6.0 ANALYSIS OF EXAMPLE OPTIONS FOR THE §403 STANDARDS

CHAPTER 6 SUMMARY

This chapter presents the methodology developed by EPA to characterize reductions in childhood health effect and blood-lead concentration endpoints expected to result after interventions are conducted in response to the proposed §403 rule. This chapter also applies the risk management methodology to estimate the risk reductions for a broad range of example options for the §403 standards. For each example standard, projected health effect and blood-lead concentration endpoints associated with predicted residential lead exposures in the post-§403 environment are compared to baseline estimates computed in Chapter 5. Post-§403 risk is estimated separately using the IEUBK model and an empirical model applied to environmental-lead levels observed in the HUD National Survey. Post-§403 environmental-lead levels are adjusted for the assumed effects of interventions initiated by the proposed §403 rule, under various example options for standards for lead in dust, soil, and paint.

Results presented in this chapter are dependent on a number of assumptions. A sensitivity analysis was performed to characterize this dependence. Alternative assumptions and procedures were considered for characterizing post-intervention blood-lead distributions. However, the largest differences in results, especially those representing the most extreme health effects, tended to appear when making alternative assumptions on post-intervention environmental-lead levels.

Figure 6-1 presents the approach for risk management analysis. Conclusions for risk management are presented in Section 6.5.

This chapter has two primary objectives:

1. Present the methodology used by EPA for evaluating options for the §403 standards.

2. Illustrate the application of this methodology for a broad range of example standards.

The methodology and its application using example §403 standards represent risk management analysis. The role of risk management in the overall risk analysis is outlined in Figure 6.1 and Figure 6.3 in Section 6.2 illustrates the approach for evaluating example options for the §403 standards.

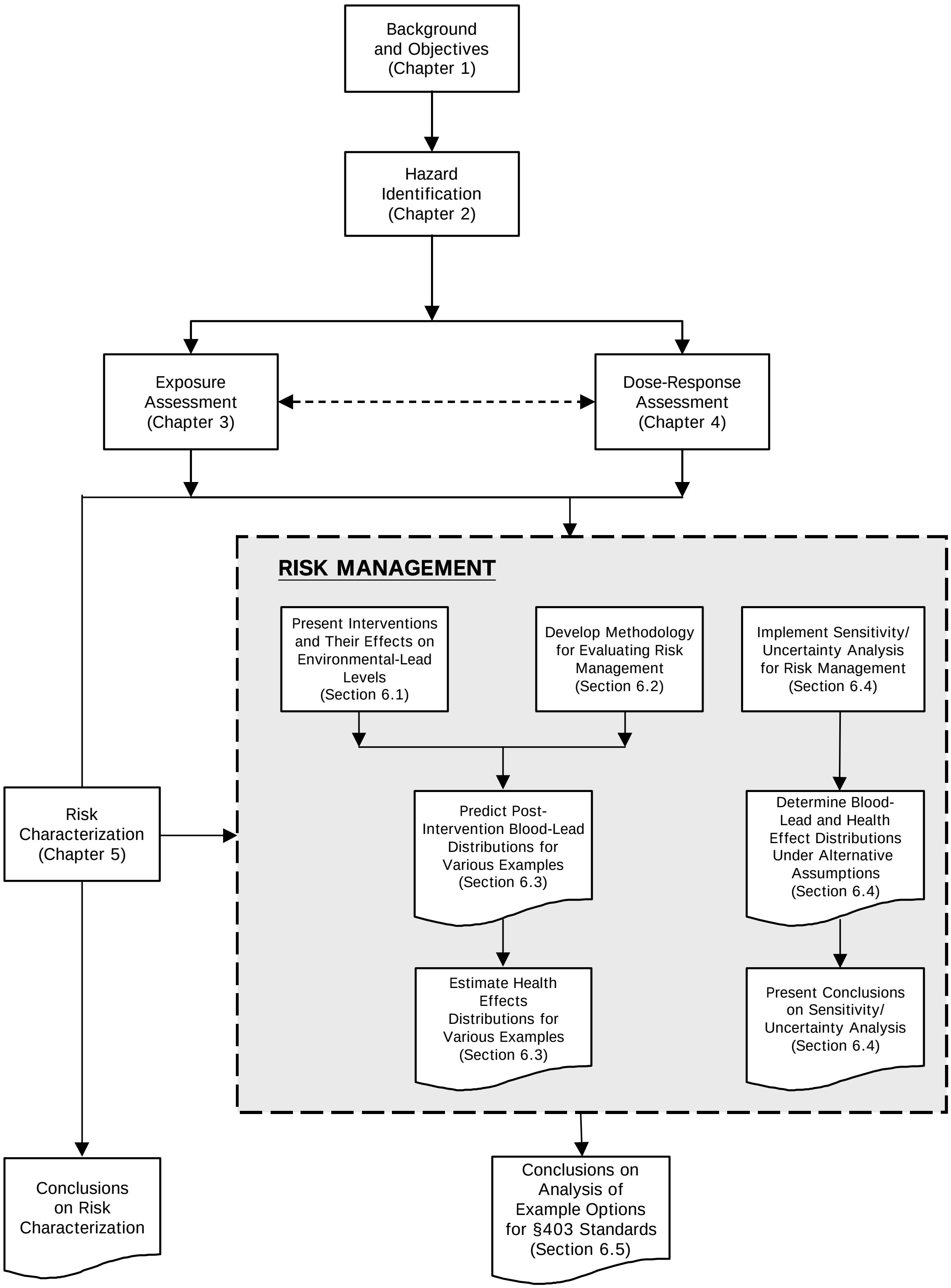


Figure 6-1. Detailed Flowchart of the Approach to Risk Management.

The risk management methodology is used to predict childhood health effect and blood-lead concentration endpoints that are expected to result after activities are conducted in response to the proposed §403 standards. Estimating the selected endpoints after the §403 rulemaking is promulgated (post-§403) required developing an answer to each of the following questions:

1. What will home owners do in response to the proposed rulemaking?

2. How much will environmental-lead levels change due to the activities of home owners?

3. How many homes will be affected by the rulemaking?

4. How much will blood-lead levels change due to changes in the distribution of environmental-lead levels?

5. How much will health effect endpoints change due to changes in the distribution of blood-lead concentrations for children aged 1-2 years.

