely to fail than paint stabilization treatments to interior trim or interior walls/ceilings.

8.6.2.3 Treatment Failures by Treatment Class. Treatment failure rates varied by the class of treatment. Four classes of treatments were commonly conducted in the Evaluation: paint stabilization, component replacement or removal, component enclosure and paint removal. The failure rates for these classes of treatments are presented by phase of data collection in Figure 8-20.

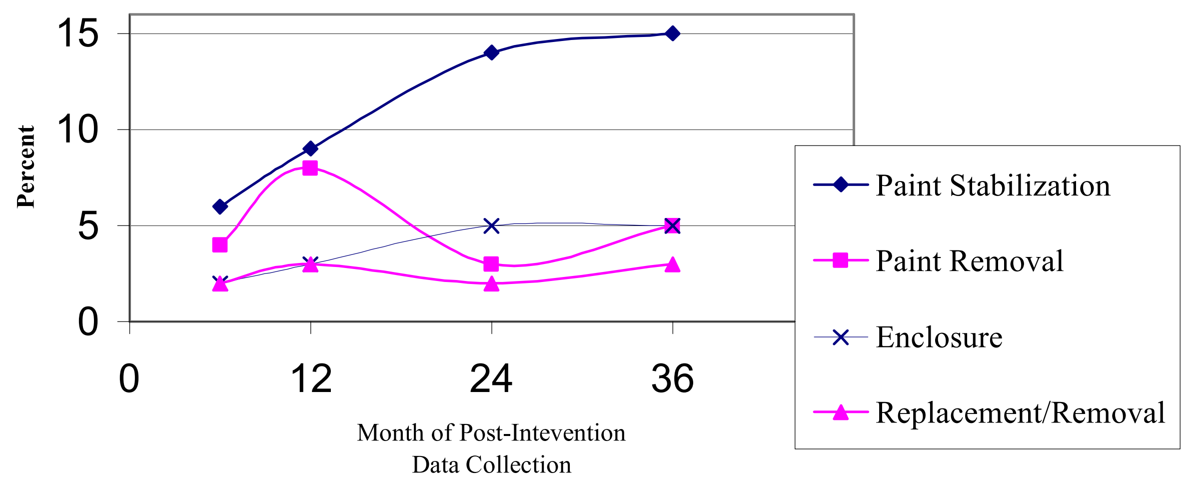
At six months and one year post-intervention, treatment classes that were most likely to fail were (in order): 1) paint stabilization, 2) paint removal and repainting, 3) component replacement/removal, and 4) component enclosure. Paint stabilization treatments were three times more likely to fail than component replacement/removal or enclosure treatments. Six percent of paint stabilization treatments failed at six months post-intervention compared to two percent of both replacement/removal treatments and enclosure treatments.

At two years and three years post-intervention, paint stabilization remained the class of treatment most likely to fail, while component replacement/removal treatments were least likely to fail. At three years post-intervention, paint stabilization (15% failures) was again three times more likely to fail than enclosure treatments (5% failures) and was *six* times more likely to fail than component replacement/removal treatments (2.5% failures).

As discussed in Section 8.6.1, a failure of a treatment did not necessarily indicate that a lead-based paint hazard was created. Obviously, failures of replaced or removed components would not create a lead hazard. Failures of components where the lead-based paint was completely removed suggest that the new paint became deteriorated, but no new hazard was created. Even failures of enclosures may not have created a hazard if the enclosure was applied to create a smooth and cleanable surface rather than to enclose lead-based paint (e.g., a new layer of vinyl flooring). Of greatest concern were failures of components treated with paint stabilization, where the original lead-based paint may have become deteriorated as part of the failures.

8.6.2.4 Examination of Failures to Individual Treatment Equivalent Categories. Of the 25 most commonly used treatment equivalent categories, six categories were at or above the mean failure rate in each of the four post-clearance data collection phases. Two other treatment categories were above the mean failure rate during the first two post- clearance phases. The failure rates of the eight treatment categories by phase are presented in Table 8-23.

Figure 8-20: Percentage of Treatments Where at Least One Use of Treatment In a Room by Treatment and Month of Post-Intervention Data Collection



Of interest, the treatment, the treatment category that had the highest percentage of failures in each phase was the installation of window jamb liners. Six months after installation, 17 percent of the rooms where jamb liners were installed had at least one jamb liner failure. Three years after installation, nearly half of the rooms with jamb liners (46%) failed; four and half times the average and twice that of the treatment with the next highest failure rate. Just over half of the jamb liner failures were attributed to inadequate installation, while 29 percent failed because they were physically damaged.

Of the remaining five treatment categories that were most likely to fail at all four post-clearance phases, all were paint stabilization treatments. These treatments covered all components treated with paint stabilization with the exception of paint stabilization to interior walls/ceilings. The failure rates for paint stabilization treatments to interior walls/ceilings were just under the mean failure rate in all four phases.

Two treatment categories had an above-average failure rate during just the first two post-clearance phases: paint removal on doors and exteriors. The failure rates for both of these treatment categories were well below average at the dwellings that participated in the Extension of the Evaluation.

Discussion

This last observation may be due in part to differences in specification definitions. Both of these treatment categories included specifications that combined the paint removal with repainting, but the paint removal specifications used in dwellings in the Extension did not tend to include repainting (i.e., a separate repainting spec was used). Thus, the early failures of these treatments appear to reinforce the paint stabilization findings rather than reflect problems with paint removal.

8.6.2.5 Treatment Failures of Encapsulants. As reported in Section 5.3.1, encapsulation treatments were infrequently applied to dwellings in the Evaluation and only trim encapsulation was in the top 25 most commonly used treatment categories (Table 8-22) while wall/ceiling encapsulation were ranked 30th. Although encapsulants were neither frequently used nor broadly applied across the grantee sites, components in over 100 rooms were treated with encapsulants on interior trim or interior walls/ceilings. The results for these treatments are presented here with the caveat that conclusions drawn from these few data should be made with caution.

At one year post-intervention, encapsulants appeared to hold up better than paint stabilization, but after that, encapsulants generally had a failure rate equivalent to that of paint stabilization on both interior trim and interior walls/ceilings (Table 8-24). Both encapsulation and paint stabilization treatments on walls/ceilings were more likely to fail than the enclosure of walls.

8.6.3 Summary of Findings

Lead hazard control treatments tended to hold up for the three-year period for which they were observed. Out of roughly 73,000 treatments in dwellings with six-month follow-up inspections, 3.4% of the treatments failed. Failure rates for other phases were 5.1%, 7.4% and 7.6% for one, two, and three-years post-intervention, respectively.

The median dwelling in the Evaluation had only one failure two and three years post-intervention. On average, 10 percent or less of the treatments had a failure at any of the post-intervention phases of the Evaluation. The percentage of treatments that had at least one failure per room and yielded lead hazards was even lower because the reports included failures of abated surfaces where the original lead-based paint had been removed.

Failures appeared to level off two years after clearance. For at least the first three years after the intervention, failures appeared to occur logarithmically, with the percentage of failures quickly rising over the first year after treatment, then more slowly over the next two years. Since most if not all of the treatments were expected to last three years, the early slope in failure rates suggests that these failures were more attributable to poor installation or poor surface preparation than to product failure. For example, inspectors attributed half of the jamb liner failures to inadequate installation.

Comparisons of failures by class of treatment generally followed expected trends. Treatments that included paint stabilization were more likely to fail than treatments where lead hazard abatement (i.e., component enclosure, removal or replacement) was conducted. Although little data on encapsulants were available, the findings suggest that by two years after clearance, encapsulants performed similarly to paint stabilization. Although further study is needed, these results suggest that encapsulation does not perform better than stabilization.

The comparisons of failure rates by component supports common assumptions that components subject to abrasion, impact or weather are more likely to experience paint failure than other components. During each post-clearance phase, paint stabilization of doors, windows and exterior components was more than twice as likely to fail than paint stabilization of interior trim and interior walls and ceilings.

Although the treatment failure data could not be used quantitatively in the models of effectiveness as measured by dust lead loadings, the data were used to identify trends. These trends correspond to findings presented earlier in this chapter that identified rising dust lead loadings on windows within one year of treatment with lower intensity treatments. One factor that may have contributed to these increasing dust lead loadings was the higher rates of paint stabilization failure on both windows and building exteriors.

Table 8-23: Treatment Categories with Above-Average Percentages of Treatments that Failed by Phase of Data Collection

	Six Months Post-Intervention		One Year Post-Intervention		Two Years Post-Intervention		Three Years Post-Intervention	
Treatment Category	Treatments Inspected	% Failed	Treatments Inspected	% Failed	Treatments Inspected	% Failed	Treatments Inspected	% Failed
Window-Jamb Liner	722	17%	713	21%	427	35%	261	46%
Door-Stabilization	5334	9%	5307	16%	1825	24%	1414	23%
Window-Stabilization	2067	8%	2063	12%	757	21%	651	23%
Exterior-Stabilization	1704	10%	1773	13%	663	18%	561	22%
Floor/Stair-Stabilization	1059	8%	1060	11%	352	13%	303	15%
Trim-Stabilization	8625	4%	8457	6%	2733	11%	2270	11%
Exterior-Rem. Paint	546	6%	624	14%	192	6%	168	8%
Door-Rem. Paint	407	14%	443	15%	84	5%	68	3%

Data from: Form 25 and Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Tables 370-03, 370-04, 370-05, 370-06

Table 8-24: Comparison of Treatment Failure Rates for Encapsulation, Paint Stabilization and Enclosure Treatments to Trim and Walls/Ceilings by Phase of Data Collection

	Six Months Post-Intervention		One Year Post-Intervention		Two Years Post-Intervention		Three Years Post-Intervention	
Treatment Category	Treatments Inspected	% Failed	Treatments Inspected	% Failed	Treatments Inspected	% Failed	Treatments Inspected	% Failed
Trim-Encapsulant	217	0%	217	2%	260	12%	267	18%
Trim-Stabilization	8625	4%	8457	6%	2733	11%	2270	11%
Wall-Encapsulant	196	2%	174	4%	156	6%	155	8%
Wall-Stabilization	6833	4%	6877	6%	2108	7%	1722	9%
Wall-Enclosure	2769	1%	2835	1%	563	1%	431	2%

Data from: Form 25 and Specmaster
Data as of: June 1, 2000
Source of Data: NCLSH Tables 370-03, 370-04, 370-05, 370-06 with additional analysis

8.7 Effects on Individual Treatments on Dust Lead Loadings

The focus of this chapter has been the effect of different intervention strategies on the housing unit as a whole. The analyses previously discussed sought to determine how the different intensities of lead hazard control interventions (as defined by interior strategies and the presence or absence of exterior or site work) affected the average dust lead loadings in a dwelling. Such analyses address the basic questions of lead hazard control policy that were raised in the 1990s: can less intensive lead hazard control activities (i.e., interim controls) reduce lead hazards and successfully maintain those reductions over time, and how do such activities compare with the performance of more intensive lead hazard control activities? These analyses are limited in that they do not measure the effect of specific lead hazard control treatments. For example, the analyses of strategies are not specific enough to compare the effects of installing jamb liners versus replacing windows. This section goes beyond the analyses of treatments by intensity (i.e., Interior Strategy) and explores the effects of some specific lead hazard control treatments on specific building components within rooms.

8.7.1 Introduction

Part of Evaluation Objective 4 was to determine the effects of lead hazard control treatments on post-intervention dust lead loadings. To accomplish this objective, dust lead data were examined by room instead of by dwelling unit. These analyses were called *room level models*. By examining data at the room level, the Evaluation team was able to link a specific treatment directly to a specific dust lead result. The room level models controlled for the particular conditions of the component of interest, such as the lead-based paint levels and paint and surface conditions *within* the room and treatments to other components in the room.

Four components (windows, doors, trim, floors) that were addressed with a variety of treatments were expected to be of interest. For example, comparisons between the effects of door replacement, door paint removal and door paint stabilization on floor dust lead loadings were expected to prove useful to select optimal treatments. Initially, a list of 14 component/dust location combinations (e.g., window treatments on floors, window treatments on sills, door treatments on floors, etc.) was developed for exploration. However, early investigations had difficulty separating the factors that affect floor dust lead loadings in a room. Floor dust lead loadings were simultaneously affected by treatments to all four components within the room, as well as treatments to other rooms of the dwelling and treatments to the building exterior. Because these treatments were often related to each other, attributing a floor dust lead effect to a single component proved too difficult to model statistically.

The 14 combinations of treatments were therefore reduced to six combinations. The combinations included: window treatments on window sill, window trough or floor dust lead; trim treatments on floor dust lead; door treatments on floor dust lead; floor treatments on floor dust lead; and the effect of paint removal from any component in the room on floor dust lead. When additional preparatory work was conducted, the Evaluation team determined there were an insufficient number of floor treatments to conduct an analysis. The Evaluation team also discovered that the trim treatments were often difficult to separate because grantees often replaced trim or removed trim paint and stabilized trim paint in the same room. As a result, the analyses reported here are limited to four treatment/dust location combinations: window treatments on window trough dust lead, window treatments on window sill dust lead, window treatments on floor dust lead and the effect of paint removal from any component in the room on floor dust lead. Because of concerns that the models could not appropriately control for the effect of carpeting on floor dust lead loadings, the models measuring effects on floors were limited to bare floor samples.

8.7.2 Methodology

Room level analyses explored the effect of specific treatments such as window replacement or window paint stabilization on individual dust lead loadings on a specified component in a room. The effects of the treatments were measured at one-year post-intervention and three-years post-intervention. To conduct these analyses, the treatments of interest had to be defined and eligible rooms had to be identified. Because fewer dwellings participated in the Evaluation Extension, the number of eligible rooms was smaller at three-years than at one-year post-intervention.

8.7.2.1 Selection of Eligible Rooms for Room Level Analyses. In order to be eligible for the room level analysis, a room had to have a dust lead loading result for the surface being examined (i.e., bare floor, window sill, window trough) at both pre-intervention and at the post-intervention period of interest (i.e., one-year or three years post-intervention). Like all of the analyses in this chapter, the dwelling unit had to have evidence that it passed clearance. The room had to have one of the treatment categories described in Section 8.7.2.2 conducted.

Rooms in dwellings with concurrent work were excluded from analysis. Rooms were also excluded when some lead hazard control work was reported as a universal treatment to the whole dwelling or when window treatments were reported as an exterior treatment and the location of room being treated could not be determined. In such cases, the effect of the additional work on the room of interest could not determined, so the room was excluded to protect against the additional work biasing the results.

8.7.2.2 Selection of Treatments for Room Level Analyses. Two different groups of treatments are presented in this report: treatments to windows and paint removal treatments to any components in a room. The categories of window treatments were defined based on a subset of the equivalent treatment categories for effectiveness described in Section 5.3.1. Window treatments were divided into four categories for comparison: window - replacement, window - jamb liners, window - paint stabilization, and window – no treatment. The latter category included rooms where the window received no treatment other than cleaning[16]. A fifth category (window-encapsulation) was originally considered for analysis but not enough windows (<20) were treated with encapsulants to properly assess outcomes. When window treatments were being analyzed, paint lead measurements for a window in that room had to available.

The total number of eligible rooms by window treatment was: window – replacement (1,366), window – jamb liner (93), window – paint stabilization (499), and window – no treatment (1,838). The numbers were smaller in the final dataset because of further requirements of the statistical analyses (Table 8-26). A room with more than one of the window treatments (replacement, jamb liners or paint stabilization) was classified as being treated with the most intensive treatment. Of the 1,366 rooms treated with window replacement, less than one percent were also treated with window stabilization (4) or a jamb liner (1). Of the 93 rooms treated with a jamb liner, 12 percent (11 rooms) also had the window paint stabilized. The Evaluation lacks information to determine whether the additional treatments were applied to the same window or a different window in the room. On average, two windows were treated per room.

The rooms used in the room level analysis of the effect of paint removal were selected if any component in the room was treated with any one of 27 on-site paint removal specifications. Because the purpose of the analysis was to assess the possible negative impact of within-room paint removal on dust lead loadings, paint removal that was done off-site was not considered. The paint removal treatments were primarily conducted on

[16] For these analyses, no treatment was defined as no physical treatments to the window. In order to achieve clearance, the window sampling surfaces may have been cleaned. Because of reporting differences from grantee-to grantee, windows that were cleaned could not be separated from completely untreated windows.

trim (23 specs, 875 uses), with some doors (1 spec, 26 uses) and walls (3 specs, 11 uses) also treated. In all, 694 eligible rooms had paint removal treatments, while 3,369 rooms did not have paint removal treatments.

8.7.2.3 Statistical Method of Analysis. An examination of factors that could explain the variation in dust lead loadings at one year and three years post-intervention based on individual treatments was conducted using four separate nested analyses of covariance for each post-intervention period. Nested analyses were selected to account for the effects in multiple rooms in a dwelling. Each analysis considered a list of variables believed to be possible influences on the specific dust lead location given the component treated. The variables were categorized into four areas of interest: factors related to the dust sample location; factors related to the treated component; factors related to other components treated; and other factors. The specific variables considered are listed in Table 8-25. Dust lead loadings and paint lead levels were log-transformed. Backward elimination of insignificant covariates was performed. Variables were considered significant at a p-value of 0.05.

8.7.3 Findings of Room Level Models

The dataset of eligible rooms at one-year post-intervention allowed for an examination of the effects of all four window treatment categories on dust lead loadings. The number of rooms available for each category in each of the models is presented on Table 8-26. A full description of the differential effects of the window treatments at one-year post-intervention is presented in Section 8.7.3.1. At three years post-intervention, the number of eligible rooms dropped by 70 to 80 percent in the three models, leaving fewer opportunities for comparisons. In the three-year post-intervention window sill and window trough models, only window replacement and no treatment remained available for comparison. Given the limited number of comparisons, the effects at three years post-intervention are only described briefly at the end of Section 8.7.3.1.

In Section 8.7.3.2, the effects of paint removal from any component in a room on bare floor dust lead loadings are presented. At one year post-intervention, 1,768 rooms were eligible, with 336 rooms (19%) treated with paint removal. At three years post-intervention, 466 rooms were eligible, with 82 rooms (18%) treated with paint removal.