For the purposes of the risk management analyses, a set of six interventions were defined and utilized for modeling actions homeowners would take in response to the §403 standards. The definition of each of these intervention strategies includes their efficacy in terms of the expected reductions in environmental-lead levels, the expected duration of their effectiveness, and the circumstances (i.e., environmental-lead levels) under which they will be performed (Section 6.1). The defined interventions are an essential component of the methodology developed by EPA to evaluate various options for risk management. The risk management methodology is presented in Section 6.2. This methodology is utilized to estimate the number of homes affected by the rulemaking, and to predict post-§403 blood-lead concentration and health effect endpoints for children aged 1-2 years. Application of the risk management methodology is illustrated for a broad range of example §403 standards in Section 6.3. A sensitivity analysis on the effects of the uncertainty present in the key assumptions, parameters, data sources, and analysis tools is presented in Section 6.4. The sensitivity analysis examines the impact on the predicted blood-lead concentration and health-effects distributions of changes to the key pieces of the risk management methodology. Finally, conclusions derived from the analysis of the various example options for the §403 standards are stated in Section 6.5.

6.1 INTERVENTION ACTIVITIES

Once defined, the proposed §403 rule will prompt intervention activities targeting residential lead hazards. These interventions will be conducted on behalf of children already exposed to the targeted lead hazards, as well as children who would otherwise be exposed if the hazards are not abated or controlled. For the purposes of the risk management analyses, a lead hazard intervention is defined as any non-medical activity that seeks to prevent a child from being exposed to the lead in his or her surrounding environment. An intervention, therefore, may range from the education of parents regarding the dangers of a young child's hand-to-mouth activity, to the abatement of lead-based paint.

An intervention conducted on behalf of children already exposed to the targeted hazard is termed *secondary prevention* (e.g., paint abatement in the home of a child who has an elevated blood-lead concentration). A *primary prevention* intervention prevents exposure before it occurs (e.g., paint abatement in a home before a new family with children moves in). The distinction between primary and secondary prevention efforts is one of the population targeted rather than the activity conducted. In fact, a given intervention can have both primary and secondary prevention benefits.

One objective of §403 is to prompt primary prevention interventions targeting lead hazards in residential soil, dust, and paint. (Secondary prevention will, of course, also take place.) As the risk analysis needs to model the expected benefits following promulgation of §403, measures of the effectiveness of these lead hazard interventions are required. Unfortunately, there is no information currently available in the scientific literature regarding the efficacy (as measured by either avoided health outcomes or by prevented changes in children's blood-lead concentrations) of primary prevention interventions targeting paint, dust, or soil. There are limited data on the effectiveness of secondary prevention interventions (USEPA, 1995b, 1998).

Research suggests that primary prevention interventions will produce greater efficacy than secondary prevention interventions (Gulson et al., 1995). Bone-lead stores accumulated by exposed children continue to mobilize into the blood following an intervention and may mask the intervention's full effectiveness. The reported effectiveness of interventions studied in the literature, therefore, has shortcomings as an estimate of the efficacy stemming from the interventions when performed as primary prevention. Thus, these blood lead declines from a secondary prevention situation are not used to assess the health effect and blood-lead concentration endpoints stemming from the §403 rule. However, a method which uses the changes in blood-lead concentrations from secondary prevention settings with a modeled effect of the bone lead stores is examined in the sensitivity analysis (Section 6.4.4).

Data on changes in environmental-lead levels for interventions targeting paint, dust, and soil were used to estimate environmental-lead levels following interventions conducted as a result of §403. It is important to note, however, that only some of the interventions considered viable in the regulatory and scientific communities have been studied and documented in the literature. Where published data are available, the reported post-intervention environmental-lead levels may then be translated into blood-lead concentrations representing the benefit of primary prevention interventions. The translation is accomplished using both the IEUBK model and the empirical model. Where little or no environmental effectiveness information is available to characterize a particular intervention, EPA has used its current understanding of the intervention to develop an estimated effectiveness.

Fully characterizing an intervention requires addressing four questions:

1. What "triggers" the intervention?
2. What procedures are conducted during the intervention?

3. How effective is the intervention at reducing environmental-lead levels?
4. What is the duration for which the environmental-lead levels will remain reduced?

The interventions and their associated procedures utilized in the risk management analyses are discussed in Section 6.1.1. The effectiveness of these methods in reducing environmental-lead levels and blood-lead concentrations is documented in Section 6.1.2 and 6.1.4, respectively. Section 6.1.3 discusses the circumstances under which each of the defined interventions is triggered. The methods used to predict childhood health effect and blood-lead concentration endpoints after performing the defined interventions in response to the proposed §403 rule are presented in Section 6.2.

The characteristic of greatest importance associated with an intervention is its ultimate effect on children's blood-lead levels. In this analysis, this characteristic is estimated using two blood-lead concentration prediction models, the IEUBK model (Section 4.1), and an empirical model (Section 4.2). The impacts of the interventions, as triggered by different example options for the standards, are illustrated in Section 6.3.

6.1.1 Interventions

For the purposes of evaluating various example options for risk management, a total of six interventions were defined for lead in paint, dust, and soil. The six interventions are dust cleaning, exterior LBP maintenance, exterior LBP encapsulation/abatement, interior LBP maintenance, interior LBP encapsulation/abatement, and soil removal. For interior paint and exterior paint, two intervention approaches were defined. These two approaches are intended to reflect the viable range in scope achieved by paint interventions. For residential soil, there are several options for reducing exposure to elevated soil-lead levels – soil removal, soil till, or sod, mulch, or pavement application. As EPA has data only on the effectiveness of soil removal (no data on soil cover efficacy are available in the scientific literature), this approach is the only soil intervention evaluated in the analysis of example options for risk management. For residential dust, a dust-cleaning method was included to follow interior LBP interventions and soil removal. The dust-cleaning method is also applied in homes where interior dust-lead loadings are high and no residential sources of lead (LBP or soil lead) are identified. Table 6-1 presents these six interventions by defining the procedures conducted and the expected duration of the intervention's benefits.

The procedures defined in Table 6-1 for each of the interventions are consistent with intervention practices currently recommended by EPA (and mandated in some communities) in §402 and by HUD in its "Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing," (HUD, 1995b). For example, paint removal must be conducted using appropriate precautions (e.g., avoid soil or dust contamination), and LBP encapsulation must utilize materials approved as encapsulants (i.e., remain effective for 20 years). The procedures exclude interventions previously utilized but now considered hazardous, such as open-flame burning or abrasive sanding of lead-based paint.

Table 6-1. Interventions Defined for the §403 Risk Analysis Effort.