Table 8-25: List of Variables Used in Room Level Models

Factors Related to the Dust Sampling Location

Dust Lead Loading of Dependent Variable (Pre-Intervention)
Surface Type of Dependent Variable (Painted/Not Painted) (Post-Intervention)
Surface Condition of Dependent Variable (Post-Intervention)
Interaction of Surface Type and Condition of Dependent Variable
Interaction of Pre-Intervention Dust Lead Loading of Dependent Variable and Occupancy

Factors Related to the Component Treatment

Level of Treatment to Component
For Window: (Replacement, Jamb Liner, Paint Stabilization, No Treatment)
For Paint Removal: (Yes/No)
Mean Paint Lead Level of Component
Interaction of Level of Treatment and Mean Paint Lead Level
Interaction of Level of Treatment and Pre-intervention Dust Lead Loading of Dependent Variable and Occupancy[1]
Interaction of Level of Treatment and Surface Type and Condition of Dependent Variable[2]

Factors Related to Other Components Treated

Average Window Trough Dust Lead Loading Outside of Room (post-intervention) [3]
Level of Treatment to Trim/Door[4]
Mean Paint Lead Level of Trim/Door[4]
Interaction of Level of Trim/Door[4] Treatment and Trim/Door[5] Paint Lead Level
Level of Treatment to Wall/Ceiling
Mean Paint Lead Level of Wall/Ceiling
Interaction of Level of Wall/Ceiling Treatment and Wall/Ceiling Paint Lead Level
Exterior LHC Work (Yes/No)
Site LHC Work (Yes/No)

Other Factors

Season of Dust Sample Collection (at Post-Intervention)
Building Type (Single unit, 2-4 units, >4 units)
House Age (by decade)
Occupancy Status (Pre-Intervention)

[1]Used Only in Window Treatment Models
[2]Used Only in Models with Window Sill or Trough as Dependent Variable
[3]Used Only in Models with Bare Floor or Window Sill as Dependent Variable
[4]Only Trim included in Models with Window Sill or Trough as Dependent Variable

Table 8-26: Number of Rooms Analyzed in the Room Level Models by Window Treatment Category

	Total Rooms Avail.	Bare Floor Models		Window Sill Models		Window Trough Models	
		OneYear	ThreeYear	OneYear	ThreeYear	OneYear	ThreeYear
Replacement	1,366	638	181	609	138	406	108
Jamb Liner	93	49	25	42	-	29	-
Stabilization	499	216	51	170	-	125	-
No Treatment	1,838	711	213	359	120	212	66
All	3,796	1,614	470	1,180	258	772	174

Data from: Forms 1, 19 and Specmaster
Data as of: June 1, 2000
Source of Data: Descriptive Statistics Associated with Room Level Models

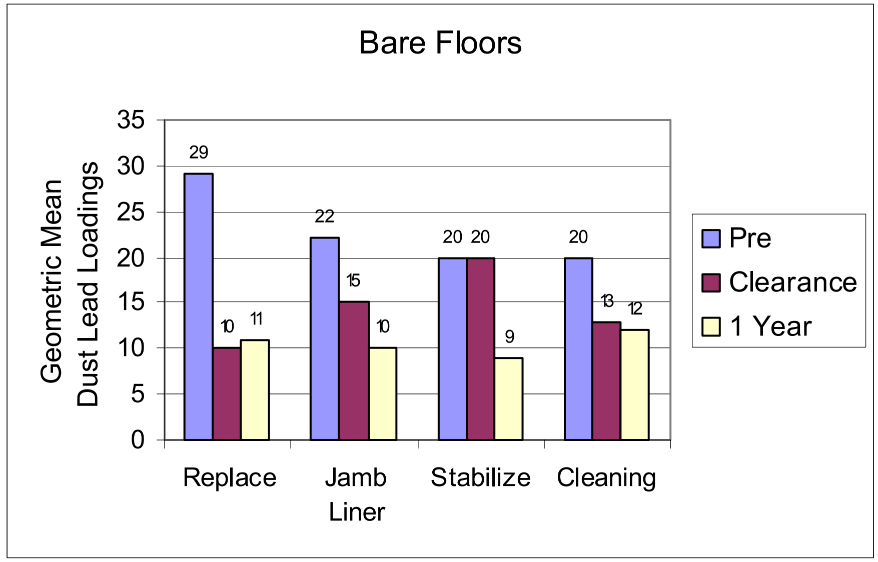
8.7.3.1 Effects of Window Treatments. Figure 8-21 presents the pre-intervention, clearance and one-year post intervention geometric mean dust lead loadings on bare floors, window sills and window troughs by the window treatment applied. Figure 8-22 provides the percentage that the geometric mean dust lead loadings declined from pre-intervention to one year after clearance by window treatment. These results are unadjusted statistics and do not reflect the estimated effects after the models accounted for all significant factors.

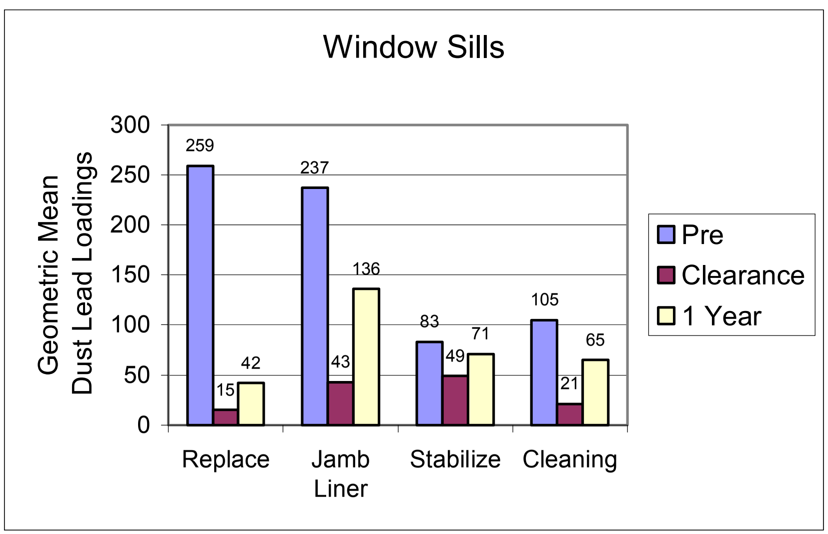
When the room level modeling was conducted, factors that influenced dust lead loadings on all three surfaces at one-year post-intervention were:

> Pre-intervention dust lead loadings log-transformed (lower pre-intervention loadings : lower post-intervention loadings);
> Pre-intervention paint lead levels log-transformed (lower levels : lower loadings);
> Surface condition at post-intervention (better condition : lower loadings); Interaction of Pre-Intervention Dust Lead Loading and Occupancy Status at Pre-intervention[17];
> Post-intervention trough dust lead loadings (log-transformed) outside room (see Section 8.7.3.1.3); and
> Window Treatments (see discussion below).

[17] See Section 7.3.3.2 about how higher pre-intervention dust lead loadings that are associated with vacant dwellings may have influenced this finding. In summary, the differences between dust lead loadings in occupied and vacant dwellings at pre-intervention disappear after the intervention.

Figure 8-21: Geometric Mean Dust Lead Loadings on Bare Floors, Window Sills and Window Troughs at Pre-Intervention, Clearance and One-Year Post-Intervention





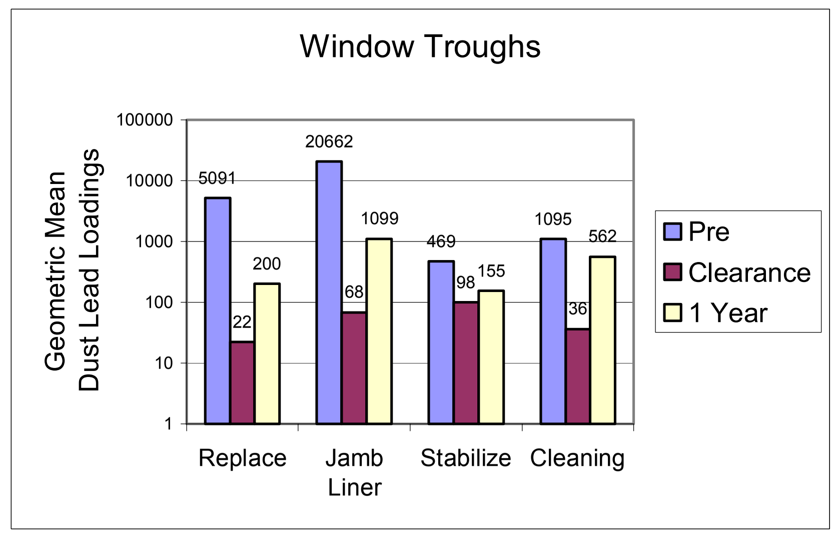
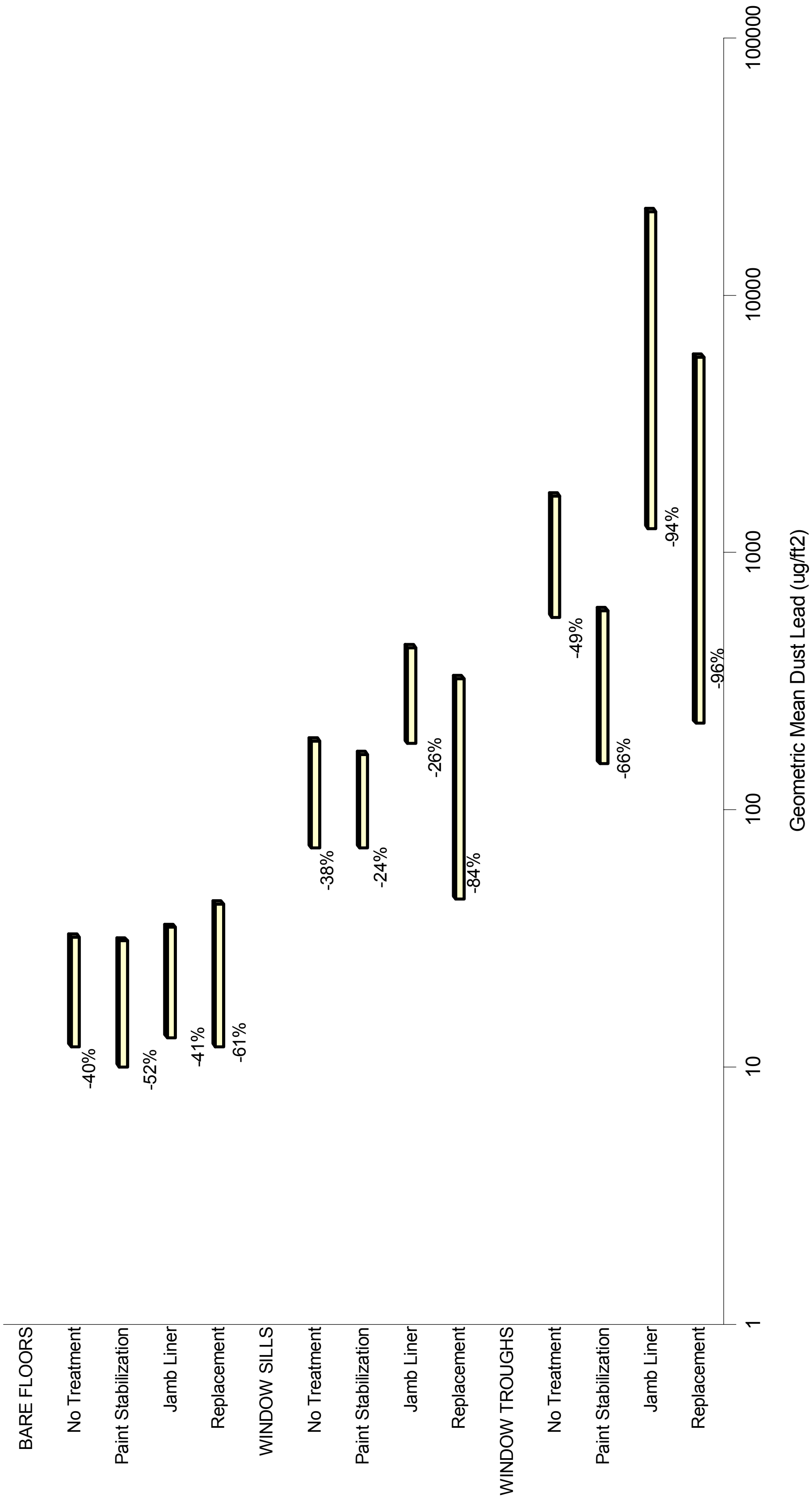


Figure 8-22: Pre-Intervention and One-Year Post-Intervention Geometric Mean Dust Lead Loadings (w/Percent Change) on Bare Floors, Window Sills, and Window Troughs by Window Treatment



Window treatments significantly influenced dust lead loadings on bare floors, window sills and window troughs. Rooms treated with window replacement had *lower* one-year post-intervention dust lead loadings on window sills and window troughs[18] than rooms treated with window paint stabilization, window jamb liners or no window treatments. Rooms where the windows received no treatment had *higher* bare floor dust lead loadings at one-year post-intervention than rooms where the windows received paint stabilization. Rooms where windows were not treated also had higher bare floor dust lead loadings than rooms where windows were replaced, although the results were only marginally significantly different (p=0.08). These findings support conventional wisdom that window replacement is the most effective treatment for windows and that the treatment of windows is an important component of an intervention aimed at reducing floor dust lead loadings.

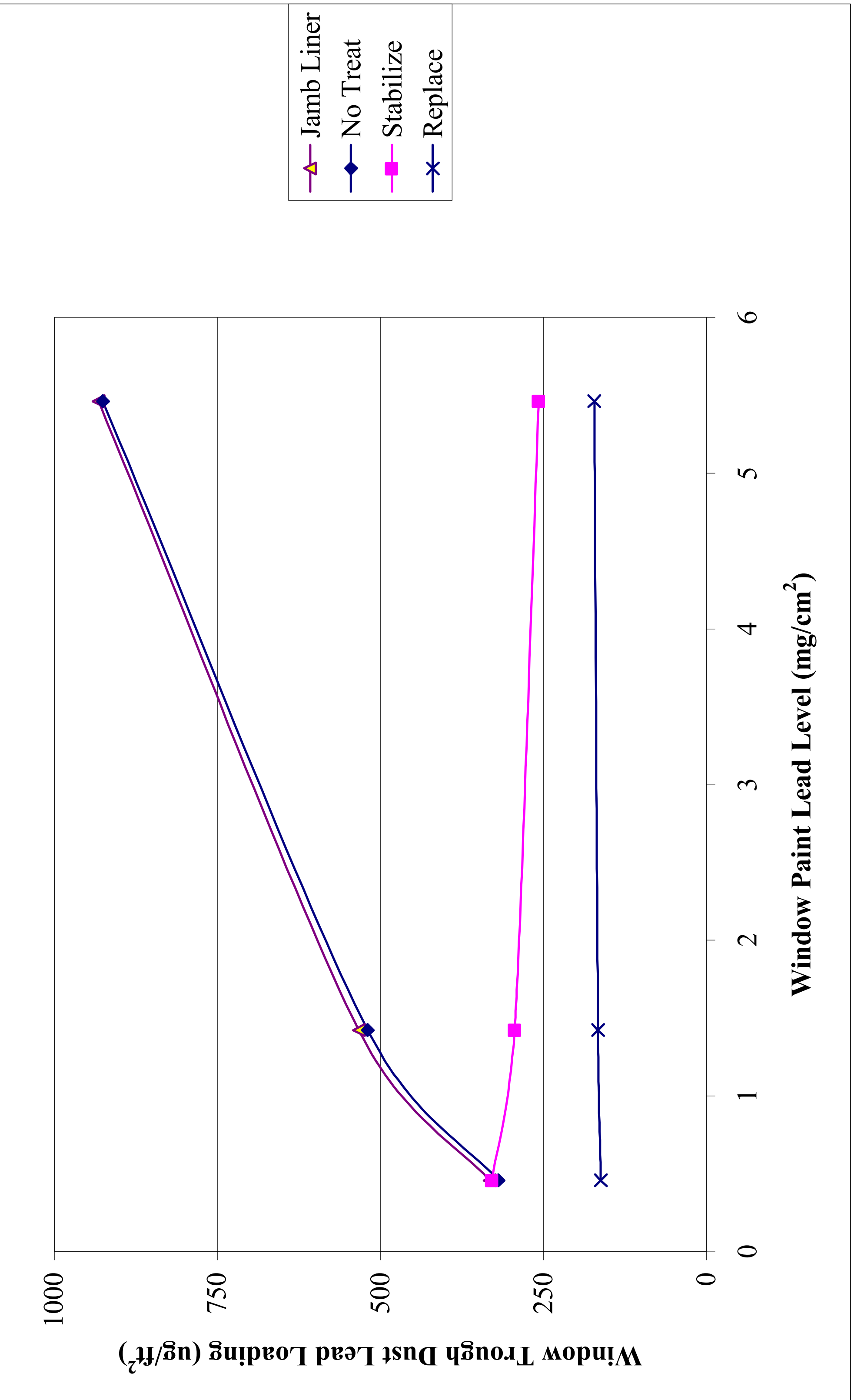
8.7.3.1.1 *Effect of Window Paint Lead Levels on Window Trough Dust Lead Loadings*

Dust lead loadings on window troughs were influenced by an interaction between the window treatments and the window paint lead levels. When window paint was stabilized or the windows were replaced, the slope of the relationship between paint lead on windows and the window trough dust lead loading was not significantly different from zero (Figure 8-23). In other words, higher window paint lead levels did not change the effect of these window treatments on window trough dust lead loadings. When windows received no treatment or the windows were treated with jamb liners, the slope of the relationship was significantly different (positive) from the slope for paint stabilization.
On untreated windows, as window paint lead levels increased, the window trough dust lead loadings increased. These findings support the hypothesis that treated windows are unaffected by paint lead levels on the windows because the treatments will remain protective for at least one year. Untreated windows would be more likely to experience paint deterioration after one year and as a result, the paint lead levels would affect the window trough dust lead loadings.

When windows were treated with jamb liners, as window paint lead levels increased, the window trough dust lead loadings also increased. With just 29 rooms treated with jamb liners in the window trough lead model, the conclusions that can be drawn about this treatment should be made cautiously. However, as reported in Section 8.6, jamb liners had a rate of failure that was 75 percent higher than the paint stabilization failure rate. The possibility that these failures resulted in higher dust lead loadings on window troughs warrants further examination of the effectiveness of jamb liners in future studies.

[18] Window trough dust lead findings presented for a dwelling with the median window paint lead level. See Section 8.7.3.1.1 for a discussion of interaction between window treatments and paint lead.

Figure 8-23: Predicted One-Year Post-Intervention Window Trough Dust Lead Loadings by Window Paint Lead Level (Quartiles)



8.7.3.1.2 *Effect of Surface Condition on Dust Lead Loadings*

The post-intervention surface condition of the wiped surface had a significant effect on the dust lead loadings in all analyses. Surfaces that were in worse condition had higher dust lead loadings. This variable demonstrated the importance of creating and maintaining smooth and cleanable surfaces. The Evaluation team realizes that surface condition may be related to the treatment that was selected. More intensive treatments such as window replacement were expected to create a good surface condition on window sills and window troughs that should have held up long after clearance. By including surface condition in the models as an independent variable, the magnitude of the effects attributable to the treatments could have been altered. An examination of surface condition by type of window treatment suggests that windows that were replaced did have better surface conditions on their sills and troughs than windows that were treated with other treatments or were untreated (Table 8-27). The surface condition of bare floors did not appear to be related to the window treatments suggesting that the surface condition variable in this model was less likely to "overadjust" the treatment effect.

Table 8-27: Arithmetic Mean Surface Condition of Wiped Surfaces in the Room Level Models by Window Treatment Categories

	Bare Floor Models		Window Sill Models		Window Trough Models	
	OneYear	ThreeYear	OneYear	ThreeYears	OneYear	ThreeYears
Replacement	1.3	1.2	1.2	1.1	1.0	1.1
Jamb Liner	1.6	1.3	1.4	-	1.2	-
Stabilization	1.3	1.2	1.4	-	1.4	-
No Treatment	1.3	1.3	1.4	1.3	1.4	1.4
All	*1.3*	*1.2*	*1.3*	*1.2*	*1.2*	*1.2*

Surface Condition: 1= Good, 2=Fair, 3=Poor

Data from: Form 19 and Specmaster
Data as of: June 1, 2000
Source of Data: Center Table

8.7.3.1.3 *Impact of Dust Lead Loadings Outside the Room on Treatment Effects*

The variable "Average Window Trough Dust Lead Loading Outside of Room" was used in the bare floor and window sill models to represent the dust lead that was available to be blown into the room (or tracked in) from the exterior. This variable was not included in the window trough dust lead models because frequently there was only one trough sample available per dwelling. The window trough dust lead loading outside the room was one of the most influential factors in both the floor and sill room level analyses.

After initial analyses were completed, the Evaluation team was concerned about the use of the trough variable to represent outside dust sources. As presented in Section 8.5, the exterior dust and soil project did not observe a significant relationship between exterior dust lead and window trough dust lead loadings, after controlling for all other variables. In addition, there were practical concerns that the window trough dust lead loading in other rooms was too intercorrelated with the treatments of interest. Because grantees frequently treated all windows throughout a dwelling with a similar treatment, the trough dust lead loadings in other rooms would be expected to be as reflective of the effects of the common window treatment as they would be of the effects of exterior dust lead. As a result, the Evaluation team's attempt to control for exterior dust may have inadvertently led to overcontrolling for the effects of the window treatments. In response to the concerns, the bare floor and window sill models were reanalyzed removing outside window trough dust lead leadings as a variable from the final equation.

The remaining variables in the models continued to be significant after the removal of the window trough dust lead loading. However, in both the bare floor model and the window sill model, the contrasts between the window treatments changed. In the revised bare floor model, rooms with no window treatments had significantly different (higher) floor dust lead loadings than rooms treated with either window replacement or paint stabilization. In the revised window sill model, rooms treated with jamb liners had significantly different (higher) window sill dust lead loadings than rooms with any of the other window treatment categories. This latter finding was unanticipated, since jamb liners were expected to perform as well if not better than either paint stabilization or no window treatment. However, these findings match the results of the trough dust lead model. With 42 rooms treated with jamb liners in the sill model, these results offer further evidence that jamb liners, as installed in this Evaluation, did not result in window dust lead loadings as low as other window treatments one year after clearance, after controlling for all other variables.