Intervention		Procedures Defining the Intervention	Expected Duration[1]
Dust Cleaning		Cleaning the unit using HEPA vacuums and wet mopping.	4 years or permanent[2]
Exterior LBP	Maintenance	Painted surfaces with deteriorated LBP are repaired by feathering the edges of deteriorating paint and repainting with new, lead-free paint (less than 0.06% lead by weight). Measures are taken to preclude soil contamination during intervention.	4 years for paint
	Encapsulation/ Abatement	Deteriorated LBP is removed, and the affected surface encapsulated or enclosed, if necessary, using currently acceptable practices and materials. Measures are taken to preclude soil contamination during intervention.	20 years for paint
Interior LBP	Maintenance	Painted surfaces with deteriorated LBP are repaired by feathering the edges of deteriorating paint and repainting with new, lead-free paint. Window sills are covered with permanent barrier. A *Dust Cleaning* of the affected area follows the intervention.	4 years for paint, 4 years for dust
	Encapsulation/ Abatement	Deteriorated LBP is removed, and the affected surface encapsulated or enclosed, if necessary, using currently acceptable practices and materials. A *Dust Cleaning* of the housing unit follows the intervention.	20 years for paint, permanent[2] for dust
Soil Removal		Soil from areas with elevated lead concentrations are removed and replaced with clean soil, or the areas are permanently covered. A *Dust Cleaning* of the housing unit follows the intervention.	Permanent

[1] Duration is defined as the length of time before the lead levels in the targeted medium or conditions of the medium require further intervention.
[2] If the cleaning is accompanied by paint and soil abatements, the duration of reduced dust-lead levels is permanent (20 years if accompanied by paint abatement).

The specified durations of the interventions reflect the length of time before the targeted media returns to levels or conditions requiring further interventions. For example, the duration of a paint intervention represents the estimated period of time before formerly intact or repaired surfaces deteriorate. The expected duration of an intervention is assumed applicable only to residential environments consistent with the circumstances under which that intervention would be triggered (Section 6.1.3). When defining the duration of interior lead-based paint abatements, moreover, the duration of reduced interior residential dust-lead levels is also defined. Since paint interventions target only deteriorated lead-based paint, it would be unrealistic to assume that dust-lead levels remain low permanently. The once intact lead-based paint could, over time, deteriorate and produce elevated lead levels in residential house dust. Some deterioration over time, if not due to normal abrasion (e.g., opening and closing windows), can be avoided if the intact paint is properly maintained. Moreover, one can reasonably expect such maintenance from most homeowners.

Unfortunately, there were only limited data available for estimating the duration of the methods defined in Table 6-1. Though numerous intervention studies are documented in the literature, none traced effectiveness for more than a couple of years (most less than one year). The effectiveness durations, and their underlying motivations, outlined in the draft HUD Regulatory Impact Analysis (RIA) (ICF, 1995, pages 3-21 through 3-22) provided a reasonable starting point. The HUD RIA utilized 4 and 8 years as the duration of reduced dust-lead levels following interim paint controls and paint abatements, respectively. These durations were based on estimates of the annual rate of increased dust-lead loading (µg/ft² per year) stemming from residential recontamination reported in studies of LBP interventions conducted in Baltimore and Cincinnati (page 3-22). A standard of 100 µg/ft² was considered in deriving the recontamination rates (e.g., floor dust lead was estimated to reaccumulate to levels exceeding 100 µg/ft² by four years following repair of the deteriorated lead-based paint). Though a different standard would imply a different duration, a constant duration of four years was assumed following paint maintenance in the risk analysis. The duration for reduced dust-lead loading following paint abatement was assumed to be consistent with the duration assumed for the intervention itself. Lead levels would only re-elevate when their source reappeared. The HUD RIA assumed a paint duration of 20 years following lead-based paint abatement. This degree of efficacy is consistent with HUD's definition of a LBP abatement practice: requiring the abatement to be effective for at least 20 years in order to be called an abatement. Since "paint repair should provide approximately five years of protection against significant amounts of deteriorated LBP" (page 3-22), the HUD RIA assumed a paint duration of 5 years following lead-based paint maintenance. A more conservative effectiveness duration of 4 years (Table 6-1) is assumed in the risk management analyses for both the paint itself and the surrounding dust. Finally, the assumption that soil removal intervention has a permanent effectiveness (Table 6-1) was made since the soil exhibiting elevated lead concentrations has been either removed or permanently covered.

6.1.2 Reductions in Environmental Lead Levels Following Interventions

The effectiveness of the interventions outlined in Table 6-1 is defined in terms of how environmental-lead levels are reduced following conduct of the intervention. Table 6-2 presents the assumed post-intervention environmental-lead levels for each of the interventions described in Table 6-1. For each intervention, the post-intervention lead levels are defined for those media expected to be affected by the intervention. For example, interior paint abatement can be expected to prompt reductions in interior dust-lead loadings as well as in interior paint-lead loadings. Where relevant, additional details are provided regarding the effectiveness of the interventions.

The interventions outlined in Tables 6-1 and 6-2 are intended to include state-of-the-art practices. As a result, defining the effectiveness of these interventions as measured by reduced environmental-lead levels is difficult. Though numerous intervention studies are documented in the literature, many utilized methods that today would be considered inappropriate. The available information on intervention effectiveness often is of little relevance. Where possible, however, the available data were utilized.

Table 6-2. Expected Post-Intervention Lead Levels Associated With Performing §403 Interventions.

Intervention		Post-Intervention Lead Level	Comments on Performing the Intervention
Dust Cleaning[1]		Floors: • Wipe dust-lead loading equals minimum of 40 $\mu g/ft^2$ and pre-intervention level • Dust-lead concentration is determined by the approach outlined in Figure 6-2 Window Sills: • Wipe dust-lead loading equals minimum of 100 $\mu g/ft^2$ and pre-intervention level	It is assumed that this intervention would occur as the sole intervention only if dust-lead levels were above the standard, and if no sources of lead exposure remain in the housing unit.
Exterior LBP	Maintenance	• 0 square feet of deteriorated exterior LBP	Deteriorated LBP is eliminated as a potential exposure source for the duration specified in Table 6-1.
	Encapsulation/ Abatement	• 0 square feet of deteriorated exterior LBP	Deteriorated LBP is eliminated as a potential exposure source for the duration specified in Table 6-1.
Interior LBP	Maintenance	• 0 square feet of deteriorated interior LBP • Floor and window sill dust-lead loading unchanged from pre-intervention levels • Floor dust-lead concentration is determined by the approach outlined in Figure 6-2	Deteriorated LBP is eliminated as a potential exposure source for the duration specified in Table 6-1.
	Encapsulation/ Abatement	• 0 square feet of deteriorated interior LBP Floors: • Wipe dust-lead loading equals minimum of 40 $\mu g/ft^2$ and pre-intervention level • Dust-lead concentration is determined by the approach outlined in Figure 6-2 Window Sills: • Wipe dust-lead loading equals minimum of 100 $\mu g/ft^2$ and pre-intervention level	Deteriorated LBP is eliminated as a potential exposure source for the duration specified in Table 6-1.
Soil Removal		• Soil-lead concentration equals 150 ppm in areas where soil removal is conducted Floors: • Wipe dust-lead loading equals minimum of 40 $\mu g/ft^2$ and pre-intervention level • Dust-lead concentration is determined by the approach outlined in Figure 6-2 Window Sills: • Wipe dust-lead loading equals minimum of 100 $\mu g/ft^2$ and pre-intervention level	Residential dust is not recontaminated by the intervention

[1] Triggered by window sill as well as floor dust-lead loadings exceeding their respective standards.

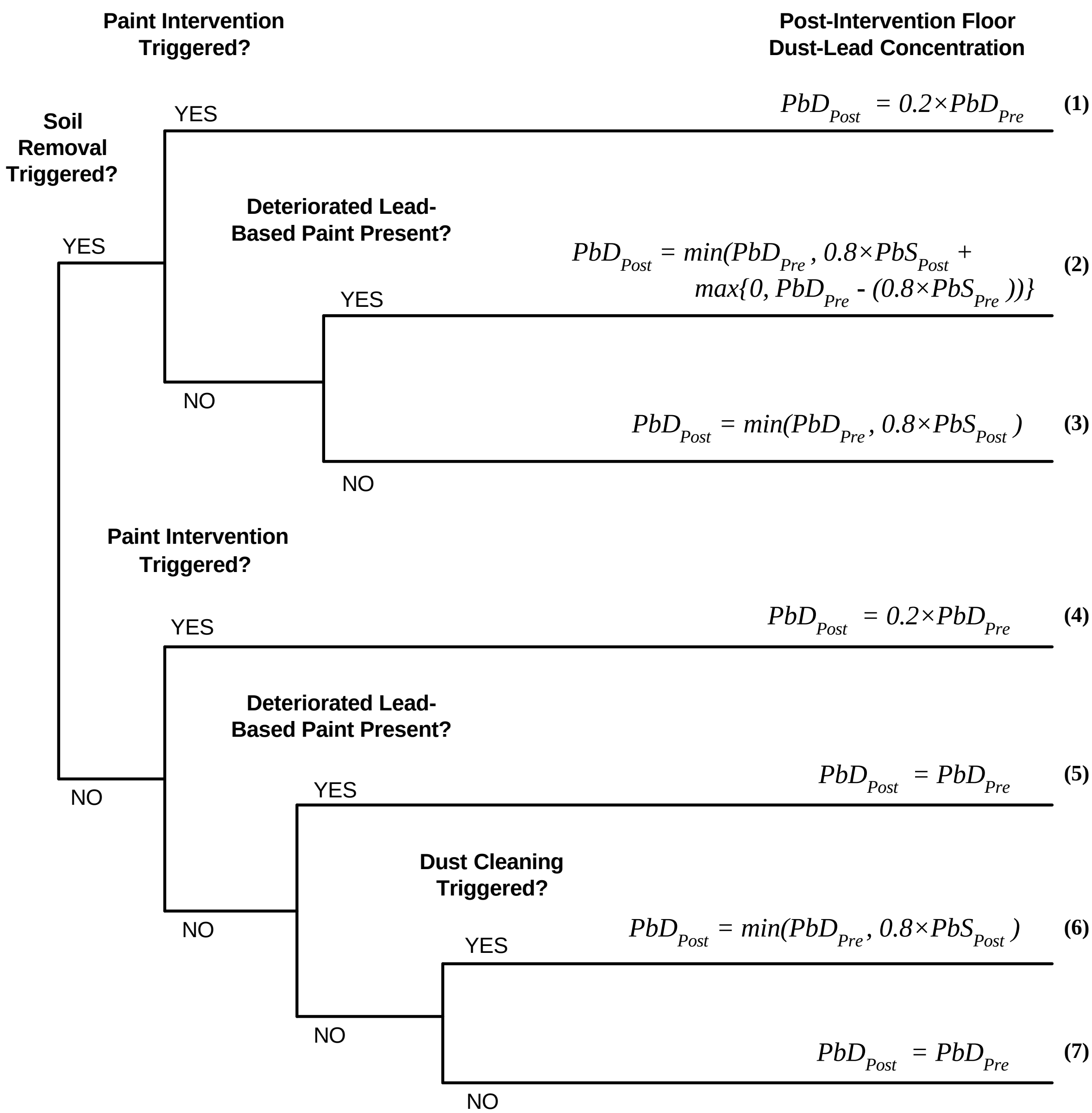
Encapsulation/abatement of interior paint is assumed to reduce residential floor and window sill dust-lead loadings to 40 and 100 $\mu g/ft^2$, respectively, while effectively eliminating (for the duration outlined in Table 6-1) the hazard from deteriorated lead-based paint. The same degree of effectiveness with regard to residential dust was assumed for soil removal and dust cleaning. Dust-lead loadings were not reduced following maintenance of interior paint because the dust cleaning accompanying interior paint maintenance was assumed to be conducted in the affected area only. These values were selected after considering the efficacy reported for housing units in the Denver Comprehensive Abatement Performance (CAP) Study and in the Baltimore Experimental Paint Abatement Study. The geometric mean floor vacuum dust-lead loading measured in abated units studied by the Denver CAP Study was 29.0 $\mu g/ft^2$ approximately two years following extensive paint abatements; the geometric mean window sill vacuum dust-lead loading was 91.6 $\mu g/ft^2$ among the same units (page 34 of USEPA, 1995e). Similarly, the Baltimore Experimental Paint Abatement Study reported a geometric mean floor wipe dust-lead loading of 40.9 $\mu g/ft^2$ among 13 housing units 18-42 months following complete paint abatements; a geometric mean of 103 $\mu g/ft^2$ was reported for the unit's window sill wipe dust-lead loadings at the same time (page 62 of USEPA, 1995c).