8.7.3.1.4 *Impact of Window Treatments Three Years After Intervention*

The number of rooms available for analysis at three-years post-intervention was greatly reduced from the one-year post-intervention. In the analyses of bare floor dust lead loadings, the effects of all four categories could be compared but with 71 percent less rooms, resulting in 470 rooms in the model. The effects of window treatments were only marginally significantly different from each other ($p=0.07$). While differences were not statistically significant, floor dust lead loadings in rooms treated with window replacement tended to be lower than in rooms treated with jamb liners or no window treatments.

The reduction in available rooms resulted in fewer categories of treatments being available for comparison in the analyses of the impact of window treatment on window sill and window trough dust lead loadings. For these analyses, enough data were available to compare the effects of window replacement versus no window treatments. Surprisingly, window sill dust lead loadings were not significantly different for window replacement versus no window replacement, even though the sill dust lead loadings were lower in rooms treated with window replacement ($p=0.13$). However, when the effect of trough lead loadings in another room was removed from the model, window replacement did have a significantly different effect on window sill dust lead loadings than rooms without a window treatment ($p<0.03$).

There was no significant difference between the effect of window replacement and no window treatment on window trough dust lead loadings at three-years post-intervention unless pre-intervention trough dust lead loadings were over 1,750 $\mu g/ft^2$. These results may have been influenced by a second treatment that was a significant factor in the model: the presence or absence of exterior lead hazard control work. The ability of the model to separate the effects of window replacement from that of exterior lead hazard control work was inhibited because dwellings receiving window replacement treatments were more likely to receive exterior treatments ($p<0.01$). Ninety-six (96) percent of rooms with window replacement were in buildings with exterior lead treatments, as opposed to 52 percent of rooms with no window treatments. The effect of exterior treatments may have diluted some of the positive effects attributable to window replacement. Taken together, modeling results suggest that dwellings treated with both treatments had window trough dust lead loadings that were significantly lower than dwellings without either exterior or window replacement treatments, regardless of the pre-intervention trough dust lead loading.

8.7.3.1.5 *Summary of Effects of Window Treatments on Dust Lead Loadings*

The statistical models found a number of significant relationships between different types of window treatments and post-intervention dust lead loadings. The challenge for the Evaluation team was to postulate whether the descriptive statistics and the statistical models offer enough evidence to suggest that specific window treatments caused the lower dust lead loadings. On windows, it was easier to create a causal argument because any window treatments would have directly affected the clearance window sill and trough dust lead loadings. The same argument could not be made for floor dust lead loadings. Furthermore, there were fewer sources of lead that were expected to influence longitudinal window dust lead loadings than floor dust lead loadings; therefore the post-intervention condition of windows would have been expected to have a greater impact on the window dust lead loadings than on floors.

At one year post-intervention, window sill and window trough dust lead loadings in rooms with window replacement were significantly different from those in rooms treated with all other treatments. A theoretical causal relationship between the window treatments and the window dust lead loadings is also supported by the descriptive statistics. It was expected that window replacement would create window surfaces with no lead-based paint in the immediate vicinity, while the other treatments would leave leaded paint on the windows that could deteriorate with time. The descriptive statistics for the one-year post-intervention window sill model suggest that window replacement performed better at clearance; rooms treated with window replacement had the lowest final clearance window sill dust lead loadings (15 $\mu g/ft^2$) and the largest percentage declines from pre-intervention (94%) compared to rooms with other window treatments. The rooms treated with window replacement also had the smallest increase in dust lead loadings from clearance until one-year post-intervention (27 $\mu g/ft^2$). The descriptive statistics for the one-year window trough model offered similar findings: rooms treated with window replacement had the lowest final clearance window trough dust lead loadings (22 $\mu g/ft^2$) and a percentage decline from pre-intervention (99.6%) that was the same or larger compared to those in rooms with other window treatments. The rooms treated with window replacement also had the second smallest increase in trough dust lead loadings from clearance until one-year post-intervention (178 $\mu g/ft^2$) after window paint stabilization (56 $\mu g/ft^2$).

Both the modeling results and the descriptive statistics suggest that window replacement resulted in lower window dust lead loadings than other window treatments. It must be recognized, however, that one-year post-intervention geometric mean sill dust lead loadings remained below the window sill dust lead clearance standard of the time (500 $\mu g/ft^2$) for each of the window treatment categories. Only windows treated with jamb liners had one-year post-intervention geometric mean trough dust lead loadings that were above the window trough dust lead clearance standard of the time (800 µg/ft^2).[19]

On floors, the models generally supported a finding that rooms treated with window replacement had lower bare floor dust lead loadings than rooms that received no window treatments. Looking further, the one-year models identified window treatments as a better predictor of the bare floor dust lead loadings than treatments to other components in the room, while the three-year model identified trim treatments as the better predictor of those loadings. Further exploration of the data in the three-year model found that 78 percent of rooms with window replacement also had trim treatments, while just 32 percent of rooms with no window treatments had trim treatments. Because grantees tended to treat many components in a room when window replacement was conducted, attributing lower floor dust lead loadings to the window replacement alone must be made with caution.

At one-year and three-years post-intervention, the geometric mean dust lead loadings on bare floors were the same or similar for rooms treated with window replacement and no window treatment (both 12 µg/ft^2 at one-year; 8 and 6 µg/ft^2, respectively, at three-years). These levels are well below the current EPA floor dust lead standard of 40 µg/ft^2 and could arguably be considered well below a level of concern. However, Lanphear et. al (Lanphear1998) identified a correlation between floor dust lead loadings and blood lead levels at loadings below the standard and that more than five percent of the blood lead levels are likely to be greater than 10 ug/dl. This study would suggest that differences at these lower levels may well be of practical significance.

The descriptive statistics could also raise questions about how post-intervention results that appear quite similar can be significantly different. This finding was largely attributable to the fact that rooms treated with window replacement had higher baseline paint and dust lead levels. For example, rooms treated with window replacement had pre-intervention geometric mean bare floor dust lead loadings that were approximately 50 percent higher than rooms treated with no window treatments in the one-year model (31 v. 20 µg/ft^2). Only after considering all other factors did a room treated with window replacement have a post-intervention bare floor dust lead loading that was at least marginally significantly different (lower) than that in a room with no window treatments. Although the results of the statistical modeling met expectations, it must be recognized that the findings are partially based on projections that could benefit from further analysis in a more controlled study.

The one-year post-intervention model also identified a difference in effects of window paint stabilization and no window treatment on bare floor dust lead loadings. This finding appears to go in an expected direction, but a comparison of dust lead loadings at clearance and at one-year post-intervention raises questions about causality. In the one-year model, geometric mean floor dust lead loadings in rooms treated with window paint stabilization did not change from pre-intervention to clearance (20 µg/ft^2 at both phases), but then declined 55 percent to a one-year post-intervention loading of 9 µg/ft^2. Floor dust lead levels in rooms treated with no window treatments declined 35 percent from pre-intervention to clearance (20 to 13 µg/ft^2), but then

[19] Although clearance is based on the maximum dust lead loading for all samples in a dwelling, we use the standard as a measure for comparison against the geometric mean of the arithmetic mean for a dwelling. Even when the geometric mean is below the standard, a percentage of dwellings are expected to exceed the standard.

remained essentially the same to one-year post-intervention (12 µg/ft^2). Arguably, window paint stabilization contributed to the declines in floor dust lead loadings since a smaller amount of leaded dust reaccumulating on window sills after windows were stabilized compared to any other treatment including window replacement (as reported above). However, it is hard to assert this position conclusively given the findings reported in Section 8.7 that almost one in eight rooms with window stabilization had a failure to this treatment by one-year post-intervention.

8.7.3.2 Effects of Paint Removal. A model was developed to explore whether paint removal in a room resulted in increased floor dust lead loading due to contamination from the paint removal. Work by Farfel and Chisholm in the 1980s demonstrated that if traditional methods of lead hazard control including paint removal were conducted without cleaning (other than dry sweeping), post-intervention dust lead loadings increased from pre-intervention (Farfel 1990). The Evaluation designers theorized that even when final cleaning was required, clearance dust lead loadings after paint removal would be higher than those for other treatments because paint removal introduces more lead particles into a room, and those particles may be difficult to clean up.

For dwellings in the one-year room level analysis, 16 percent of bare floors in rooms treated with paint removal failed initial clearance compared with eight percent of bare floors in rooms without such treatments, based on a clearance level of 100 µg/ft^2. After final clearance was achieved, the geometric mean bare floor dust lead loading (16 µg/ft^2) in rooms treated with paint removal was 60 percent higher than that in rooms without paint removal (10 µg/ft^2).

Even if dwellings treated with paint removal were more likely to have higher dust lead loadings, it was not apparent what the long-term effects of paint removal would be. Paint removal has the advantage of creating surfaces that are lead-free. If the dust lead generated at intervention can be removed following initial clearance failure or through routine cleaning post-intervention, then paint removal may be more successful than other treatments in the long run. However, if the newly generated dust lead is not or cannot be removed, then the positive effects of paint removal may not be apparent for a long period of time and at least in the near term, an increased risk of exposure may result.

One year after intervention, the geometric mean bare floor dust lead loadings were 11 µg/ft^2 in the rooms with paint removal and 12 µg/ft^2 in the rooms without paint removal. The pre-intervention dust lead loadings in rooms with paint removal treatments were 17 percent higher (27 vs. 23 µg/ft^2) than rooms without these treatments. After controlling for other variables including the pre-intervention levels, the models determined that rooms where some components had paint removed on site did not have significantly different one-year post-intervention bare floor dust lead loadings than rooms that did not have paint removal treatments (p=0.08).

Three years after intervention, the geometric mean bare floor dust lead loading was 6 µg/ft^2 in rooms with paint removal and 8 µg/ft^2 in rooms without paint removal. For this set of dwellings, the geometric mean pre-intervention dust lead loadings were 20 percent higher in rooms with paint removal (30 µg/ft^2) than in rooms without paint removal (24 µg/ft^2). As at one year, rooms where some components had paint removed on site did not have significantly different bare floor dust lead loadings at three-years post-intervention than rooms that did not have paint removal treatments.

These findings suggest that by one year post-intervention, rooms treated with paint removal no longer had higher dust lead loadings than rooms not treated with paint removal. This remained true at three years after clearance. At both periods, rooms treated with paint removal were estimated to have dust lead loadings roughly 5 to 14 percent lower than those in rooms treated with no paint removal, a difference that was not statistically significant. The results support the conclusion that while paint removal is more likely to increase floor dust lead loadings at clearance, there does not appear to be a long-term detrimental effect on dust lead loadings. The geometric mean bare floor dust lead loading declined 5 $\mu g/ft^2$ between clearance and one-year post-intervention in rooms treated with paint removal, while bare floor dust lead loadings increased 2 $\mu g/ft^2$ between clearance and one-year post-intervention in rooms without paint removal.

A limitation of the analysis is that paint removal treatments were often only a portion of a broad set of treatments applied to a room. On average, 19 linear feet of paint was removed from rooms analyzed with one-year dust lead data and 14 linear feet of paint was removed from rooms analyzed with three-year dust lead data. These treatments were accompanied in some rooms with similar quantities of trim or other components being replaced and/or stabilized. The findings presented may not be representative of the outcomes that might be expected from the grantee that on average removed 64 linear feet of paint per room using on-site paint removal.

While these room level analyses could assess differences over time between rooms treated with paint removal and rooms not treated with paint removal, they could not assess the effects of paint removal against other specific treatment categories. The comparison groups included rooms treated with the complete range of treatments from abatement by component replacement to no treatment other than cleaning. The mixture of treatments both in rooms treated with paint removal and in rooms without paint removal made it impossible to determine how paint removal compared with other abatement treatments that were less likely to generate leaded dust during the intervention or to interim controls that left lead-based paint in the room.

Exhibit 8-1: List of Variables Used in Pre-Intervention and Post-Intervention Dust Lead Models

Lead Hazards

Pre-intervention Variables:

Entryway Dust Lead Loading [a]
Surface Type of Entry Floor (Hard, Painted or Carpet) [a]
Surface Condition of Entry Floor [a]
Average Interior Floor Dust Lead Loading [b]
Percent of Painted Floors [b]
Percent of Hard Floors [b]
Percent of Carpeted Floors [b]
Percent of Painted Floors * Average Surface Condition [b]
Percent of Carpeted Floors * Average Surface Condition [b]
Percent of Hard Floors * Average Surface Condition [b]
Average Window Sill Dust Lead Loading [c]
Average Surface Condition of Window Sills [c]
Percent Painted Window Sills [c]
Average Window Trough Dust Lead Loading [d]
Average Surface Condition of Window Troughs [d]
Percent Painted Window Troughs [d]
*Percent Dust Collected in Same Room for Each Component (Entries, Floors, Window Sills, Window Troughs)
Average Paint Lead on Interior Doors/Trim (Mean of Log(XRF))
Average Paint Lead on Windows (Mean of Log(XRF))
Average Paint Lead on Exterior Components (Mean of Log(XRF))
Average Paint Condition of Interior Doors/Trim
Average Paint Condition of Windows
Average Paint Condition of Exterior Components
Interaction between Paint Lead Loading and Paint Condition for Each Component (Interior Doors/Trim, Windows, Exterior Components)
*Interaction between % Dust Collected in Same Room and Dust Lead Loading (Pre-Intervention) for Each Component (Entries, Floors, Window Sills, Window Troughs)
Interaction of Surface Type and Condition of Entry Floor [a]

*Post-intervention Variables:

Entryway Dust Lead Loading
Surface Type of Entry Floor (Hard, Painted or Carpet)
Surface Condition of Entry Floor
Average Interior Floor Dust Lead Loading
Percent of Painted Floors
Percent of Hard Floors
Percent of Carpeted Floors
Percent of Painted Floors *Average Surface Condition
Percent of Carpeted Floors * Average Surface Condition
Percent of Hard Floors * Average Surface Condition
Average Window Sill Dust Lead Loading
Average Window Trough Dust Lead Loading
Average Surface Condition of Window Sills
Average Surface Condition of Window Troughs

Exterior Street Dust Lead (ug/ft^2) ***
Exterior Entry Dust Lead (ug/ft^2) ***
Soil Lead (ppm) ***

Pre-Intervention Building/Dwelling Condition
Number of Interior Elements with Deterioration (0,1,2)
Roof Leak (Yes/No)
Plumbing Leak (Yes/No)
Number of Exterior Elements with Deterioration (0,1,2)
Living Space of Dwelling at Pre-intervention (sq. ft)
Entry Height in Stories
Market Value

Household Characteristics
Pre-intervention Variables:
Was Home Renovated (Yes/No)
Years of Education of Female Parent (< High School, ≥ High School, Vacant, Unknown)
Presence of Cleaning Equipment (Percentage of five classes of equipment)
Frequency of Cleaning the House
Frequency of Washing Exterior Window Sills [d]
Cleanliness of the Home
(1=Appears clean, 2=Some evidence of cleaning, 3=No evidence of cleaning)
Household Income ($)
Number of Children Less than 6 Years
Number of People between 6-18 Years
Number of People in Home

Other Characteristics
Season of Dust Sample Collection (Pre-Intervention)
*Season of Dust Sample Collection (at Post-Intervention)
Building Type (Single unit, 2-4 units, >4 units)
House Age
Occupancy Status (Pre-Intervention)
Ownership (1=Rented, 2=Owner occupied, 3=Other)

*****Intervention***
Interior LHC Work (by Strategy)
Exterior LHC Work (Yes/No)
Site LHC Work (Yes/No)
Interaction between Interior LHC Work and Exterior LHC Work
Interaction between Interior LHC Work and Site LHC Work
Interaction between No. of Exterior Elements with Deterioration and Exterior Strategy
Interaction between No. of Interior Elements with Deterioration and Interior Strategy
Interaction between Entry Floor Dust Lead (Pre-Intervention) and Interior Strategy [a]
Interaction between Floor Dust Lead (Pre-Intervention) and Interior Strategy [b]
Interaction between Window Sill Dust Lead (Pre-Intervention) and Interior Strategy [c]
Interaction between Window Trough Dust Lead (Pre-Intervention) and Interior Strategy [d]
Interaction between Entry Floor Condition (Pre-Intervention) and Interior Strategy [a]
Interaction of Average Floor Surface Condition (Pre-Intervention) and Interior Strategy [b]

Interaction between Average Surface Condition of Window Sills and Interior Strategy [c]
Interaction between Average Surface Condition of Window Troughs and Interior Strategy [d]
Interaction between Paint Lead on Interior Doors/Trim and Interior Strategy
Interaction between Paint Lead on Windows and Interior Strategy
Interaction between Paint Lead on Exterior Components and Exterior LHC Work

*Dust SEM – 1 Yr only
**Dust SEM- 1 Yr and Multiple Regression models
***Dust SEM- Exterior Dust/Soil only

For Multiple Regression Models:

[a] These variables were used only in "entry" model.
[b] These variables were used only in "floor" model.
[c] These variables were used only in "window sill" model.
[d] These variables were used only in "window trough" model.

9.0 EFFECTS OF INTERVENTIONS ON CHILDREN'S BLOOD LEAD

9.1 INTRODUCTION

When the Evaluation was designed, it was recognized that there are important limitations to using children's blood lead levels as a measure of lead hazard control effectiveness. Lead can enter a child's blood stream from many sources beyond those affected by the environmental interventions funded by HUD. For example, blood lead levels can also be affected by the child's nutrition and can vary with the age of child and season of the year. The introduction to the Evaluation study design protocols further noted that:

> "Finally, chronically lead-poisoned children may continue to have elevated blood lead levels for months or years after exposure has ceased due to body stores that usually decline very slowly. Thus, monitoring changes in blood lead levels after environmental intervention may underestimate the primary preventive benefit of exposure reduction in a treated dwelling from birth onward. For this reason, the most important outcome measure for this evaluation will be changes in dust lead loading in dwellings undergoing environmental intervention."

Despite these limitations, blood lead data, in conjunction with data on changes in environmental conditions in dwellings, are relevant and useful outcome measures. Over the period of one to three years after the interventions, reductions in household lead hazards should be reflected in blood lead level reductions. Previous studies of lead hazard control interventions identified declines in blood lead levels on the order of 18-34 percent from pre-intervention to six to 12 months post-intervention (EPA 1995b; EPA, 1998). This chapter explores the effects of the interventions conducted in the Evaluation on blood lead levels at the four post-intervention collection periods (6-months, 1-year, 2-years, and 3-years post-intervention).

The Evaluation designers were also interested in analyzing the effects of treated dwellings on the blood lead levels of children who were enrolled *after* intervention (Objective 7b). The designers were especially interested in children born into the dwellings, because there were (and continue to be) few studies that examine the effects of treated homes on children who have not been previously exposed to lead in the environment (i.e., effects of primary prevention). However, only 23 children were identified who were born into the dwelling after intervention and provided at least one blood lead sample. The enrolled cohort was too small to pursue analyses of the effects of primary prevention.

9.2 METHODOLOGY

For parents who agree to participate, blood lead testing of resident children between the ages of six months and six years is a requirement of the HUD LHC Grant Program. However, neither the presence of a child nor the participation of the child in the Evaluation is a requirement for a dwelling unit to be eligible for HUD LHC Grant funds. During the first two funding rounds of the HUD LHC Grant Program, blood lead testing was to be conducted prior to intervention, immediately after intervention and 6 and 12 months after intervention. Blood lead levels were primarily to be used to measure the safety and effectiveness of the lead hazard control activities that the grantees selected.

9.2.1 Blood Collection Methodology

The Evaluation protocols required the collection of the pre-intervention blood lead sample occur within six weeks prior to the lead hazard control intervention. This sample would serve as a baseline level for each child. Grantees were allowed to substitute a previously collected blood lead sample from a child for the pre-intervention sample if the earlier blood sample result was verified by the grantee through the release of medical records.

As described in Section 7.4.1.2, the protocols required the collection of an immediate post-intervention blood lead sample to help determine if the child had a blood lead increase that may have resulted from any aspect of the intervention or occupant protection activities. The findings related to this blood sample are reported in Section 7.4.