The flowchart presented in Figure 6-2 illustrates the approach for determining post-intervention floor dust-lead concentrations. For instance, the upper most branch in the top half of Figure 6-2 (Branch 1) presents the method for determining post-intervention dust-lead concentration if a soil intervention and either paint abatement or maintenance are conducted: post-intervention dust-lead concentration on floors is set equal to 20 percent of the pre-intervention dust-lead concentration. The upper-most branch in the lower half of Figure 6-2 (Branch 4) presents the method for determining post-intervention dust-lead concentration if a soil intervention is not conducted and either paint abatement or maintenance is conducted: post-intervention dust-lead concentration on floors is set equal to 20 percent of the pre-intervention dust-lead concentration. The assumption of an 80 percent reduction in dust-lead concentration following conduct of a paint intervention was developed by examining the results of paint interventions conducted in the Study Group homes in the Boston phase of the Urban Soil Lead Abatement Performance Study (USLADP), and in the R&M Level III homes in the Baltimore R&M Study.

The remaining branches portrayed in Figure 6-2 are applicable to determining post-intervention dust-lead concentration if no paint abatement or maintenance is conducted. Branches 2 and 3 are employed if a soil intervention is conducted. Branches 5, 6 and 7 are applied if no soil intervention is conducted. Branches 2 through 6 are based on the assumption that approximately 80 percent of interior floor dust mass comes from the surrounding soil, and the additional assumption that the lead in soil is uniformly distributed across particle sizes that migrate and become interior dust. The assumption that 80 percent of the mass of interior floor dust stems from soil was examined using the data from the Baltimore phase of the USLADP. The assumption that the lead in soil is uniformly distributed across particle sizes that can migrate and become interior dust was made by necessity. EPA is not aware of any available data to evaluate this assumption.

Reducing amounts of deteriorated LBP to zero square feet following the four paint interventions is consistent with the procedures defined for the interventions and their assumed durations. These interventions are defined as utilizing practices that ensure the surfaces with deteriorated paint remain intact following the intervention for the specified duration. Recall that the durations were defined to recognize the potential for paint, intact at the time of the intervention, becoming deteriorated over time. Thus, the potential hazard posed by deteriorated paint is assumed to be completely eliminated by each of the interventions (both interior and exterior) for the durations specified in Table 6-1.

The post-intervention soil-lead concentration assumed following soil removal is primarily dependent upon the concentration of lead in the backfill soil used to replace the contaminated soil being removed. Usually soil with a lead concentration at background or minimal level is utilized for backfill. Given that the recontamination of the new soil by remaining lead-contaminated soil at the residence may occur, EPA chose to assume a post-intervention soil-lead concentration of 150 ppm.



PbD: Floor Dust-Lead Concentration (µg of Pb per g of dust)
PbS: Soil-Lead Concentration (µg of Pb per g of soil)

Figure 6-2. Calculation of Post-Intervention Floor Dust-Lead Concentration.

6.1.3 Intervention Triggers

An intervention is triggered at a housing unit if environmental-lead levels at the unit exceed the §403 standards. Results of the risk management analyses do not depend upon when the intervention occurs, only on its effectiveness once the intervention is conducted. It is assumed that the specific interventions conducted target the environmental media exhibiting the elevated levels. If either dust, soil, or paint exhibit levels in excess of those specified by the §403 standards, appropriate interventions that target the problematic media are assumed.

Table 6-3 summarizes the circumstances under which each of the defined interventions in Table 6-1 is conducted. At a given residence, the circumstances outlined in Table 6-3 could trigger multiple interventions. The choice of an encapsulation/abatement approach versus a maintenance approach to paint intervention is based on the extent to which deteriorated lead-based paint is present. Although in practice the choice between paint maintenance and encapsulation/abatement is based on a number of factors, including surface area and location of deteriorated LBP (USHUD, 1995b), for the purposes of the risk management analyses only surface area of deteriorated LBP is being considered. As noted earlier, dust cleaning is prompted as a clean-up activity following an interior paint intervention or soil removal, or when elevated dust-lead levels are observed despite the absence of residential sources of lead exposure (e.g., soil or paint). Non-residential lead sources are assumed absent.

Table 6-3. Intervention Triggers Defined for the §403 Risk Management Analyses.

<table>
<tr><th colspan="2">Intervention</th><th>Circumstances Prompting Conduct of the Intervention</th></tr>
<tr><td colspan="2">Dust Cleaning</td><td>Follows any interior paint intervention or soil removal, and when dust-lead loadings are elevated despite absence of residential sources of lead exposure (e.g., no deteriorated LBP or elevated soil lead).</td></tr>
<tr><td rowspan="2">Exterior LBP</td><td>Maintenance</td><td>When deteriorated exterior LBP is present, but not extensive (e.g., confined to a limited area).</td></tr>
<tr><td>Encapsulation/ Abatement</td><td>When deteriorated exterior LBP is present and extensive (e.g., not confined to a limited area).</td></tr>
<tr><td rowspan="2">Interior LBP</td><td>Maintenance</td><td>When deteriorated interior LBP is present, but not extensive (e.g., confined to one area of the housing unit).</td></tr>
<tr><td>Encapsulation/ Abatement</td><td>When deteriorated interior LBP is present and extensive (e.g., greater than one area of the housing unit).</td></tr>
<tr><td colspan="2">Soil Removal</td><td>When residential soil-lead concentrations exceed the soil standard. It is assumed this degree of intervention would only be warranted in specific areas of the yard (e.g., dripline, entryway).</td></tr>
</table>

6.1.4 Reductions in Blood-Lead Levels Following Interventions

For each home in the HUD National Survey, the post-intervention environmental-lead levels presented in Table 6-2 were employed to predict the blood-lead concentrations of resident children. If an intervention was triggered by one or more of the example standards, then the environmental-lead levels in the post-intervention time frame were set equal to those displayed in Table 6-2. The IEUBK and empirical models (discussed in Sections 4.1 and 4.2) were employed to predict a geometric mean blood-lead concentration for children aged 1-2 years exposed to environmental conditions represented by the residence following the intervention activity. In this manner, the risk management analyses estimated the impact of various example options for the §403 standards on environmental-lead levels in the nation's housing and blood-lead concentrations in children aged 1-2 years.

6.2 METHODOLOGY FOR EVALUATING RISK MANAGEMENT OPTIONS

This section describes the methods developed to predict distributions of blood-lead concentrations and values of specific health effect endpoints following promulgation of the proposed §403 rule. This methodology is applied in Section 6.3 to characterize risk reductions associated with various example sets of standards. These example standards are associated with interventions designed to reduce environmental-lead levels, which in turn are expected to reduce lead exposure and consequently reduce blood-lead concentrations. The consequent distribution of environmental-lead levels expected to result from the example standards, together with the IEUBK or empirical models, were used to estimate the post-§403 distribution of blood-lead concentrations. The health effect and blood-lead concentration endpoints were then computed from the post-§403 distribution of blood-lead concentrations.

The methodology presented in this section is illustrated in Figure 6-3. In this figure, boxes with rectangular corners represent datasets or tables of results. Boxes with rounded corners represent steps in the process that transform the inputted data – either through a predictive model (e.g., the IEUBK and empirical models are used to predict blood-lead concentrations from environmental-lead levels) or computation.

The four numbered steps in the process are illustrated by the four boxes with rounded corners in Figure 6-3. These steps form the basis of the methodology and are now presented in more detail.

Step 1: Predict Post-§403 Environmental-Lead Levels. Data from the HUD National Survey were used to predict post-§403 environmental-lead levels. As described in Chapter 3, the HUD National Survey included 284 homes for which data are given on lead levels in dust, soil, and paint. Each of the homes in the survey represented a specified number of U.S. homes having similar environmental-lead levels. These data were used to infer how many U.S. homes would have lead levels above specified examples for the §403 standards for dust, soil, and paint.

In the risk management analyses, example dust standards are defined in terms of wipe dust-lead loadings. However, dust samples in the HUD National Survey were collected with the Blue Nozzle vacuum method. Therefore, to infer which HUD National Survey houses had floor or window sill dust-lead loadings above the wipe standard, the Blue Nozzle lead loadings were converted to "equivalent" wipe dust-lead loadings and compared to the example standards. This conversion process is summarized in Section 4.3 and described in more detail in USEPA, 1998. Other conversions necessary for predicting blood-lead levels from environmental-lead levels are discussed in Step 2.

Table 6-2 in Section 6.1.3 presented the assumed effect of a §403 intervention on environmental-lead levels, and Table 6-3 displayed the circumstances assumed for triggering an intervention. To illustrate how the procedures in the tables were applied in the risk management analyses, the following text discusses their application for a particular example set of standards to house number 0411207 in the HUD National Survey. The standards and intervention trigger levels assumed for this example are:

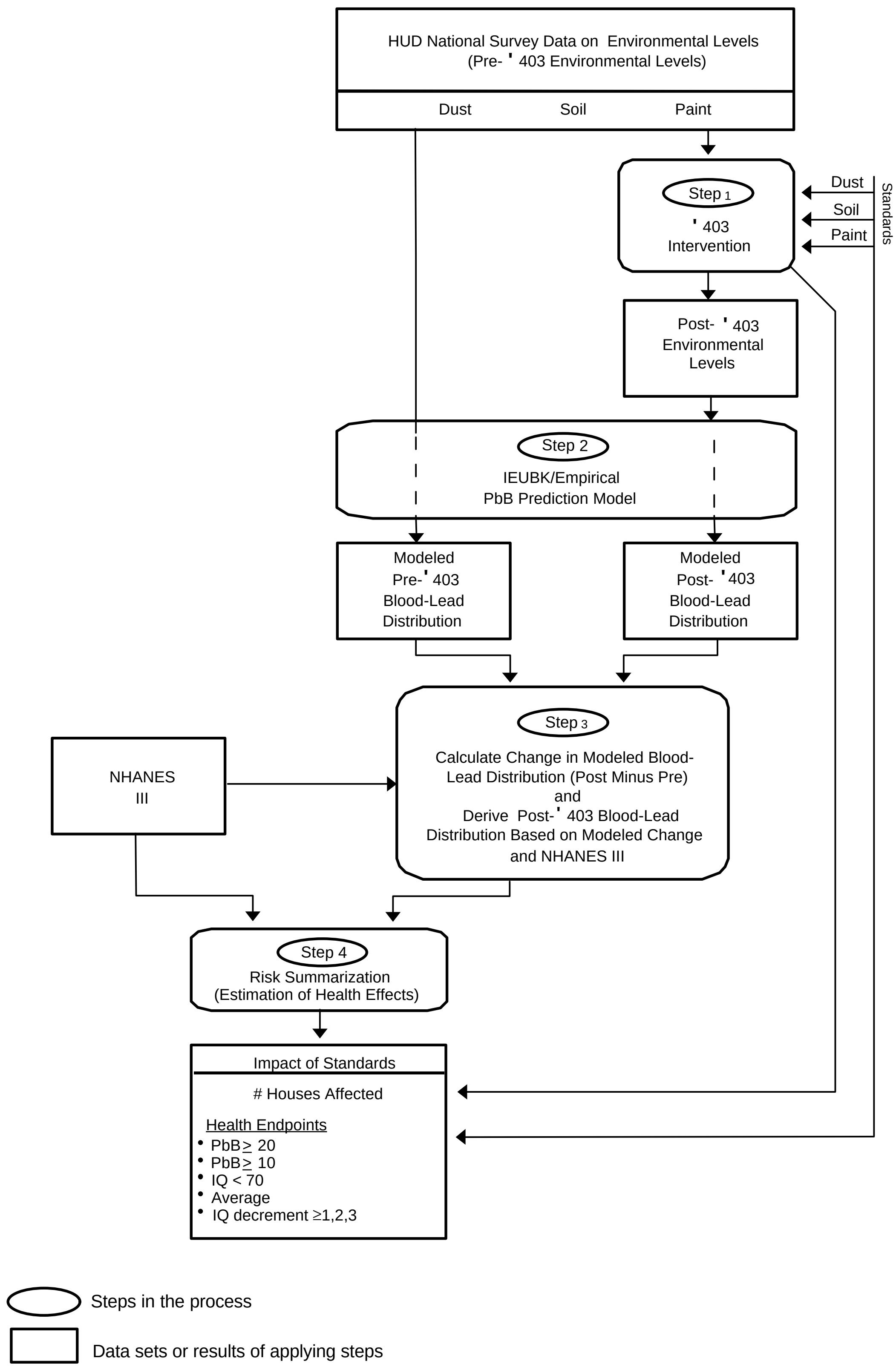


Figure 6-3. Post-§403 Risk Management Process.

floor dust-lead loading: 200 µg/ft²
window sill dust-lead loading: 500 µg/ft²
soil-lead concentration: 3,000 µg/g
paint (maintenance): 10-40 ft² of damaged LBP
paint (abatement): 40 ft² of damaged LBP.

House number 0411207 had the following environmental-lead levels measured in the National Survey, representing baseline (pre-intervention) levels:

floor dust-lead loading (wipe-equivalent): 235.5 µg/ft²
floor dust-lead concentration: 1,812 µg/g
window sill dust-lead loading (wipe-equivalent): 14.6 µg/ft²
soil-lead concentration: 805 µg/g
maximum XRF: 0.4 mg/cm²
damaged LBP: 0 ft².