The Evaluation protocols specified that following intervention, blood lead samples would also to be collected at 6 and 12 months after the date of clearance. When HUD approved the extension of the Evaluation, the protocols were amended to require additional blood lead samples be collected at two-years and three-years after the clearance date, for those children living in homes participating in the extension.

Trained phlebotomists obtained blood specimens from participating children, primarily using venipuncture methods. On a case-by-case basis, if a venous sample could not be obtained, the phlebotomist could collect a capillary sample instead. Three grantees, Milwaukee, Vermont and Wisconsin, received approval to use capillary sampling (fingerstick) as their primary blood collection method. Phlebotomists at these three sites were trained in proper fingerstick techniques. Sixty-six percent of all blood samples were collected by venipuncture. Among samples that were collected at both pre-intervention and one-year post-intervention and both pre-intervention and two-years post-intervention, 93 and 97 percent, respectively, were collected using the same sampling methodology.

Each grantee selected its own laboratory (or laboratories) to analyze the blood specimens. Each laboratory was required to meet the proficiency standards set under the Clinical Laboratory Improvement Act of 1988. Lead was measured by either graphite furnace atomic absorption spectrophotometry or anodic stripping voltametry. The procedures for the quality assurance for blood lead samples and the procedures for the substitution of blood lead values below the levels of detection are presented in Section 3.2.

9.2.2 Statistical Methodology

Of the 1,766 children who were enrolled in the Evaluation prior to intervention and who lived in dwellings that were treated and passed clearance, 1,273 children had a valid pre-intervention blood lead test reported. Valid blood lead tests included samples collected under the study protocols as well as blood lead results reported by the parent that could be verified by medical record. Blood lead results were considered invalid when samples were analyzed during a period when the blood analysis laboratory did not meet the Evaluation quality control standards. Valid blood lead tests came only from children whose age fell between six months and six years at enrollment, the acceptable age range for enrollment of a child in the Evaluation.

The availability of a valid pre-intervention blood lead result was a requirement for all longitudinal analyses of blood lead levels in this report. Thus, the 1,273 children described above form the starting point of any longitudinal analysis of children's blood lead levels up to one-year post-intervention. Of these children, 367 lived in grantee sites that did not participate in the extension of the Evaluation, so a maximum of 906 children were eligible for the longitudinal analysis of children's blood lead levels between two and three-years post-intervention.

Longitudinal blood lead findings are presented at two levels: descriptive statistics of the blood lead levels across time and statistical model analyses of the effect of treatment strategies on blood lead results over time. The Evaluation team had originally planned to examine blood lead results at two points in time: one-year after the intervention and three-years after the intervention. However, the number of children with both pre-intervention and three-years post-intervention blood lead results was too limited[1] to draw firm conclusions about three-year results. Three-year blood lead data were considered in only one statistical model. Descriptive statistics are presented at one-year and two-years post-intervention.

Two methods of statistical modeling were employed to examine variables influencing post-intervention blood lead. Repeated measures and structural equations models were fit to the longitudinal blood lead data to determine predictors of blood lead levels. Exhibit 9-1 presents the possible predictors examined in the models.

All lead variables (i.e., blood, dust and paint) were transformed to their natural logarithm to normalize their statistical distributions. An individual blood lead result was only included in a model when data for the set of predictors under consideration for that result were present. The blood lead data of children, who according to their caregiver received medical chelation treatments prior to enrollment, were included in the statistical models. Because only four children meeting the criteria were chelated, the inclusion of their blood lead results should not affect the outcomes.

Blood lead results were analyzed statistically when post-intervention blood and dust lead samples were collected eight weeks before or after the six-month target date, and ten weeks before or after the one-, two- and three-year post-intervention dates. The original study protocols called for samples to be collected within two weeks of the target dates to limit the variation in the passage of time from intervention. Grantees were not always successful in obtaining a sample within the collection window because of the practical difficulties when scheduling appointments with families. After data had been submitted to the Evaluation, the acceptable collection windows were revised in order to balance the goals of the original protocols with the need to retain data. On average, blood lead samples were collected one week after the target dates at each of the four post-intervention data collection phases.

The SAS procedures PROC GLM and PROC SYSLIN were used to run the repeated measures (RM) and structural equations (SEM) models, respectively. Volume I of the Compendium presents a detailed explanation of how each model was developed and run.

[1] Ninety-five children who were between 6 months and 6 years at enrollment and lived in dwellings that passed clearance had both a pre-intervention and three-year blood lead sample. This number would be further reduced for statistical modeling purposes because of factors such as missing variables, samples collected outside of protocol specified collection window, and other model specific restrictions. For the 78 children who met the age and clearance criteria, and whose three-year post-intervention blood lead test was collected within the +/-10 week collection window, geometric mean blood lead loadings declined 40% from pre-intervention to three year post-intervention. There was no significant difference between the geometric mean blood lead levels at 2 years and 3 years post-intervention while controlling for pre-intervention blood lead.

9.2.2.1 Repeated Measures Model. A RM model used the blood lead results of each child in a dwelling at each phase as the outcome. The model is referred to as a "repeated measures model" due to the fact that multiple children per dwelling and multiple phases of blood results per child are included and accounted for in the model. This report presents the results of an analysis of blood outcomes at six-months, one-, two- and three-years post-intervention for dwellings in the extended Evaluation (Blood RM-Extended Evaluation). Backward elimination of the possible predictors in the model (see Exhibit 9-1) was performed. The variable *interior lead hazard control strategy* was forced into the model to allow for a test of its potential effects in the final, reduced models.

9.2.2.2 Post-Intervention Structural Equations Model. A Structural Equations Model (SEM) is a means of estimating direct and indirect effects within or on a set of interrelated variables. To examine longitudinal effects of the treatments on blood lead levels, an SEM was created that included blood lead as a primary outcome at one-year post-intervention (Blood SEM-1 Yr). The analysis explored the relationships between the pre-intervention and post-intervention environmental and blood lead measurements, as mediated by the intervention itself.

Under the constraints of the SEM methodology, variables associated with only one child per dwelling can be analyzed. The Evaluation team chose the youngest child who had lived in the dwelling for at least three months prior to enrollment.

A SEM developed for the pre-intervention data (pre-intervention Blood SEM) was used as a starting point for the model that utilized the post-intervention data. The predictors of the pre-intervention outcomes established in the pre-intervention model (see Section 9.2.2.3) were included as predictors of pre-intervention outcomes in the post-intervention model. No step-wise inclusion or elimination of pathways was performed for pre-intervention outcomes. All variables specified in Exhibit 9-1 were included as possible predictors of post-intervention outcomes. Backward elimination of insignificant predictors of the post-intervention outcomes was performed, followed by forward inclusion steps to re-enter, as needed, previously excluded pathways. The variable *interior lead hazard control strategy* was forced into the Blood SEM-1 Yr model. However, if interior strategy was not a significant variable, it was not included in the final output figures.

9.2.2.3 Pre-intervention Structural Equations Model. The use of a cross-sectional SEM is well suited for analysis of lead exposure data because it is capable of showing the direct and indirect pathways that occur in the movement of lead in the environment. While the Blood SEM-1 Yr described above examined effects only at one-year post-intervention, this model also involved longitudinal linkages to the pre-intervention data and therefore could be used to test hypotheses regarding the stability or change in lead levels from those observed pre-intervention. In order to explore the possible changes in pathways, the pre-intervention Blood SEM had to be developed to establish the baseline pathways of lead through the home environment to a child's bloodstream.

Pre-intervention environmental, family, demographic, and child data were used to develop the pre-intervention Blood SEM. Blood lead level was an endogenous variable, meaning that the sources of variation in pre-intervention blood lead levels were determined by other variables in the model. These other variables included exogenous variables (e.g., paint lead levels, child's age) that were not controlled for by the model and four other endogenous[2] variables (e.g., pre-intervention window sill dust lead). Over 70 potential variables were identified (Exhibit 9-1).

Complete data were available to run the pre-intervention Blood SEM for 459 children. Like the Blood SEM-1 Yr, the output of this model was a list of factors considered to have a direct or indirect statistically significant influence on blood lead levels. "Significant influence" was defined as a 95-percent probability that the factor had an effect on blood lead levels.

The model accounted for 44 percent of the variance in blood lead. As shown in Figure 9-1, ten factors were determined to have a direct and significant influence on children's blood lead levels at pre-intervention (presented in order of percent variance explained):

- Parental report of the child previously being lead poisoning (15.6%),
- Child's age (cubic function)[3] (3.6%),
- Child's race (3.1%),
- Education of the principal female caregiver (2.0%),
- Paint lead levels on windows (1.8%),
- Market value of dwelling unit (1.4%)
- Season of blood sample collection (1.1%),
- Percent of sampled window troughs that were painted (1.0%),
- Surface condition of entry floor (0.6%), and
- Interior floor dust lead loadings (0.6%).

Of the explained variance, 13 percent could not be attributed independently to any single variable. Of the ten significant variables, four environmental factors — lead paint loading on windows, percent of sampled window troughs that were painted, surface condition of entry floor, and interior floor dust lead loading --- were found to directly and significantly affect children's pre-intervention blood lead levels.

Several additional environmental factors indirectly influenced blood lead levels (Figure 9-1). Through their direct or indirect influence on interior floor dust lead loadings, the entry floor, window sill and window trough dust lead loadings had an indirect bearing on blood lead levels. The paint lead loading on interior doors/trim, windows and exterior components; the condition of paint on the interior doors/trim; and exterior building condition indirectly affected blood lead by directly affecting dust lead loadings. The condition of the sampled surface also indirectly influenced blood lead levels by directly influencing dust lead loadings at all dust sampling locations.

These direct and indirect pathways of lead in the child's home to the child formed the baseline for further analysis. These effects and changes to these effects post-intervention are discussed in further detail in Sections 9.4.5 and 9.4.6.

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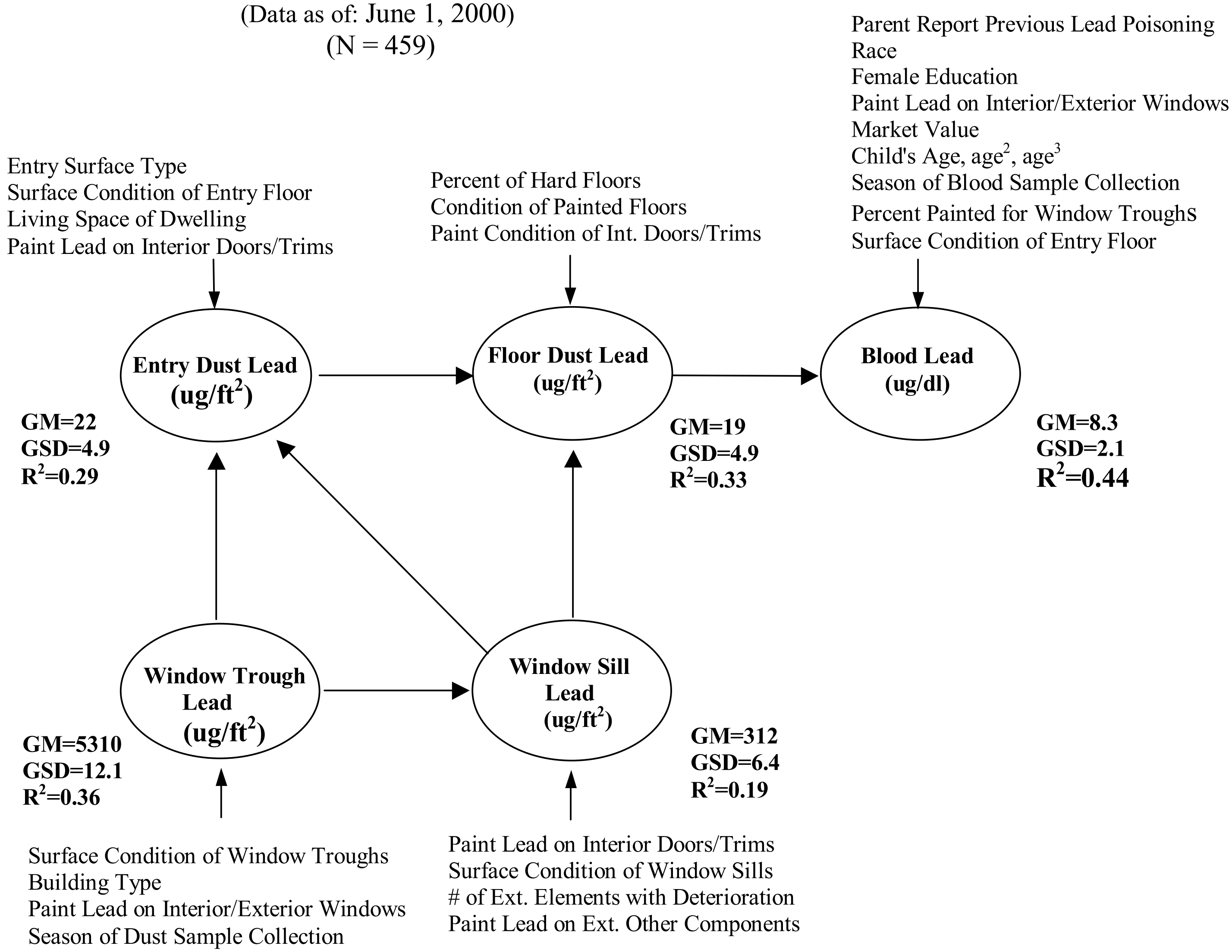
[2] Dust lead loadings at the four locations previously investigated using the Dust SEM (see Chapter 8) were the other endogenous variables in the model; however, factors influencing dust lead loadings are discussed in this chapter only in terms of their subsequent influence on pre-intervention blood lead levels. With more dwellings available for the Dust SEM, that model provides more accurate information concerning factors significantly influencing dust lead loadings.

[3] A cubic function was used because blood lead levels have been shown to rise rapidly until a child is about two to three years of age and then decline at a less rapid rate. The "age effect" is further discussed in Section 9.4.5.3.

Figure 9-1

Pre-Intervention Lead Exposure Pathways Including Blood Lead (HUD Evaluation Project)
(Data as of: June 1, 2000)
(N = 459)



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Note: Solid line indicates that a statistically significant coefficient was found.
All coefficients are significant at $P<0.05$

9.3 DESCRIPTIVE STATISTICS OF LONGITUDINAL BLOOD LEAD LEVELS

This section presents information on the overall effectiveness of the HUD LHC Grant Program on children's blood lead levels post-intervention as measured by unadjusted results. One set of descriptive statistics is presented for the children who had valid blood lead results available in each of the first four sampling phases of the Evaluation (pre-intervention, immediate post-intervention, 6-months and one-year post-intervention). A second set of descriptive statistics is presented for the children who had valid blood lead results available in each of the first five sampling phases of the Evaluation (the four previously described plus two-years post-intervention). The Evaluation team required a child to have blood lead results in all sampling phases in order to observe trends across the phases, yet avoid the possible bias introduced by mixing in results from children who later dropped out of the study.[4]

9.3.1 One-Year Post-Intervention

Twenty-five percent (321) of children with valid blood lead tests at pre-intervention had four consecutive phases of valid blood lead tests reported. There was a wide variation in the retention rates of children by grantee. Wisconsin and Boston retained 62 and 47 percent of their children, respectively. Vermont, California, Alameda County and Chicago had more difficulty retaining children: retention rates ranged from two to seven percent. While some of the variation in retention rates is the result of varying local mobility patterns and other factors outside of the control of the grantee (e.g., percentage of owner-occupied dwellings), local grant programs managed by health programs had a higher retention rate (30%) than programs managed by housing departments or housing and health department collaborations (14%).

For the 321 children, there was an overall reduction of 2.7 µg/dL (27%) in geometric mean blood lead levels from pre-intervention levels (9.9 µg/dL) to one-year post-intervention (Figure 9-2). Blood lead levels slightly decreased between pre-intervention and immediate post-intervention (on average 4 months later) and then declined at a fairly steady rate over the following two consecutive six-month sample collection periods. The declines in blood lead levels from pre-intervention to immediate post-intervention were not significant, while declines during each successive sampling phase were statistically significant ($p< 0.01$). Between immediate post-intervention and one-year post-intervention, geometric mean blood lead levels declined 25 percent.

Because of the higher retention rates at certain sites and because these same sites generally enrolled more children per dwellings, the blood lead findings tend to reflect a subset of grantees and a subset of their Evaluation dwellings. Just six of the grantees had at least 20 children with valid blood lead samples for the four phases through one-year post-intervention. Eighty-five percent of the children lived in Milwaukee (23%), Wisconsin (23%), Minnesota (14%), Cleveland (9%), Baltimore (8%), and Boston (7%). The geometric mean blood lead levels for these grantees are presented on Figure 9-2. While children at these grantee sites began with

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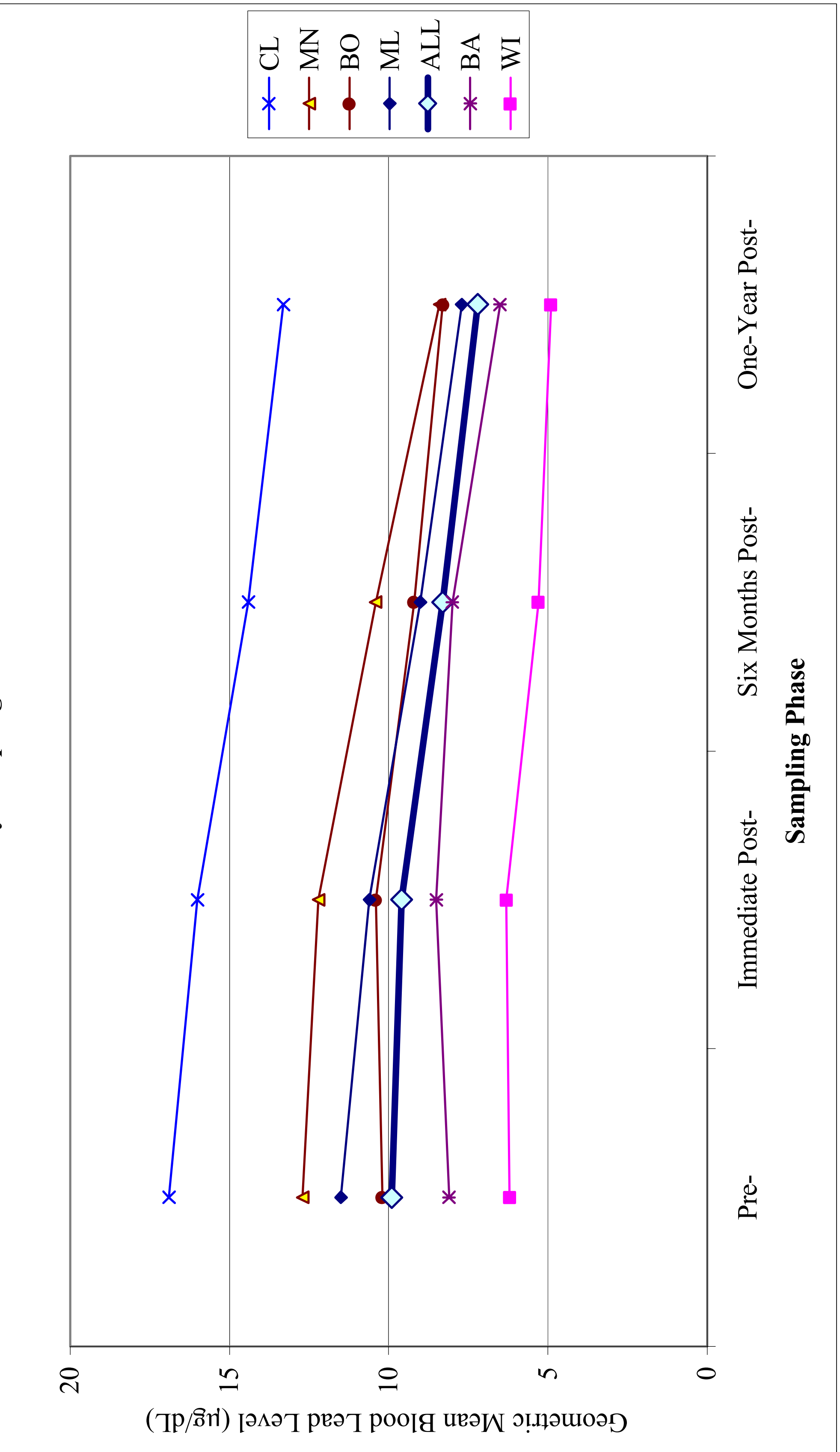
[4] The total number of children that had blood lead collected at both pre-intervention and the post-intervention phases were: 647 at six months post-intervention, 471 at one-year post-intervention, 143 at two-years post-intervention, and 95 at three-years post-intervention.