Because there is no damaged LBP at this house, no paint intervention is triggered regardless of the example intervention trigger level. There is no change, therefore, in the paint-lead loading or in the amount of deteriorated LBP. The pre-intervention soil-lead concentration was 805 µg/g which is below the example soil removal standard of 3,000 µg/g. So this remains unchanged. The floor dust-lead loading of 235.5 µg/ft² exceeds the example standard of 200 µg/ft², triggering a dust cleaning. The floor dust-lead loading is, therefore, reduced to 40 µg/ft². The window sill dust-lead loading was unchanged, as it was below the assumed post-intervention window sill dust-lead loading of 100 µg/ft². As no soil or paint interventions were triggered, only a dust cleaning was triggered. Branch 6 of Figure 6-2 indicates that the post-intervention floor dust-lead concentration is equal to the minimum of the pre-intervention concentration (1,812 µg/g) and 80% of the post-intervention soil-lead concentration (0.8 x 805 = 644 µg/g). Thus, the floor dust-lead concentration is reduced to 644 µg/g. Therefore, the post-§403 environmental-lead levels assumed for house 0411207 based on the example standards listed above are:

floor dust-lead loading: 40 µg/ft²
floor dust-lead concentration: 644 µg/g
window sill dust-lead loading: 14.6 µg/ft²
soil-lead concentration: 805 µg/g
maximum XRF: 0.4 mg/cm²
damaged LBP: 0 ft².

Step 2: Use IEUBK/empirical models to predict blood-lead concentrations. The second step in characterizing post-§403 health risks was to use the residential environmental-lead levels and assumptions on pica tendencies to predict blood-lead concentrations in children. As discussed in Chapter 4, two different models were used to predict blood-lead levels from environmental-lead levels. It was also necessary for reasons described in Step 3 (below), to characterize the pre-§403 distribution of children's blood-lead concentrations using the same two models used to predict post-§403 blood-lead levels.

This section consists, therefore, of three parts: a description of the two models used to predict blood-lead levels from environmental-lead levels, the prediction of pre-§403 blood-lead levels, and the prediction of post-§403 blood-lead levels.

Description of Models:

The first model utilized is EPA's IEUBK model introduced in Section 4.1. This model was used to predict blood-lead levels for children aged 1-2 years. The IEUBK model uses dust-lead concentrations and soil-lead concentrations to predict a geometric mean blood-lead concentration. The IEUBK model predicted blood-lead concentration was then adjusted to account for the contribution of damaged LBP at the house, and a tendency for paint pica. Details of this pica adjustment were presented in Section 4.1.3.

A second model, referred to as the empirical model, was also used to predict blood-lead levels from environmental-lead levels. This model was developed using the data in the Rochester Lead-in-Dust Study. It requires as inputs dust-lead loadings from floors and window sills collected by the Blue Nozzle vacuum method, as well as soil-lead concentrations. Information on the amount of damaged LBP is directly incorporated in the empirical model to estimate the contribution of pica for paint or childhood blood-lead concentration. Details of the model are provided in Section 4.2 and Appendix G. Thus, the two models used to predict blood-lead concentrations depend on different sets of inputs and emphasize the inputs differently. It is therefore expected that there are differences in the geometric mean blood-lead concentrations predicted by the two models.

For each home in the HUD National Survey, both the IEUBK and the empirical model were used to predict a geometric mean blood-lead concentration for children aged 1-2 years who would be exposed to the given environmental conditions. However, not all of these children will have the same blood-lead levels. Appendix E2 describes the approach taken to characterize the variability in blood-lead levels about the estimated geometric mean associated with each house and how this information was used to determine a distribution of children's blood-lead concentrations.

Predicting Pre-§403 Blood-lead Levels:

The environmental-lead levels collected in each home in the HUD National Survey were used as input to the blood-lead concentration prediction models to obtain a baseline distribution of blood-lead concentrations more directly comparable to the distribution predicted from the post-§403 distribution of environmental-lead levels. As described above, the IEUBK model requires as input floor dust-lead concentrations and soil-lead concentrations. Blue Nozzle dust-lead concentrations were used as input to the model. The empirical model requires floor and window sill dust-lead loadings measured by the Blue Nozzle vacuum method, and soil-lead concentrations. Both models require an indication of the presence of damaged LBP. Because these model-required inputs were all measured in the HUD National Survey, no conversions were necessary to estimate the pre-§403 blood-lead concentrations.

Predicting Post-§403 Blood-lead Levels:

The predicted post-§403 environmental-lead levels determined in Step 1 were used as input to the blood-lead concentration prediction models to estimate the post-§403 distribution of blood-lead levels. However, in the case of an intervention requiring dust cleaning, the projected post-intervention floor dust-lead loading of 40 µg/ft² is based on the wipe method (see Table 6-2). For input to the IEUBK model, the post-intervention dust-lead concentration was determined according to the approach in Figure 6-2. For input into the empirical model, 40 µg/ft² was converted to a Blue Nozzle equivalent dust-lead loading of 5.8 µg/ft² using the method described in Section 4.3. Similarly, the projected post-intervention window sill dust-lead loading of 100 µg/ft² based on the wipe method was converted to a Blue Nozzle equivalent dust-lead loading of 14 µg/ft².

Step 3: Adjust predicted post-§403 blood-lead concentrations using (NHANES III) baseline information. Step 2 described the process used to estimate the pre- and post-§403 distribution of blood-lead concentrations predicted to derive from environmental-lead levels. Step 3 determines the change in blood-lead concentrations resulting from the intervention (post-§403 minus pre-§403), and applies this change to the distribution of blood-lead concentrations inferred from Phase 2 of NHANES III. This step is necessary because the NHANES III data are regarded as the basis for the most reliable baseline characterization of children's blood-lead concentration available. The IEUBK and empirical models applied in Step 2 to environmental-lead levels derived from the HUD Survey, however, are the best tools available for estimating the change in blood-lead concentration associated with an intervention. Thus, there are three inputs to this step of the process:

1. A model-predicted, pre-§403 distribution of blood-lead concentration based on unadjusted HUD National Survey environmental-lead levels
2. A model-predicted, post-§403 distribution of blood-lead concentration based on projected post-§403 environmental-lead levels
3. A baseline distribution of blood-lead concentration based on NHANES III data.

In this step, the difference between pre-§403 modeled blood-lead concentration and post-§403 modeled blood-lead concentration is applied to the baseline distribution of blood-lead concentration inferred from NHANES III. The details of this step are described in Steps (1) through (4) of Appendix F1. The result is an estimate of the post-§403 geometric mean and the geometric standard deviation of blood-lead levels in the nation. These estimates are used to predict health risks to children in the next step.