Figure 9-2: Geometric Mean Blood Lead Levels (µg/dL) from Pre-Intervention to One-Year Post-Intervention by Sampling Phase and Grantee



varying levels of lead in their blood, the patterns for blood lead reduction are similar across grantees. Geometric mean blood lead levels declined between 17 and 31 percent between immediate post-intervention and one-year post-intervention across the grantees.

It is of great interest that there were substantial declines in blood lead levels (20%) for grantees where the geometric mean pre-intervention blood lead levels were less than 10 µg/dL. Earlier studies had not demonstrated positive effects of interventions on blood lead levels for children with initial levels less than 20 µg/dL (Swindell 1994; EPA 1997a; Aschengrau 1998). The effects of interventions on lower pre-intervention blood lead levels is examined in Section 9.4.5.

Dwellings treated with Interior Strategies 04 and 05 heavily influenced the findings (see Table 9-1 for strategy definitions)[5]. The 264 children living in these homes accounted for 78 percent of these data.

9.3.2 Two-Years Post-intervention

Two-years post-intervention, there was an overall reduction of 3.8 µg/dL (37%) in geometric mean blood lead levels from pre-intervention levels (10.2 µg/dL) for the 89 children with all five phases of blood lead available (Figure 9-3). Among this population, blood lead levels were more likely to decline between pre-intervention and immediate post-intervention (on average 4 months) than in the population of children in the one-year post-intervention analysis. The decline in blood lead levels between pre-intervention and immediate post-intervention was significantly different ($p=0.02$). In this population, blood lead levels appeared to decline at a faster rate during the first 6 months (2.0 µg/dL per year) than in the following next 6 months (1.4 µg/dL per year) and the period between one and two-years post-intervention (0.6 µg/dL per year). The declines in blood lead levels during each successive post-intervention sampling phase were statistically significant ($p< 0.01$ through one-year; $p=0.02$ between one-year and two-years post-intervention). Between immediate post-intervention and one-year post-intervention, geometric mean blood lead levels declined 25 percent. Between one-year and two-years post-intervention, geometric mean blood lead levels declined an additional 9 percent.

The 89 children who made up this population represented 10 percent of the children with pre-intervention blood lead tests that were potentially eligible for the two and three year extension of the Evaluation. This value somewhat underestimates the actual retention rate because not all of the 906 children from grantees participating in the extension of the Evaluation lived in homes that were eligible for the extended study. Seventy-nine percent of the children lived in three grantee sites (Milwaukee (37%), Minnesota (26%), and Boston (16%)). The geometric mean blood lead levels for the three grantees were similar, as were the trends across phases (Figure 9-3). Geometric mean blood lead levels declined 38 percent between immediate post-intervention and two-years post-intervention in both Boston and Milwaukee, while they declined 23 percent in Minnesota during the same period.

Two-years post-intervention, dwellings treated with Interior Strategies 04 and 05 continued to heavily influence the findings. Children living in these homes accounted for three quarters of the blood lead data collected in all five phases.

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[5] See Section 5.2 for a more detailed description of dwelling unit interventions. Effects of Interior Strategies 01, 06-07 are not presented in this chapter because less than 20 children with serial blood lead tests lived in dwellings treated with these interventions.

Figure 9-3: Geometric Mean Blood Lead Levels (µg/dL) from Pre-Intervention to Two-Years Post-Intervention by Sampling Phase and Grantee

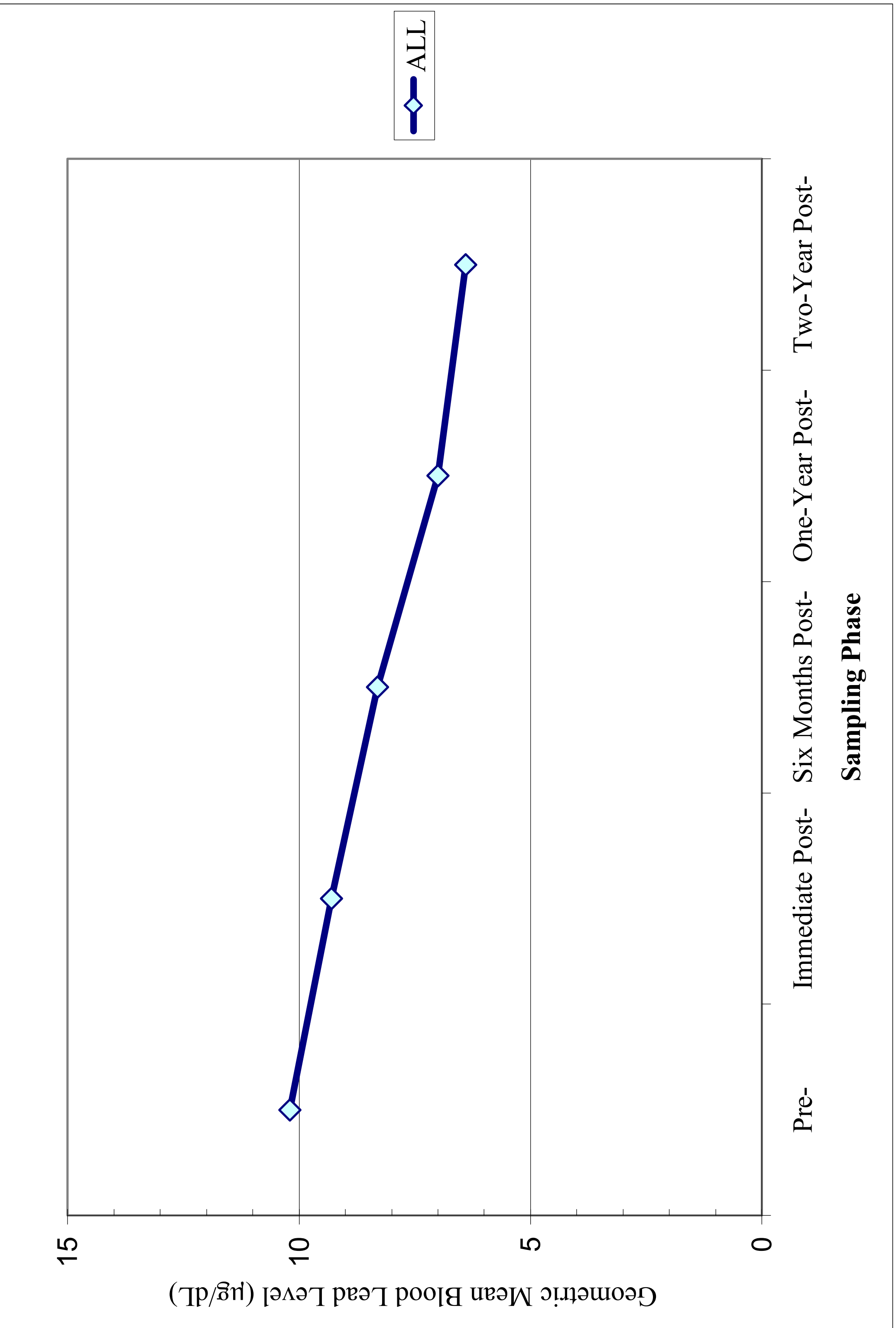


Table 9-1: Interior Strategy Code Definitions

Strategy		Definition
Interior	01	No Action
	02	Cleaning, Spot Paint Stabilization Only
	03	Level 02 plus Complete Paint Stabilization, Floor Treatments
	04	Level 03 plus Window Treatments
	05	Level 04 plus Window Replacement, Wall Enclosure/Encapsulation
	06	All Lead-Based Paint Enclosed, Encapsulated, or Removed (Meets Public Housing Abatement Standards)
	07	All Lead-Based Paint Removed

Glossary of Treatments

Encapsulation - The application of a covering or coating that acts as a barrier between lead-based paint and the environment, the durability of which relies on adhesion and which has an expected life of at least 20 years.

Enclosure - The application of rigid, durable construction materials that are mechanically fastened to the substrate to act as a barrier between lead-based paint and the environment.

Paint Stabilization - The process of repainting surfaces coated with lead-based paint, which includes the proper removal of deteriorated paint and priming.

Paint Removal - The complete removal of lead-based paint by wet scraping, chemical stripping, or contained abrasives.

Removal/Replacement - The removal/replacement of a building component that was coated with lead-based paint.

Window Treatments - The process of eliminating lead-containing surfaces on windows that are subject to friction or impact through the removal of paint or enclosure of certain window components.

9.4 TREATMENT EFFECTIVENESS

A principal goal of the Evaluation (Objectives 7 & 9) was to measure the effects of the intervention strategies on blood lead levels at each post-intervention phase of the study. Study protocols called for the use of statistical models to assess potential modifiers and confounders of the relationship between intervention strategy and blood lead levels. In particular, the effects of baseline blood lead levels, child's age and season of blood testing were to be examined. Two multivariate statistical analyses were performed to explore the factors that significantly affected longitudinal blood lead levels: the Blood SEM-1 Yr and the Blood RM-Extended Evaluation.

9.4.1 General Characteristics of the Children and Their Homes

Table 9-2 presents the general characteristics of the children and their homes for the children included in the models compared with the general Evaluation population. The post-intervention models retained 155 and 296 of the 1,273 children with pre-intervention blood lead tests. Certain characteristics of these children differed from the general Evaluation population. Children in the models were more likely to be White and less likely to be Black or Hispanic. Children in the models were more likely to live in single-family homes and owner-occupied homes. The geometric mean floor dust lead loading in the homes in the models was 17-18 $\mu g/ft^2$ compared with 24 $\mu g/ft^2$ for the general Evaluation population.

The pre-intervention geometric mean blood lead levels of the children in the post-intervention models (8.5 and 8.9 µg/dL) were similar to those levels of children in the general Evaluation population. However, the pre-intervention geometric mean blood lead levels of the children in the model populations were lower than the pre-intervention geometric mean blood lead levels of children with complete data through one-year (9.9 µg/dL) and two-years post-intervention (10.2 µg/dL)(see Sections 9.3.1 and 9.3.2).

The changes in blood lead levels over time observed across the analytical models generally corresponded to the 18-34 percent declines observed in previous lead intervention studies (EPA 1995b, EPA 1998). Geometric mean blood lead levels declined 1.8 µg/dL (20%) from pre-intervention (9.0 µg/dL) to one-year post-intervention for the 155 children in the Blood SEM-1Yr. Blood lead levels for children in the Blood SEM-1Yr declined less between pre-intervention and one-year post-intervention than in the general descriptive statistics (20% v. 27%, respectively). The difference may be attributable to the SEM eligibility requirement that limited the analysis to the youngest child in each dwelling. As explained in more detail in Section 9.4.5, a population of younger children who tend to have lower pre-intervention blood lead levels would be more likely to exhibit lower declines in blood lead levels than a population of older children with higher pre-intervention blood lead levels. In the Blood RM-Extended Evaluation, geometric mean blood lead levels declined an estimated 1.9 µg/dL (23%) from pre-intervention to one-year post-intervention.

Table 9-2: Characteristics of Children in the Blood Models

Factors	Children w/initial Blood Tests	Blood SEM-Pre-Intervention	Blood SEM-One-Year Post-Intervention	Blood RM-Extended Evaluation
N (children)	1,273	459	155	296
Age (mean) (months) SD	40.1 17.9	34.4 16.7	32.0 16.1	42.0 17.6
Gender-Female	628 (49%)	233 (51%)	75 (48%)	151 (51%)
Race Asian Black Hispanic White Other	9% 48% 15% 24% 4%	7% 40% 14% 34% 5%	5% 36% 11% 41% 6%	10% 34% 9% 41% 6%
Pre-Int. (GM) Blood Lead GSD (µg/dL)	8.7 2.1	8.2 2.1	9.0 2.2	8.5 2.1
Previous Report of Lead Poisoning	32%	29%	32%	25%
Owner-Occupied	38%	47%	60%	57%
Single-Family Building	43%	42%	54%	60%
Pre-Int. Floor GM *Dust Lead GSD* (µg/ft^2)	23.5 5.0	18.9 4.9	17.6 4.3	16.7 4.2
Interior 02 Strategy 03 04 05 Other	10% 15% 27% 46% 2%	9% 11% 19% 60% 1%	8% 10% 21% 60%	10% 10% 26% 54%

Data from: Forms 1, 5, 9, 19, 23
Data as of: June 1, 2000
Source of Data: Descriptive Statistics of Models and NCHH Table of Pre-Intervention Results

9.4.2 Effect of Interventions on Post-Intervention Blood Lead Levels Without Consideration of Other Factors

Table 9-3 presents the geometric mean blood lead levels by phase and interior strategy for all children who had all four phases of blood testing conducted from pre-intervention to one-year post-intervention[6]. Geometric mean blood lead levels for children living in homes treated with Interior Strategies 04 and 05 declined 22 and 28 percent, respectively, from pre-intervention to one-year post-intervention. The 43 children (13%) living in homes treated with Interior Strategy

[6] No children eligible for the post-intervention blood lead analyses lived in dwellings treated with Interior Strategy 06/07.

Table 9.3: Geometric Mean Blood Lead Levels (µg/dL) from
Pre-Intervention to One-Year Post-Intervention by Sampling Phase and Interior Strategy

		Interior Strategy			
Sampling Phase		02	03	04	05
Pre-Intervention	GM	9.8	10.9	13.9	7.8
	GSD	2.0	1.7	2.0	2.0
Immediate	GM	9.6	9.5	13.3	7.9
Post-Intervention	GSD	1.9	1.9	2.0	1.9
Six Months	GM	8.3	8.1	12.1	6.8
Post-Intervention	GSD	1.9	1.8	1.8	1.8
One-Year	GM	7.9	6.9	10.0	6.1
Post-Intervention	GSD	1.9	2.0	1.9	1.8
Number of Children		33	43	90	174

GM= Geometric Mean
GSD= Geometric Standard Deviation

Data From: Forms 5, 9 and 23
Data as of: June 1, 2000
Source of Data: UT Table 420-I

03 had greater percent declines in geometric mean blood lead levels from pre-intervention to one-year post-intervention (37%). The 33 children (10%) living in homes treated with Interior Strategy 02 had smaller declines in geometric mean blood lead levels from pre-intervention to one-year post-intervention (19%).

Associations existed between the pre-intervention blood lead levels, the interior strategies and post-intervention blood lead levels. For example, children living in dwellings treated with Interior Strategy 04 had the highest blood lead levels at all four phases, while children living in dwellings treated with Interior Strategy 05 had the lowest blood lead levels at all four phases. This association is addressed in further detail in Section 9.4.3.

The geometric mean blood lead levels by phase and interior strategy were also examined for the 89 children who had all five phases of blood testing conducted from pre-intervention to two-years post-intervention. Geometric mean blood lead levels for children living in homes treated with Interior Strategies 04 and 05 declined 42 and 31 percent, respectively, from pre-intervention to two-years post-intervention. Blood lead levels in homes treated with Interior Strategy 04 fell from 12.5 µg/dL to 7.3 µg/dL, while levels in homes treated with Interior Strategy 05 declined from 8.5 µg/dL to 5.9 µg/dL. Only 11 and 9 children living in dwellings treated with Interior

Strategies 02 and 03, respectively, had blood lead available in the first five phases. Given these small sample sizes, the descriptive statistics for these strategies are not presented here.

9.4.3 Effect of Interventions on Post-Intervention Blood Lead Levels When Considering Other Factors

The multivariate models described in Section 9.4.1 were used to explore the influence of lead hazard control interventions on post-intervention blood lead levels when controlling for other factors. The Blood SEM- 1Yr was used to examine effects of the interventions on blood lead levels at one-year post-intervention. The Blood RM – Extended Evaluation was used to examine the influence of interventions on the changes in blood lead levels over the three years of Evaluation.

9.4.3.1 Effects of Interventions on One-Year Post-Intervention Blood Lead

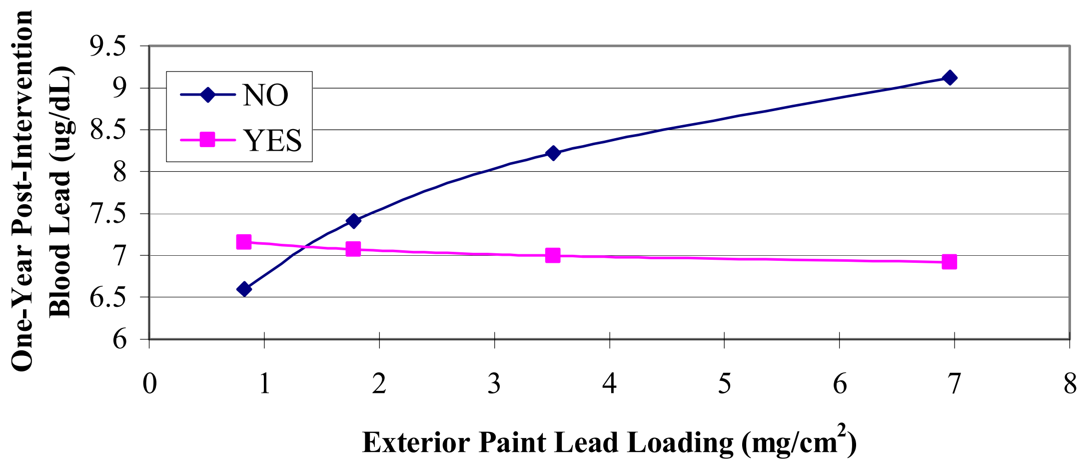
Factors that influenced one-year post-intervention blood lead levels (based on the Blood SEM-1Yr) were:

- Pre-intervention blood lead levels (log-transformed);
- Child's Age (cubic function);
- Child's Race
- Parental Report of Previous Lead Poisoning of the Child;
- Cleanliness of the Home (pre-intervention);
- Exterior Building Condition (pre-intervention); and
- Interaction between Exterior Paint Lead Level and Exterior LHC Work

Children with higher pre-intervention blood lead levels had higher post-intervention blood lead levels. Details concerning the effect of the child's race and age on post-intervention blood lead levels are provided in Section 9.4.5. Children with a parental report of being previously lead poisoning had significantly higher post-intervention blood lead levels, even after controlling for the pre-intervention blood lead level. Children living in homes with more deteriorated exterior components prior to intervention also had significantly higher post-intervention blood lead levels. Surprisingly, children living in homes judged by interviewers to be less clean prior to intervention had *lower* post-intervention blood lead concentrations.

Of interest, the variation in interior lead hazard control treatments as measured by Interior Strategy was not a significant predictor of post-intervention blood lead levels. However, post-intervention blood lead levels were associated with dwellings where exterior lead hazard control work was conducted, as long as the average pre-intervention exterior paint lead loading was taken into consideration. Figure 9-4 presents the estimated one-year post-intervention blood lead levels by Exterior Work (Yes/No) and pre-intervention exterior paint lead loadings when setting all variables to their mean values. The variation in exterior paint lead levels had a significant effect on the blood lead levels when no exterior work was conducted. Higher exterior paint lead loadings in dwellings without exterior work were associated with higher post-intervention blood lead levels. Children living in dwellings where exterior lead hazard control interventions were done had lower blood lead levels at one-year post-intervention than in dwellings without the

Figure 9-4: Predicted One-Year Post-Intervention Blood Lead by Exterior Paint Lead Loading and Exterior Work (Yes/No)



treatments (all other factors being equal), but those differences were only significant when the mean exterior paint lead loading at pre-intervention was about the 90 percentile (7.0 mg/cm^2).

Also of interest, none of the concurrent dust lead loadings in the dwellings were significantly associated with post-intervention blood lead levels. The pathways from environmental sources that had been found to be significant predictors of the children's pre-intervention blood lead levels were *not* significant predictors of the children's blood lead levels measured twelve months after the interventions were performed. Further discussion of the effect of interventions on the lead exposure pathways is found in Section 9.4.6.

9.4.3.2 Effects of Interventions on Changes in Post-Intervention Blood Lead.

Factors that influenced changes in post-intervention blood lead levels (based on the Blood RM-Extended Evaluation) were:

- Pre-intervention blood lead levels (log-transformed);
- Child's Age (cubic function);
- Parental Report of Previous Lead Poisoning;
- Season (considered as a sinusoidal effect); and
- Phase

Blood lead levels significantly declined with time. A seasonal effect that was observed prior to intervention continued to be observed post-intervention. Children had higher blood lead levels in the late summer and lower levels in the late winter.

As observed in the one-year post-intervention model, Interior Strategy was not a significant predictor of post-intervention blood lead levels. In addition, the use of exterior and/or site treatments was not significantly related to those blood lead levels.

9.4.4 Discussion of Intervention Findings

The Evaluation team hypothesized that, given the statistically significant differences observed in dust lead loadings by Interior Strategy (see Chapter 8), different Interior Strategies would yield differences in post-intervention blood lead levels. Such a finding was not observed. No individual interior strategy was related to significant differences in blood lead level.

For the four interior strategies that were examined in the blood lead models (Interior Strategies 02-05), window sill and window trough dust lead loadings were dramatically lower in dwellings treated with Interior Strategy 05. However, interior floor dust lead loadings were not significantly lower in these same dwellings. Assuming interior floor dust lead is the primary exposure pathway of dust lead to a child, as established by the pre-intervention model, this finding may suggest a reason why Interior Strategy 05 did not prove to be more effective than the other interior strategies. At the same time, the lack of significant differences between Interior Strategy 05 and the other strategies remains somewhat surprising, given the fact that this strategy would have removed the environmental factor most predictive of pre-intervention blood lead - lead-based paint on windows.

The observation in the Blood SEM- 1Yr that children living in dwellings where the exterior paint lead levels were above 7 mg/cm^2 and the exteriors were treated had lower post-intervention blood lead levels suggests that exterior lead hazard control is an important component of a lead hazard control plan. The fact that this finding was not also observed in the repeated measures model limits the strength of the conclusion, but it highlights an area where further research should take place.

9.4.5 Factors Modifying Treatment Effects

9.4.5.1 Pre-intervention Blood Lead Levels and Parental Report of Previous Lead Poisoning. Previous studies of the effects of lead hazard control interventions on children's blood lead levels reported that post-intervention blood lead levels are significantly related to the pre-intervention blood lead levels (EPA 1995b). Children's blood lead levels are affected by both the lead in the external environment and by lead that previously entered and became stored in the body (i.e., the body burden) (Nordberg 1991; Rabinowitz 1991). Lead present in the tissues of the body, especially the bones, can be released into the blood stream during periods of reduced exposure to external lead sources. As a result, it is expected that the blood lead levels of children who have previously been exposed to lead will have higher blood lead levels than children who had not been previously exposed even if they were living in the same home environment.

Pre-intervention blood lead levels of children were significantly associated with the post-intervention blood lead levels. Furthermore, a child whose caregiver reported that the child was lead poisoned prior to intervention had significantly different post-intervention blood lead levels than a child whose caregiver did not report that the child had been lead- poisoned. The children who had been lead-poisoned, as reported by their caregivers, had higher post-intervention blood lead levels after controlling other variables, including pre-intervention blood lead levels.

In the Blood SEM- 1Yr, a ten percent increase in pre-intervention blood lead levels resulted in a predicted increase in one-year post-intervention blood lead of five percent. A child whose initial blood lead level was higher than another child's level would continue to have a higher blood lead level post-intervention. For example, consider two identical children with all factors being equal to the model means except that one child has an initial blood lead level of 9.1 µg/dL and the other has an original blood lead level of 10.0 µg/dL. The predicted blood lead level of the first child fell to 7.2 µg/dL one-year post-intervention, while the predicted blood lead level of the second child was 7.6 µg/dL.

While controlling for all other factors including pre-intervention blood lead levels, children who were reported to be lead poisoned prior to enrollment had higher post-intervention blood lead levels. Children whose caregivers reported that they were previously lead poisoned were predicted to have post-intervention blood lead levels 31 percent higher than children whose caregivers did not report that the they were previously lead poisoned. For example, using the Blood SEM-1Yr results, a child whose initial blood lead level was 9.0 µg/dL was predicted to have a blood lead level at one-year post-intervention of 8.6 µg/dL if previously lead poisoned and 6.6 µg/dL if not previously lead poisoned.

Discussion

Two possible limitations must be noted when attempting to quantify the effects of previous lead poisoning and initial blood lead levels. First, the pre-intervention blood lead levels and a report of previous lead poisoning are not truly independent factors especially at the extremes. Just 5 percent of children with an initial blood lead level of 5 µg/dL or less were reported to be previously lead poisoned, while over 70 percent of children with an initial blood lead level of 15 µg/dL or more were known by the caregiver to be lead poisoned prior to the intervention.

A second limitation that may underestimate the effect of pre-intervention blood lead levels on post-intervention blood lead levels is the influence of laboratory detection limits. Approximately one-quarter of the children with post-intervention blood lead levels had initial blood lead levels of 5 µg/dL or less and one-half of those children lived in Wisconsin where the laboratory could not detect levels below 5 µg/dL. Any actual declines in blood lead levels would not have been reported by the laboratory for half of the children at the extreme end of the distribution of data, thereby possibly diminishing the predicted effect of pre-intervention blood lead.

Although previous studies had found that children with initial blood lead levels below 20 µg/dL did not have substantial declines post-intervention (Swindell 1994; EPA 1997a; Aschengrau 1998), children in the Evaluation with pre-intervention blood lead levels between 10-19 µg/dL exhibited blood lead declines of 34 percent at one-year post-intervention (Table 9-4). Table 9-4 presents unadjusted data for all children who had a blood lead result reported at both pre-intervention and one-year post-intervention as well as an associated floor dust lead result at each sample phase. Changes in blood lead levels were organized by categories of pre-intervention blood lead. Across all categories, floor dust lead loadings declined by a similar percentage ($p=0.34$), but blood lead levels varied by pre-intervention levels ($p<0.001$). For categories with pre-intervention blood lead levels at or above 10 µg/dL, changes were similar ($p=0.46$); the geometric mean blood lead levels declined an average of 36 percent or more one-year post-intervention.

9.4.5.2 Child's Race/Ethnicity. At both pre-intervention and one-year post-intervention, the child's race/ethnicity was significantly associated with the child's blood lead levels. At both of the phases, there were more than 15 children in each of three racial/ethnic groups: non-Hispanic

White, non-Hispanic Black and Hispanic.[7] Children whose parents reported that they were Black had significantly higher blood lead levels than children who were reported to be White or Hispanic. Controlling for all other significant variables in the models, Black children had blood lead levels that were approximately 25 percent higher than White or Hispanic children at both phases.

The relationship between race/ethnicity and children's blood lead levels has previously been identified in earlier surveys of health (Mahaffey 1982; Pirkle 1998) as well as other epidemiologic studies (Charney 1980; Clark 1985; Lanphear 1998). The findings of this Evaluation are consistent with earlier findings that Black children had higher blood lead levels than White children. Possible reasons for the disparity in blood lead levels by race were discussed in Lanphear, 1996b.

Table 9-4: Geometric Mean Pre-Intervention and One-Year Post-Intervention Blood Lead Levels and Blood Lead Changes by Pre-Intervention Blood Lead Levels

Pre-Intervention Blood Lead (µg/dL)	Number and Percent of Children	Geometric Mean Pre-Intervention Blood Lead (µg/dL)	Geometric Mean One-Year Post-Intervention Blood Lead (µg/dL)	Percent Change from GM Pre-Intervention Blood Lead to GM One-Year Post-Intervention Blood Lead	Percent Change from GM Pre-Intervention Floor Dust Lead[a] to GM One-Year Post-Intervention Floor Dust Lead[a]
<6[b]	105 (25%)	3.5	3.7	6%	-43%
6-9	98 (23%)	7.2	5.6	-22%	-64%
10-14	76 (18%)	11.7	7.7	-34%	-48%
15-19	62 (15%)	16.5	11.2	-32%	-59%
20-25	38 (9%)	22.4	14.2	-37%	-52%
>25	39 (9%)	31.5	18.1	-43%	-51%
All	418	9.4	7.2	-23%	-53%

[a]Floor dust lead levels are represented by the arithmetic mean dust lead loadings for all floors in a dwelling.
[b]For pre-intervention blood lead levels below 6 µg/dL, the increases may be due in part to laboratory detection limitations that restricted the number of test results that could exhibit observable declines, but did not restrict the number that could increase.
Data from: Forms 05, 09 and 19
Data as of: June 1, 2000
Source of Data: NCHH Table

[7] Other racial groups included: Asian, Native American and Other.

9.4.5.3 Child's Age. Previous studies have identified a relationship between the age of a child and their blood lead levels (Clark 1985; EPA 1996a). For children between the ages of six months and six years, blood lead levels tend to rise until a child is 18 to 36 months old and then decline. A similar pattern was identified among children in the Evaluation.

At pre-intervention, the blood lead levels of children in the Evaluation were significantly associated with the age of the child. Controlling for all other variables, children six months of age (the youngest children enrolled in the study) had the lowest blood lead levels. Blood lead levels increased until a child was two years of age and then declined until a child was about four and half years old. The effect of child's age was predicted in the statistical models using a cubic function that better matched the observed trends. The predicted effect at pre-intervention is displayed in Figure 9-5.

Child's age remained a significant variable in the post-intervention model, with trends following a similar pattern as displayed prior to intervention. At one-year post-intervention, two year-old[8] children were likely to have higher blood lead levels than they did at enrollment, all other factors being equal (Figure 9-6). While the ultimate goal of any intervention is to avoid any increases in the blood lead levels, the results of the modeling suggest that these increases were attributable to an age effect and not to any increased environmental exposure. The predicted one-year post-intervention blood lead levels for children over 10 months of age at enrollment all declined from pre-intervention, with the greatest declines for children who were between two and two and a half years of age at enrollment. Again these trends match the expected age effects, as these children on average would experience a decline from their peak blood lead levels even without the intervention.

Figure 9-7 presents the actual geometric mean blood lead levels at pre-intervention and one-year post-intervention by age of the child at enrollment. The graph displays the influence of the age effect described above. The graph also offers visual support for the finding that actual blood lead levels at one-year post-intervention could not be explained by the age effect alone. No age category had a one-year geometric mean blood lead level that was as high as the pre-intervention blood lead level in the succeeding category.

[8] On average, children were 14 months older one-year post-intervention than at enrollment, so children who were approximately two years of age at one-year post-intervention were generally 9-12 months old at enrollment.

Figure 9-5: Geometric Mean Blood Lead Levels (µg/dL) at Pre-Intervention by Child's Age Predicted from Pre-Intervention SEM

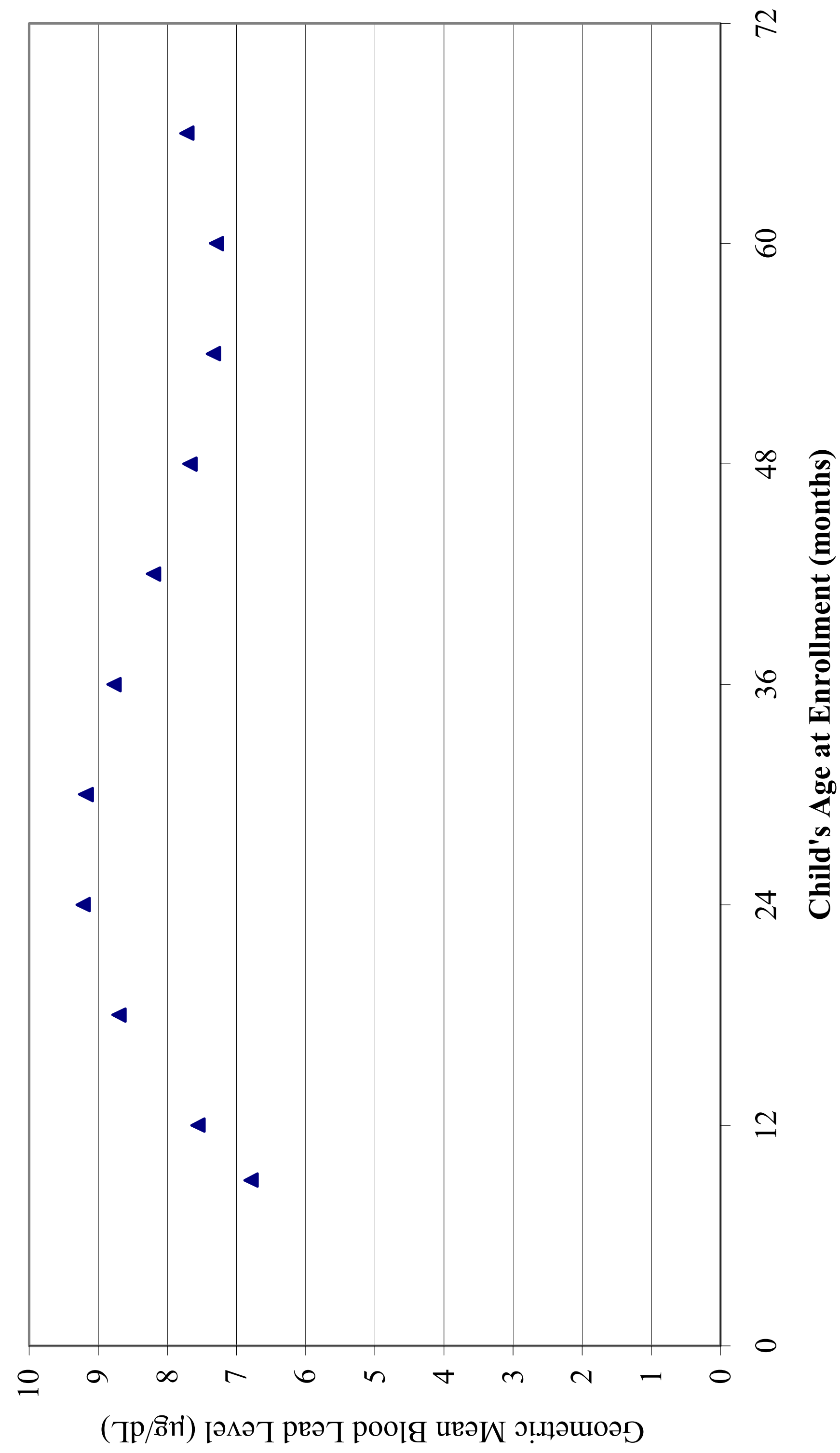


Figure 9-6: Actual and Predicted Percent Change in Blood Lead Levels from Pre-Intervention to One Year Post-Intervention by Age of Child at Enrollment: Predicted from the One Year SEM

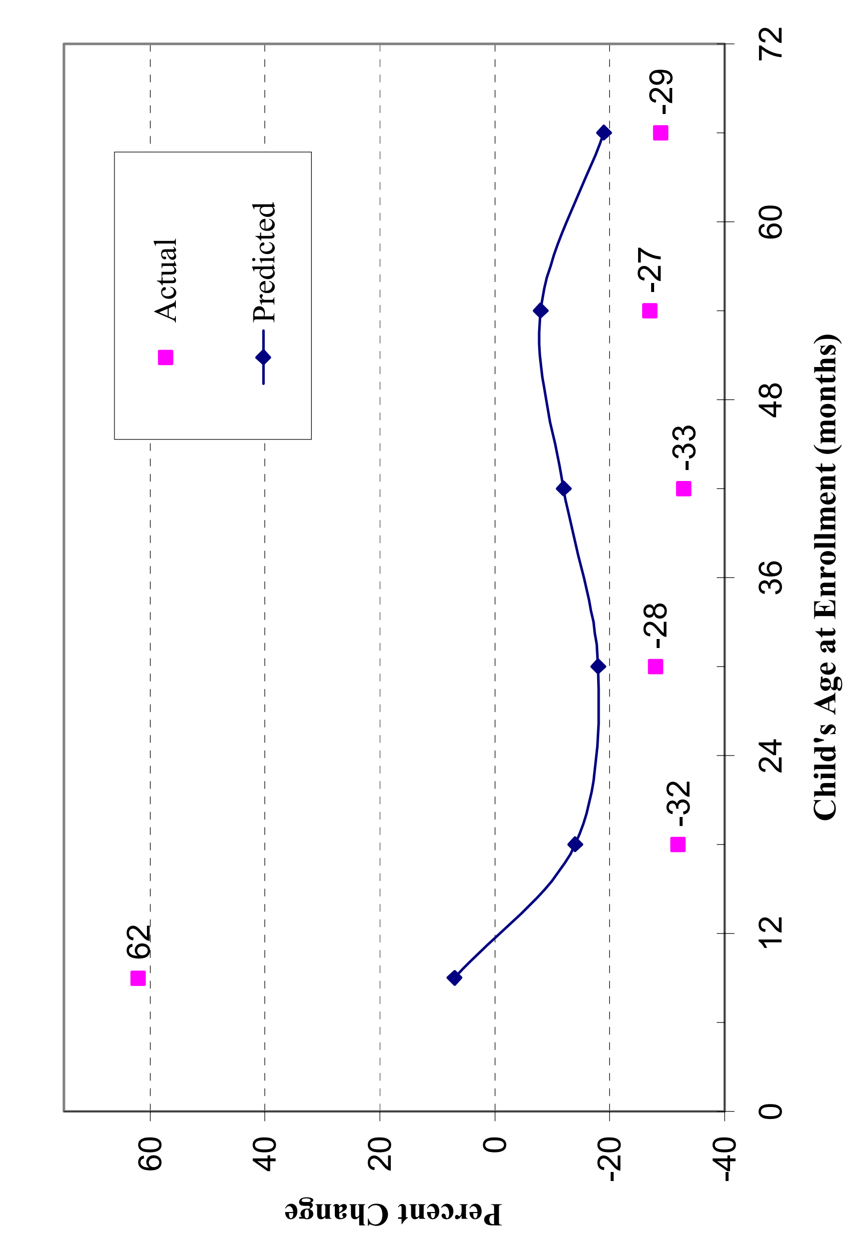
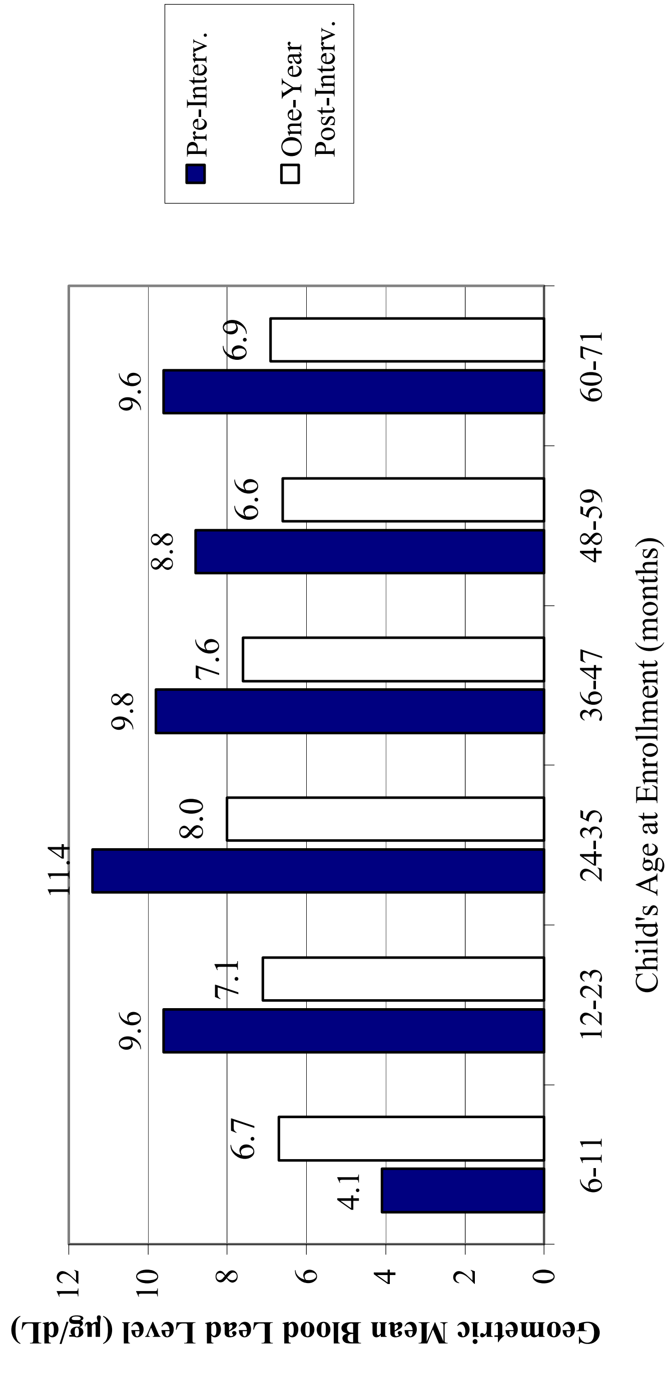


Figure 9-7: Predicted Geometric Mean Blood Lead (µg/dL) at Pre-Intervention and One-Year Post-Intervention by Age of Child at Enrollment: Predicted from the One Year SEM



9.4.5.4 Sampling Phase. Blood lead levels continued to decline with time after clearance. The phase of the blood lead tests was a variable that was tested in only the RM model. In the Blood RM-Extended Evaluation model, blood lead levels were significantly different between all phases of blood lead sampling except between two-years and three-years post-intervention. For the set of children in the Blood RM-Extended Evaluation model, the decline between six months and one-year post-intervention was 7 percent. Blood lead levels declined eight percent between one-year and two-years post-intervention, and then declined an additional three percent between two-years and three-years post-intervention. As noted above, the latter decline was not significantly different from no change. The model estimates based on least squared means are presented in Figure 9-8.

With approximately 25 percent of the children reportedly lead poisoned prior to intervention and almost one-third of the children having a pre-intervention blood lead level over 15 µg/dL in the Blood RM-Extended Evaluation model, it was expected that it would take a long time to detect the effects of the interventions on blood lead levels. Following the interventions and the reductions of lead in the child's home environment, lead that had been stored in skeletal tissues would be transferred into the blood over a period of time. According to one published study, children who had prolonged exposure to lead over the first two years of life had an apparent half-life of lead in blood between 20 and 38 months (Manton 2000). The same study found that children who were only briefly exposed had an apparent half-life of 8 to 11 months. The latter values corresponded to modeled estimates by Rust et al. (Rust 1999) for children older than two years. Half-lives of lead in the bone of children 3, 4, and 5 years of age were estimated to be 8, 10, and 12 months, respectively. Rust et al. estimated that because of bone-lead stores, an intervention that reduces a 5 year-old child's external lead exposure by 50 percent might produce only a 25 percent decline in the child's blood lead level 12 months following intervention.

The findings from the Blood RM-Extended Evaluation model support expectations that for many of the children in the Evaluation, blood lead levels began to approach equilibrium with their environment about two-years post-intervention. Even so, blood lead levels of children who had been exposed for prolonged periods continued to decline through three-years post-intervention.

The Evaluation team recognizes that a portion of the blood lead declines over time may have occurred independently of intervention (i.e., because of declines in the lead in the general environment). Over the period of data collection (1994-1999) there were small declines in air lead levels and air emissions nationally (EPA 2001b). Other sources of lead outside the home such as lead in water and lead in food may also have continued to decline during the period (Bolger 1996). With neither a control group nor testing of dietary intakes, the Evaluation was unable to determine the magnitude or the possible effects of declines of other external lead sources on Evaluation children. However, the declines in external lead sources do not appear large enough to explain the 18 to 27 percent declines in blood lead levels from pre-intervention to one-year post-intervention.

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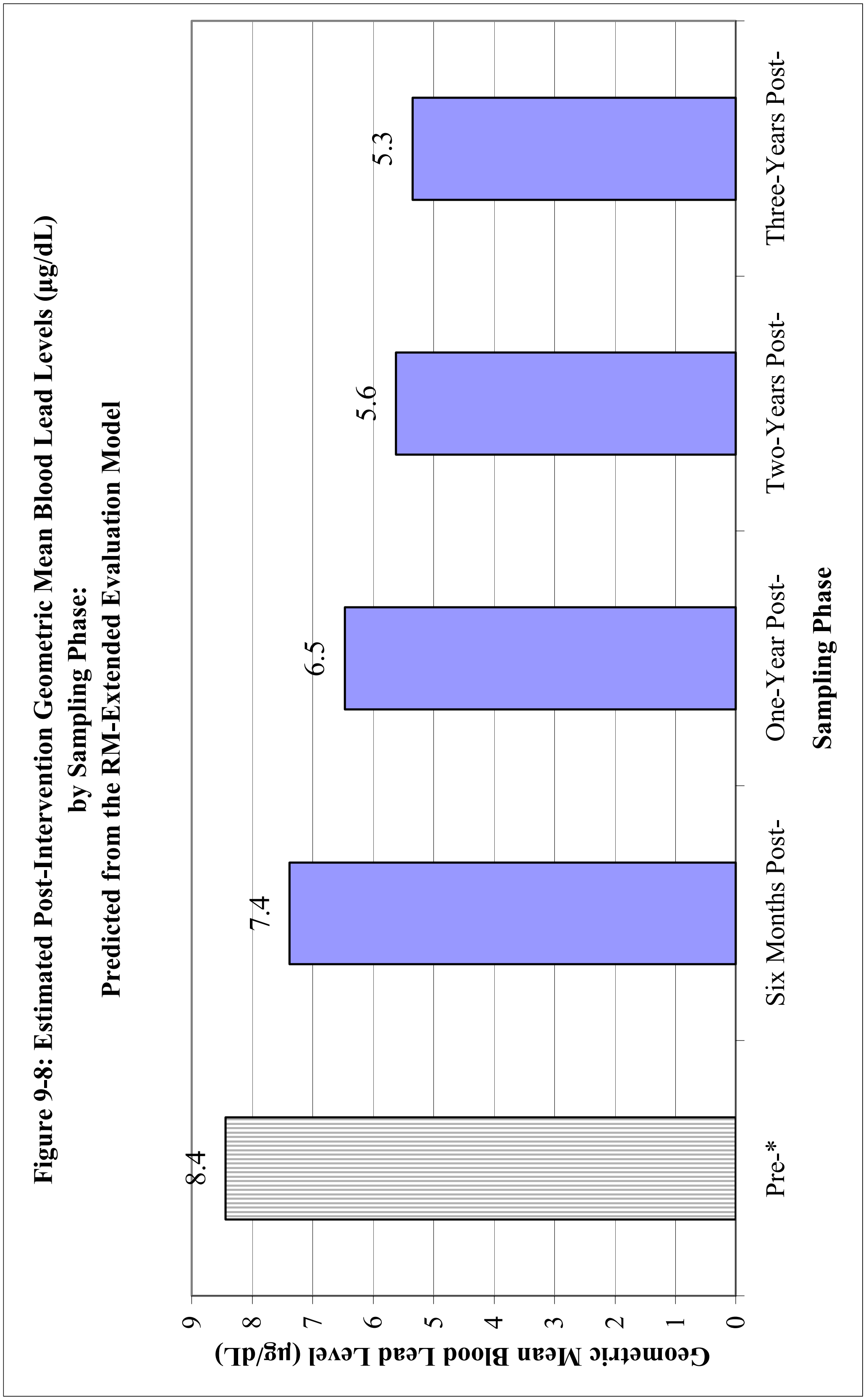


Figure 9-8: Estimated Post-Intervention Geometric Mean Blood Lead Levels (µg/dL) by Sampling Phase: Predicted from the RM-Extended Evaluation Model

9.4.5.5 Date of Testing (Seasonality). The Evaluation team was able to control for the time of the year when the blood lead was collected. Previous studies have demonstrated that blood lead levels in children tend to peak in the late summer and remain low in the winter (Hunter 1977; Rabinowitz 1985; EPA 1996a; Rothenberg 1996). Seasonal variation can be substantial: children tested by the Milwaukee Health Department between 1990-93 had blood lead levels 40 percent higher in the summer than in the winter (EPA 1996a). Failure to account for the effect of seasonal variation could either overstate or understate the impact of the interventions on the post-intervention blood lead levels.

A sinusoidal function was used to predict the effect of season. This function, which assumes seasonality is symmetric, can identify the size and timing of seasonal fluctuations. At pre-intervention, the blood lead levels in the Evaluation were predicted to be 23 percent higher at their peak in July than in January. The model-predicted values were somewhat lower post-intervention with blood lead levels 14 percent higher in late summer than in late winter. Even with the lower predicted seasonal effects at post-intervention, the magnitude of the seasonal effect was greater than the magnitude of the change in blood lead levels from six-months post-intervention to one-year post-intervention. The relative size of the effect of season compared with the effects of the treatment underscores the necessity of controlling for season in these analyses.

9.4.6 Changes in Pathways from Pre-Intervention to Post-Intervention

As expected from previous studies (Sayre 1974; Bornschein 1985; Davies 1990; Lanphear 1997), very strong pathways from dust lead to blood lead were found at pre-intervention (Figure 9-1). In the pre-intervention Blood SEM, pre-intervention blood lead levels were directly predicted by dust lead loadings on interior floors and indirectly predicted by dust lead loadings on interior entry floors, window sills and window troughs. Pre-intervention blood lead levels were also directly influenced by paint lead levels on windows and indirectly influenced by the surface condition of dust-sampled surfaces.

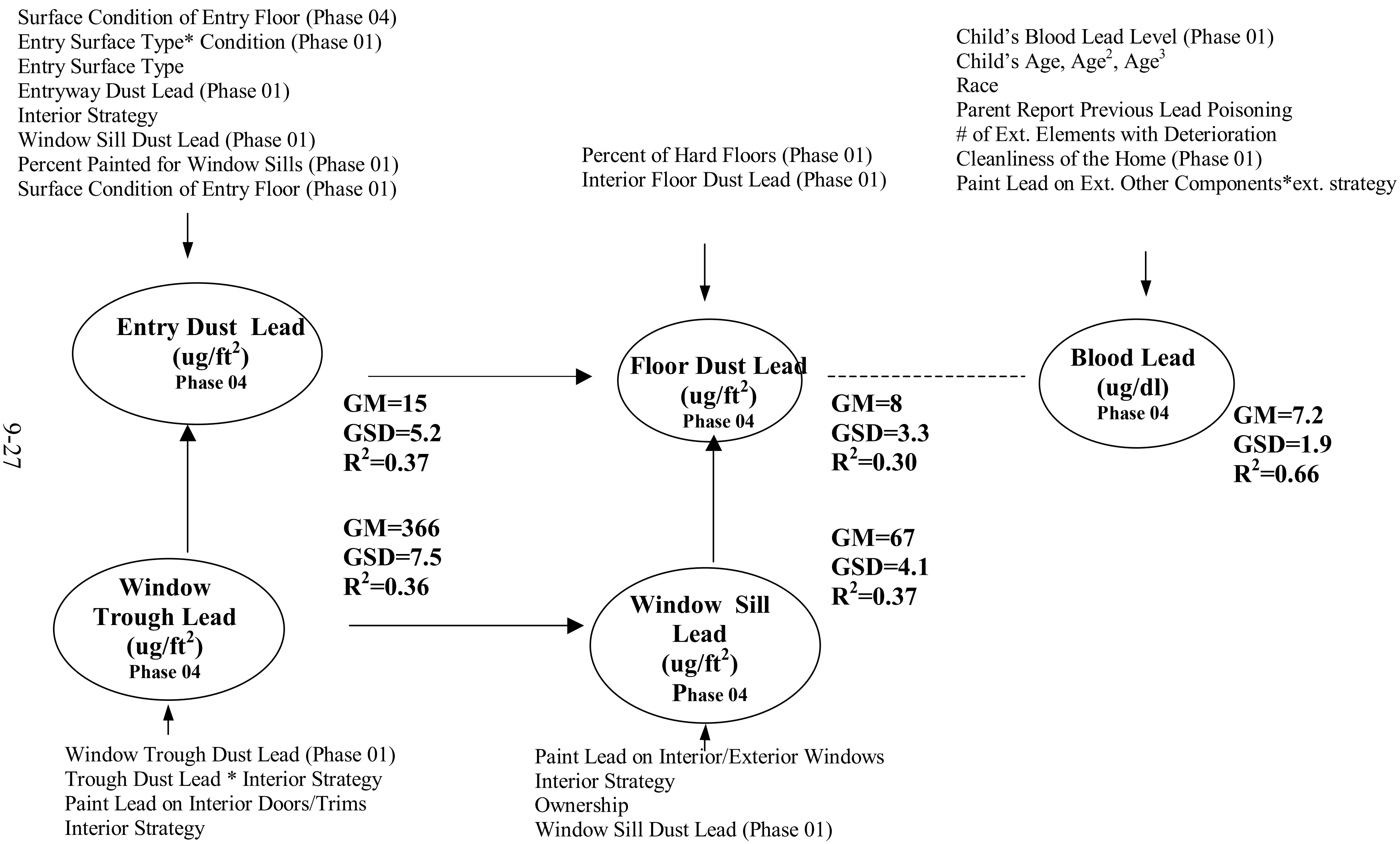
Those pathways from environmental sources of lead that were significant predictors of children's pre-intervention blood lead levels in the pre-intervention Blood SEM were not significant predictors of children's blood lead at one-year after the intervention (Figure 9-9). Specifically, although the relationships among post-intervention dust lead variables were similar to those among pre-intervention dust lead variables, the pathway from dust lead to blood lead could no longer be detected, suggesting that the interventions were successful in arresting residential lead exposure.

Although the link between concurrent dust lead and blood lead was no longer observable post-intervention, it was hypothesized that declines in residential dust lead loadings (as well as the correction of deteriorated lead-based paint) resulted in lower blood lead levels. It is likely that the relationship could not be observed because the children's body burden of lead became a better predictor of blood lead level post-intervention than post-intervention dust lead loadings.

This hypothesis was tested using bivariate analyses of the youngest child's blood lead levels and the interior floor dust lead loadings in their dwellings. Only children with both blood lead results and floor dust lead results in both phases were included (119 children). An analysis of the pre-

Figure 9-9

Twelve-Month Post-Intervention Lead Exposure Pathways Including Blood Lead
(Data as of: June 1, 2000)
(N = 155)



Note: Solid line indicates that a statistically significant coefficient was found.
Dash line indicates that no statistically significant coefficient was found.
All coefficients are significant at $P<0.05$

intervention blood lead levels and concurrent interior floor dust lead loadings (both log-transformed) identified a correlation of 0.29 ($p<0.01$). An analysis of blood lead and interior floor dust lead for these same children one-year post-intervention identified a very similar relationship, with a correlation of 0.32 ($p<0.01$).

A simple RM model was run with the same data to test the hypothesis that the relationship between blood lead levels and interior floor dust lead loadings (both log-transformed) was the same at pre-intervention and one-year post-intervention. The slope of the relationship between blood lead and floor dust lead was the same for the two groups ($p=0.94$), so the interaction term was dropped from the model. In the resulting model, the intercepts for the two groups were significantly different ($p<0.01$). Blood lead levels were 20 percent higher at the same interior floor dust lead loading at pre-intervention than at one-year post-intervention.

These analyses support the interpretation put forth above: floor dust lead loadings continued to affect blood lead levels post-intervention, but the child's previous exposure as measured by baseline blood lead had a stronger relationship to later blood lead levels, which tended to mask the effects of dust. The analyses suggest that a similar relationship between blood lead levels and interior floor dust lead loadings likely existed at one-year post-intervention as at pre-intervention in the two blood SEMs. However, the addition of a previous blood lead result into the one-year post-intervention model introduced a factor that was more predictive of later blood lead levels than were the concurrent dust lead loadings. The blood lead-dust lead relationship was not apparent post-intervention because of the significant correlations between pre-intervention blood lead and post-intervention blood lead ($r=0.73$; $p<0.01$) and between pre-intervention floor dust lead and post-intervention floor dust lead ($r=0.34$; $p<0.01$). As displayed in Figure 9-10, homes with higher floor dust lead loadings housed children with higher blood lead levels and homes with higher floor dust lead loadings continued to have higher floor dust lead loadings post-intervention (though overall lower).

9.5 CONCLUSIONS

Overall, interventions selected by grantees in the LHC Grant Program were successful in reducing blood lead levels 18 to 30 percent one-year post-intervention. These levels correspond to declines in blood lead levels observed in previous studies of lead hazard control interventions (18-34%) (EPA 1995b, EPA, 1998), although this current study is the first to demonstrate significant reductions from relatively low pre-intervention blood lead levels. Blood lead levels were significantly lower at each successive phase of testing until three-years post-intervention, at which time blood lead levels were not significantly different than at two-years post-intervention. At two-years post-intervention, geometric mean blood lead levels were approximately 37 percent lower than at pre-intervention.

Children with pre-intervention blood lead levels as low as 10 µg/dL experienced substantial declines in blood lead levels following interventions. Previous studies had not observed substantial declines unless a child's pre-intervention blood lead level was above 20 µg/dL. These results suggest that the interventions of the HUD LHC Grant Program not only had a positive overall impact on children's blood lead levels but also positively affected children at pre-intervention blood lead levels around the CDC level of concern (10 µg/dL).

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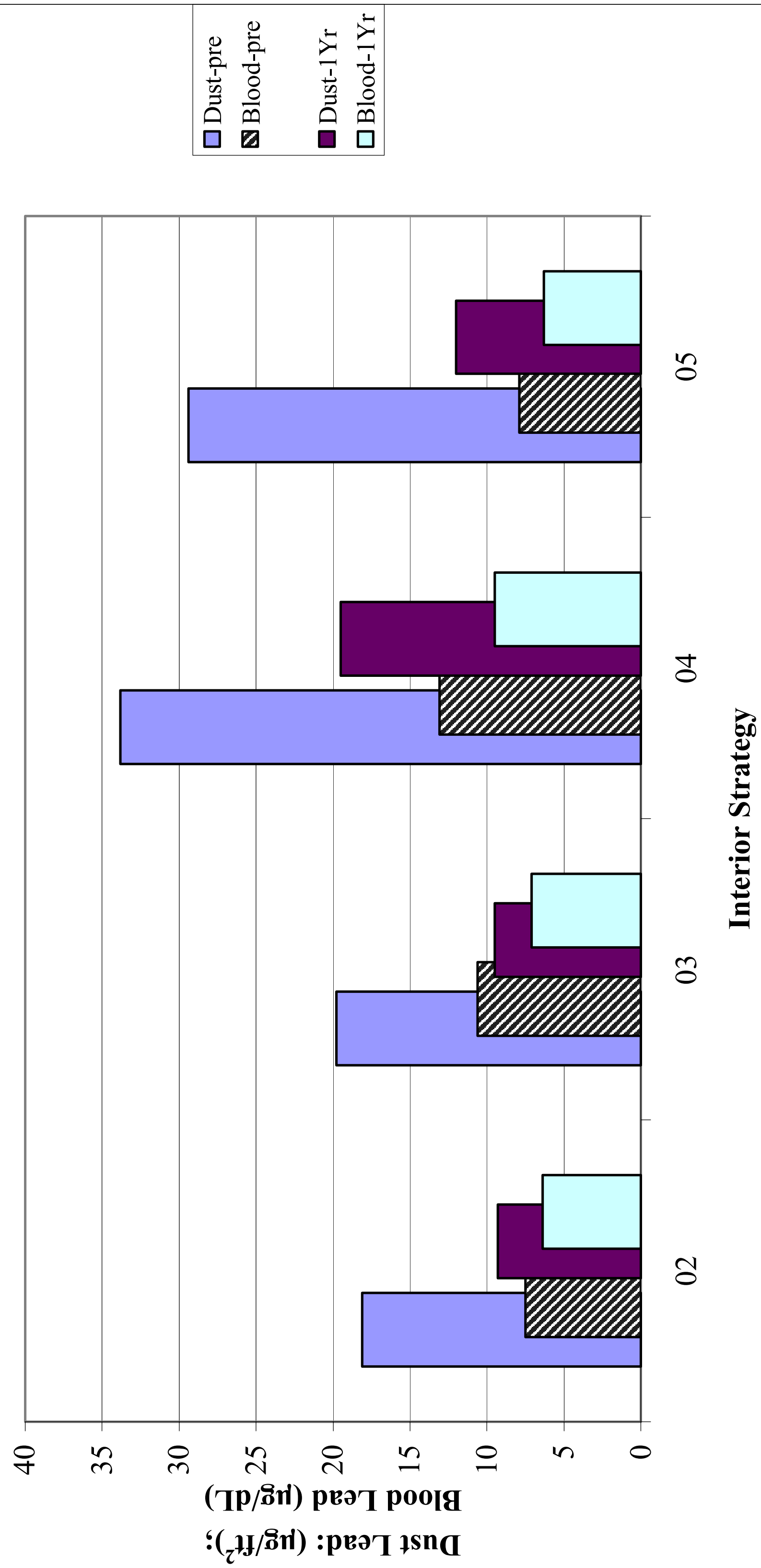
Figure 9-10: Geometric Mean Blood Lead Levels and Interior Floor Dust Lead Loadings at Pre-Intervention and One-Year Post-Intervention by Interior Strategy



Data from: Forms 05, 09, and 23
Data as of: June 1, 2000
Source of Data: NCHH Table

For at least three-years post-intervention, no interior lead intervention strategy that was examined performed substantially better or substantially worse than the other interior strategies (after controlling for other factors). Children living in buildings with higher exterior paint lead levels (> 7 mg/cm^2) that were treated with exterior lead hazard control work had significantly different (lower) blood lead levels than those living in buildings where the exterior was not treated.

The Evaluation designers acknowledged at the beginning of the study that the lack of a control population or random selection of treatments would limit the strength of these conclusions. Relationships between the interventions and childhood lead exposure will require confirmation by more controlled investigations. While the Evaluation could not statistically separate the influence of post-intervention lead exposure sources from the influence of pre-intervention blood lead (i.e., because these factors were intercorrelated), evidence suggests that the reduction in paint lead and dust lead hazards resulted in declines in blood lead levels.

Although the Evaluation did not have the advantages of a control group or random selection, it did have the advantage of a large sample size to help explore the effects of a range of factors on blood lead outcomes. Evaluation findings supported previous studies that found a need to control for child's age and season of blood lead testing. Age is especially important to consider for children less than 12 months prior to intervention because their blood lead levels would be predicted to increase in the absence of action and for children between 24 and 30 months of age prior to intervention because their blood lead levels would be predicted to decline in the absence of action. Likewise, with a 14 to 23 percent difference in blood lead levels in winter compared to summer, the season of blood lead testing needs to be taken into account.

The Evaluation designers recognized that the activities in the HUD LHC Grant Program were often a secondary prevention effort for the children who resided in the treated dwellings. Children who were reported to be previously lead poisoned experienced smaller blood lead declines post-intervention than children who were not reported to be previously lead poisoned. This finding emphasizes the need for primary prevention. Unfortunately, the Evaluation was not able to recruit enough newborn children into the study to test the primary prevention benefits of the interventions.

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Exhibit 9-1: List of Variables Used in Pre-Intervention and Post-Intervention Blood Lead Models

Lead Hazards

Pre-intervention Variables:

Entryway Dust Lead Loading
Surface Type of Entry Floor (Hard, Painted or Carpet)
Surface Condition of Entry Floor
Average Interior Floor Dust Lead Loading
Percent of Painted Floors
Percent of Hard Floors
Percent of Carpeted Floors
Percent of Painted Floors * Average Surface Condition
Percent of Carpeted Floors * Average Surface Condition
Percent of Hard Floors * Average Surface Condition
Average Window Sill Dust Lead Loading
Average Surface Condition of Window Sills
Percent Painted Window Sills
Average Window Trough Dust Lead Loading
Average Surface Condition of Window Troughs
Percent Painted Window Troughs
Percent Dust Collected in Same Room for Each Component
(Entries, Floors, Window Sills, Window Troughs)
Average Paint Lead on Interior Doors/Trim (Mean of Log(XRF))
Average Paint Lead on Windows (Mean of Log(XRF))
Average Paint Lead on Exterior Components (Mean of Log(XRF))
Average Paint Condition of Interior Doors/Trim
Average Paint Condition of Windows
Average Paint Condition of Exterior Components
Interaction between Paint Lead Loading and Paint Condition for Each Component
(Interior Doors/Trim, Windows, Exterior Components)
*Interaction between % Dust Collected in Same Room and Dust Lead Loading (Pre-Intervention) for Each Component (Entries, Floors, Window Sills, Window Troughs)
Interaction of Surface Type and Condition of Entry Floor

*Post-intervention Variables:

Entryway Dust Lead Loading
Surface Condition of Entry Floor
Average Interior Floor Dust Lead Loading
Average Surface Condition of Interior Floors
Average Window Sill Dust Lead Loading
Average Surface Condition of Window Sills
Average Window Trough Dust Lead Loading
Average Surface Condition of Window Troughs

Pre-Intervention Building/Dwelling Condition

Number of Interior Elements with Deterioration
Roof Leak (Yes/No)
Plumbing Leak (Yes/No)
Number of Exterior Elements with Deterioration

.

Living Space of Dwelling at Pre-intervention (sq. ft)
Entry Height in Stories
Market Value

Household Characteristics
Pre-intervention Variables:
Was Home Renovated (Yes/No)
Years of Education of Female Parent
Presence of Cleaning Equipment (Percent)
Frequency of Cleaning the House
Frequency of Washing Exterior Window Sills
Cleanliness of the Home
(1=Appears clean, 2=Some evidence of cleaning, 3=No evidence of cleaning)
Household Income ($)
Number of Children Less than 6 Years
Number of People between 6-18 Years
Number of People in Home

Child Characteristics (Pre-Intervention unless noted)
Child's Blood Lead Level (Pre-Intervention)
*Child's Blood Lead Level (Post-Intervention)
*Indicator of Pre-Intervention Blood Samples Collected after Start of Intervention
(Yes = after start of intervention, No = Up to 16 wks prior to start of intervention)
Child's Age, Age Square, Age Cubic
Race of Child
Sex of Child
Frequency of Putting Fingers into Mouth
Frequency of Putting Toys into Mouth
Number of Hours Awake per Week
Number of Hours Away from Home per Week
Number of Hours Inside the House per Week
Number of Hours Outside the House per Week
Parent Report Previous Child Lead Poisoning (Yes/No)
Child Received WIC Benefit (Yes/No)
*Fully Relocated during Intervention (Yes/No)
Interaction between Entry Dust Lead and Mouthing Behavior
Interaction between Interior Floor Dust Lead and Mouthing Behavior
Interaction between Mouthing Behavior and Age, Age^2, Age^3
*Interaction between Blood Lead and Age, Age^2, Age^3

Other Characteristics
Season of Blood Sample Collection (Pre-Intervention)
*Season of Blood Sample Collection (at Post-Intervention)
Season of Dust Sample Collection (Pre-Intervention)
*Season of Dust Sample Collection (at Post-Intervention)
Building Type (Single unit, 2-4 units, >4 units)
House Age (by decade)
Occupancy Status (Pre-Intervention)
Ownership (1=Rented, 2=Owner occupied, 3=Other)

.

*Intervention

- Interior LHC Work (by Strategy)
- Exterior LHC Work (Yes/No)
- Site LHC Work (Yes/No)
- Interaction between Interior LHC Work and Exterior LHC Work
- Interaction between Interior LHC Work and Site LHC Work
- Interaction between Blood Lead and Interior Strategy
- Interaction between No. of Exterior Elements with Deterioration and Interior Strategy
- Interaction between No. of Interior Elements with Deterioration and Interior Strategy
- Interaction between Floor Dust Lead (Pre-Intervention) and Interior Strategy
- Interaction between Entry Dust Lead (Pre-Intervention) and Interior Strategy
- Interaction between Window Sill Dust Lead (Pre-Intervention) and Interior Strategy
- Interaction between Window Trough Dust Lead (Pre-Intervention) and Interior Strategy
- Interaction of Average Floor Surface Condition (Pre-Intervention) and Interior Strategy
- Interaction between Average Surface Condition of Window Sills and Interior Strategy
- Interaction between Average Surface Condition of Window Troughs and Interior Strategy
- Interaction between Paint Lead on Interior Doors/Trim and Interior Strategy
- Interaction between Paint Lead on Windows and Interior Strategy
- Interaction between Paint Lead on Exterior Components and Exterior Strategy

*Post-Intervention Models only

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10.0 CONCLUSIONS

10.1 OVERALL FINDINGS

The Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program is the largest and most comprehensive study of lead hazard control in housing ever undertaken in the United States. It examined over 3,000 houses located in over a dozen jurisdictions across the country where HUD provided funding to address lead-based paint in privately owned low-income housing where the risks are greatest. The study looked at virtually all of the modern ways of controlling lead-based paint hazards and their relative effectiveness.

The study provides evidence that the program's lead hazard control activities substantially reduced dust lead levels on floors, window sills and troughs and generally, the dust lead remained well below pre-treatment levels for at least three years. On floors, three-year post-intervention geometric mean dust lead loadings were roughly 80% below pre-intervention levels, while on windows (sills and troughs, separately), the three-year levels were at least 89% below pre-intervention. Neither lead-based paint that remained in the dwellings nor exterior lead-contaminated dust or soil appear to have had a significant impact on dust lead levels during the three year period of post-intervention observation.

More importantly, the interventions and the reductions in dust lead loadings were accompanied by substantial declines in children's blood lead levels over the three years after lead hazard control. Based on the blood lead modeling, an average child with a parental report of lead poisoning and a baseline blood lead level of 8.4 ug/dl is expected to experience a 37 percent decline in blood lead three-years after intervention. Furthermore, unlike findings from earlier studies (Farfel 1990; Amitai 1991), average children's blood lead concentrations did not display an increase immediately after intervention. The requirements placed on the grantees by the Grant Program, including local monitoring of occupant and worker safety and verification of achievement of clearance standards, proved effective in protecting children.

Although previous studies had found that children with initial blood lead levels below 20 μg/dL did not have substantial declines post-intervention (Swindell 1994; EPA 1997a), children in the Evaluation with pre-intervention blood lead levels between 10-19 μg/dL exhibited blood lead declines of 34 percent at one-year post-intervention. Children with this range of blood lead leads did not experience significantly different declines in blood lead from children with pre-intervention blood lead levels 20-25 μg/dL and above 25 μg/dL.

It was originally anticipated that dust lead loadings would increase after treatment as lower intensity interventions began to fail. Interestingly, dust lead loadings on window sills and troughs and on a subset of dwelling entry floors did increase from clearance to 6 months post-intervention, but then those levels stabilized and often declined after that point. This pattern was similar to findings in the Baltimore Repair and Maintenance Study (EPA 1997b). In that study, samples collected within two months of intervention displayed significant increases from clearance levels and then dust lead loadings stabilized. The authors of that study hypothesized that the immediate increases in dust lead were associated with move-in. In the Evaluation, the locations where six-month dust lead levels increased (entries and windows, but not interior floors) suggest that external sources are the likely source of this lead.

Both exterior and soil lead hazard control work influenced reductions in post-intervention floor dust lead loadings. In the model describing the data, interior floor dust lead loadings in dwellings not receiving exterior treatments were predicted to be 32 percent higher than the dwellings receiving exterior treatments, while floor dust lead loadings in dwellings not receiving soil work were 45 percent higher than dwellings receiving soil treatments. Site treatments (mainly interim soil controls) were also associated with lower post-intervention exterior entry dust lead loadings. Because exterior entry dust lead levels were found to contribute directly to interior entry floor, floor, and window sill dust lead loadings, these treatments were also likely to reduce dust lead loadings on these surfaces.

The lead hazard control treatments themselves tended to hold up for the three-year observation period. The median dwelling in the Evaluation had only one treatment failure (7.5% of all treatments) two and three years post-intervention. This result actually overstates the number of failures that created lead-based paint hazards, because inspectors were required to report all treatment failures including failures to abatements (e.g., inoperable replacement windows). As expected, paint stabilization on surfaces subject to abrasion, impact or weathering (doors, windows, and exteriors) had some of the highest failure rates among the individual treatments: 23% of these treatments had failed three-years post-intervention. However, as noted above, these failures did not correspond with increases in the average dust lead loadings post-intervention.

10.2 Findings for Specific Intervention Strategies

The strength of the Evaluation is not only its overall findings, but also the availability of a range of lead hazard control strategies to make comparisons about the effectiveness those strategies. This report presents findings on five intensities of interior interventions that the participating grantees conducted as well as assessments of the effects of interventions to the exterior and site of a building. In earlier sections of this report, the effects of the different strategies were reported by measure of effectiveness (clearance, longitudinal dust lead and longitudinal blood lead). This section summarizes those effects by strategy.

Although not one of the original study objectives, the cost-effectiveness of the various interventions was briefly examined, but the evaluators determined that it could not be adequately assessed. The Evaluation collected detailed cost information about the interventions that is presented in Section 6. However, a critical piece of information that was not part of the Evaluation design was the size, frequency and cost of lead hazard control activities undertaken by property owners and/or residents after the HUD funded work was complete. Any assessment of the short-term cost-effectiveness of interventions would be weakened by the absence of the ongoing costs of maintaining interim controls. Tables 10-1 and 10-2 summarizes the costs of each intervention strategy, but these costs should be considered with this limitation in mind.

The primary measures of effectiveness in the Evaluation were interior dust lead loadings and children's blood lead levels. Although there was a substantial overall decline in children's blood lead levels following lead hazard control activities, no differential effect was identified between the intervention strategies on one-year blood lead levels. For this reason, the comparisons between interventions are limited to effects on dust lead loadings.

Interventions that abated windows (Interior Strategy 05 and 06/07) had lower dust lead loadings on window surfaces during the post-clearance phases[1] than interventions where windows were spot painted or just cleaned (Interior Strategy 02) (Table 10-3). For example, when controlling for other factors, one-year post-intervention dust lead loadings on window sills and troughs with median baseline levels (416 and 5,768 $\mu g/ft^2$, respectively) or higher were estimated to be at least 50 percent lower in homes with abated windows than in homes where windows received only spot painting and cleaning and in some cases, well caps. Significant differences were also observed between dust lead levels on window sills when window abatement was compared to window paint stabilization. Results in homes where windows were only partially abated (Strategy 04 – sash replacement or jamb liners) fell between the abatement and non-abatement groups. These findings match common wisdom that more intensive window interventions will more effectively reduce dust lead loadings on window surfaces.

Interestingly, dwellings where windows were abated but other components were not completed abated (Strategy 05) had the highest estimated dust lead loadings on floors post-clearance. Even though window dust lead is a source of floor dust lead, the abatement of windows in these homes did not result in greater declines on floors. Interventions that also abated all other lead-based painted surfaces (Strategies 06/07) had the lowest floor dust lead loadings during the two post-clearance phases when these interventions were assessed. Dwellings treated with cleaning only or limited paint stabilization (Strategies 02 and 03) had the highest dust lead loadings on window surfaces post-clearance. Yet, dust lead loadings on floors in these dwellings were not higher than the floor lead loadings in dwellings treated with any of the intervention strategies.

While window abatement was demonstrated to be the most effective measure to reduce dust lead loadings on windows, this treatment must be performed in conjunction with other treatments that influence predictors of floor dust lead (e.g., floor surface type and condition, door and trim paint lead, and general interior building condition, as well as exterior dust/soil lead). Although pathway analysis suggests that window dust lead influences floor dust lead, only treating "up-stream" hazards would not result in substantial "down-stream" dust lead reductions. Furthermore, window dust lead loadings increased substantially shortly after clearance without influencing the floor dust lead loadings up to three years after treatment. These findings support the current requirement to address all interior, exterior and soil lead hazards in an integrated manner.

Final clearance test results were not necessarily predictive of the longer-term post-clearance performance of the intervention strategies. For example, floor dust lead loadings in dwellings that were fully abated had the highest average levels at clearance, but by six months post-intervention, the loadings had declined below all other strategies. This finding suggests that if there are no sources to create dust lead in the dwelling, routine cleaning by the residents following professional lead hazard control work can reduce dust lead to levels below what was achieved through professional cleaning.

Although differences between intervention strategies were identified, only one of the individual strategies may be considered unsuccessful during the three-year observation period. All lead hazard control interventions except spot painting and cleaning (Strategy 02) reduced average

[1] The outcomes presented on this page were significant ($p<0.05$) in the one-year post-intervention multivariate regression models and followed the same trends across the three-year post-intervention observation period of the Evaluation. Chapter 8 presents the full set of statistical analyses that examined these effects.

dust lead loadings on all surfaces examined and maintained those levels significantly below the pre-intervention loadings throughout the Evaluation. Consideration of a second measure of success, whether post-intervention dust lead levels remained below current risk assessment standards (40 $\mu g/ft^2$ on floors and 250 $\mu g/ft^2$ on window sills), is complicated by the fact that grantees did not attempt to achieve these recent (EPA 2001a) standards during the Evaluation. However, for each of the intervention strategies, the geometric mean dust lead loadings remained below these standards for the three-year period of the Evaluation.

HUD is sponsoring further research of the Evaluation dwellings to assess the effectiveness of the individual strategies six years after intervention. This research will provide additional evidence about the longer-term effectiveness of the treatments. For the three-year time period studied here, the data show that, with the exception of "clean-only" strategies, the hazard control methods employed by the HUD grantees succeeded in protecting children and creating lead-safe housing.

Table 10-1: Characteristics and Costs of Interior Lead Hazard Control Intervention

Intervention	Defining Characteristics	Primary Contributing Grantees	Costs
Interior Strategy 02	Cleaning-only, or Cleaning-only w/sill & trough caps, or Spot painting w/sill & trough caps, or Spot painting w/replacement of a few components	Vermont Milwaukee Alameda Co. Minnesota	Mean: $ 730 Median: $ 430 25^{th} %tile: $ 170 75^{th} %tile: $ 1,070
Interior Strategy 03	Paint stabilization of most components, or Paint stabilization w/sill & trough caps, or Paint stabilization w/minor window repair	New York City Milwaukee Alameda Co. California	Mean: $ 4,730 Median: $ 4,930 25^{th} %tile: $ 3,410 75^{th} %tile: $ 6,040
Interior Strategy 04	Window jamb liners w/sill & trough caps and paint stabilization, or Sash paint removal or replacement w/trough caps and paint stabilization, or Enclosure of walls/ceilings, replacement of trim, but minimal window work	Milwaukee New York City Vermont Minnesota Cleveland	Mean: $ 6,370 Median: $ 6,120 25^{th} %tile: $ 3,980 75^{th} %tile: $ 8,570
Interior Strategy 05	Window replacement or paint stripping, and combinations of the following: Door/trim replacement, paint removal, encapsulation, or paint stabilization; Wall/ceiling enclosure or stabilization; Floor enclosure	Baltimore Vermont Wisconsin Rhode Island Massachusetts Chicago California Cleveland	Mean: $ 7,150 Median: $ 6,800 25^{th} %tile: $ 4,850 75^{th} %tile: $ 9,170
Interior Strategy 06/07	Removal and enclosure of all LBP Removal only of all LBP	New York City New Jersey Boston	**Strat.06/ 07** Mean: $ 9,510/ 4,410 Median: $ 9,570/ 4,110 25^{th} %tile: $ 8,860/ 910 75^{th} %tile: $ 9,880/ 5,890

*Pre-intervention levels were set at their median levels (30 µg/ft^2 (floors), 416 µg/ft^2 (sills) and 5,768 µg/ft^2 (troughs)

Table 10-2: Characteristics and Costs of Lead Hazard Control Work to Exterior and Site

Intervention	Defining Characteristics	Primary Contributing Grantees	Costs
Exterior Work	Treatments (% of all *Treated* Buildings) Paint Stabilization (84%) Component Enclosure (29%) Component Replacement (26%) Paint Removal (25%) Encapsulation (3%)	Baltimore Vermont Milwaukee Rhode Island Alameda Co. Wisconsin Massachusetts California	Mean: $ 3,930 Median: $ 1,870 25^{th} %tile: $ 840 75^{th} %tile: $ 5,970
Site Work	Treatments (% of all *Treated* Buildings) Mulch/Seed/Sod/Plant (90%) Soil Enclosure (22%) Soil Removal (10%) Structure Removal (3%)	Rhode Island Alameda County Cleveland Minnesota Vermont	Mean: $ 2,220 Median: $ 1,080 25^{th} %tile: $ 400 75^{th} %tile: $ 2,450

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