In reality, of course, a myriad of other factors in addition to residential environmental-lead levels will influence the post-§403 national distribution of blood-lead levels. The baseline distribution of blood-lead concentration was first presented in Section 5.1.1. For reasons stated in Section 5.1.1, the baseline distribution, which is based on data collected from 1991 to 1994 was not projected to 1997. Because of this, both baseline risks due to lead exposure and predicted post-§403 risks due to lead exposure may be overestimated for 1997.

Step 3 was necessary to ensure that the predicted distribution of blood-lead concentrations (as derived from the HUD National Survey environmental-lead levels) would yield appropriate results when high example standards are considered. In particular, if the selected example standards were set sufficiently high as to trigger no interventions, then the predicted distribution should agree with the distribution predicted by NHANES III (which is regarded as the best characterization available). When the model predictions are used directly, no such agreement is evident. Appendix F1 describes the details of the approach that was developed to correct this inconsistency.

Step 4: Predict health effects and blood lead endpoints for children 1-2 years old. The last step in the process is the summarization of health effect and blood-lead concentration endpoints associated with the baseline and the predicted post-§403 distributions of blood-lead concentrations. This step estimates the proportion of children with blood-lead levels at or above specified thresholds, the proportion of children anticipated to experience IQ decrements of specified amounts due to elevated blood lead concentrations, the proportion of children with IQ levels below 70 due to elevated blood-lead concentrations, and the average IQ point decrement in children due to elevated blood-lead concentrations. Each of these endpoints is estimated from the geometric mean and geometric standard deviation of children's blood-lead concentrations, assuming a lognormal distribution. The mathematical approach used to make these inferences is described in Appendix E1.

6.3 RESULTS OF THE EVALUATION OF EXAMPLE RISK MANAGEMENT OPTIONS

This section applies the methods presented in Section 6.2 to evaluate the health effect and blood-lead concentration endpoints associated with various example options for the §403 standards. Several different example sets of standards were selected for illustrative purposes. The example standards examined are not meant to encompass all possible options for the §403 rule, and the Agency fully anticipates considering other sets of candidate standards. To simplify the presentation, the effect of changing the levels in the example standards is examined separately for dust, soil, and paint. To accomplish this, it was necessary to hold the example standards for soil and paint fixed at a specified level while the levels were varied for dust.

To illustrate the approach taken in this section, Table 6-4 presents estimated health effect and blood-lead concentration endpoints and percentages of housing units exceeding the standards under six sets of example options (A–F) for floor and window sill dust-lead loading standards. In this example, the soil removal is triggered if soil-lead concentration exceeds 3,000 µg/g, paint maintenance is prompted at 5 ft² of damaged LBP, and paint abatement at 20 ft² of damaged LBP. For this illustration, the example standards range from 25 to 400 µg/ft² (in reverse order) for floor dust-lead loading, and from 25 to 800 µg/ft² for window sills. Each column (A-F) in Table 6-4 is devoted to a specific pair of example standards for floor and window sill dust-lead loading. For each example set of standards, the rows in the top part of Table 6-4 indicate the percentage of homes that would exceed each of the example floor and window sill dust-lead loading standards, the percentage of homes that would exceed either the floor or window sill dust-lead loading example standards, and the percentage of homes that would exceed any one of the example standards for dust, soil, or paint specified in this table.

Table 6-4. Characterization of Impact of Various Example Options for Dust Standards: Soil and Paint Standards Fixed (3,000 µg/g for Soil Removal, 5 ft² Damaged LBP for Paint Maintenance, 20 ft² Damaged LBP for Paint Abatement).

Example Options for Dust-Lead Loading Standard (µg/ft²)							Baseline
EXAMPLE OPTION CODE	A	B	C	D	E	F	
Floor Dust Standard	400	200	100	100	50	25	
Window Sill Dust Standard	800	500	500	200	100	25	
Percentage of Homes Exceeding Floor Dust Standard	0.00	0.694	4.04	4.04	8.28	13.8	
Percentage of Homes Exceeding Window Sill Dust Standard	10.3	12.5	12.5	24.3	32.5	48.1	
Percentage of Homes Exceeding Any Dust Standard	10.3	13.0	13.9	25.5	34.4	50.6	
Percentage of Homes Exceeding Any Dust, Soil, or Paint Standard	19.5	21.0	21.6	30.9	37.9	52.6	
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on Empirical Model)							
PbB≥20 µg/dL (%)	0.442	0.430	0.427	0.410	0.396	0.395	0.588
PbB≥10 µg/dL (%)	4.93	4.85	4.84	4.72	4.63	4.62	5.75
IQ < 70 (%)	0.111	0.111	0.111	0.110	0.110	0.110	0.115
IQ decrement≥1 (%)	36.9	36.7	36.6	36.3	36.1	36.1	38.5
IQ decrement≥2 (%)	9.65	9.53	9.50	9.33	9.19	9.17	10.8
IQ decrement≥3 (%)	3.09	3.04	3.02	2.94	2.88	2.87	3.70
Avg. IQ decrement	1.02	1.01	1.01	1.01	1.00	1.00	1.06
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on IEUBK Model)							
PbB≥20 µg/dL (%)	0.168	0.153	0.0991	0.101	0.0867	0.0749	0.588
PbB≥10 µg/dL (%)	2.97	2.82	2.28	2.23	2.01	1.74	5.75
IQ < 70 (%)	0.104	0.103	0.101	0.100	0.0994	0.0978	0.115
IQ decrement≥1 (%)	32.4	31.9	30.5	29.4	28.1	25.4	38.5
IQ decrement≥2 (%)	6.61	6.35	5.44	5.27	4.84	4.21	10.8
IQ decrement≥3 (%)	1.71	1.61	1.24	1.22	1.09	0.942	3.70
Avg. IQ decrement	0.920	0.910	0.885	0.868	0.847	0.803	1.06

As column A of Table 6-4 indicates, virtually no houses in the nation would be expected to exceed a floor dust-lead loading standard of 400 µg/ft², 10.3 percent of the nation's homes would be expected to have a window sill dust-lead loading exceeding 800 µg/ft², and 10.3 percent of the nation's homes would be expected to exceed at least one of these two standards. Notice that the percentage of homes exceeding any example dust standard is less than or equal to the sum of these two percentages. Consider example option C, with the example floor dust standard set at 100 µg/ft² and the example window sill dust standard set at 500 µg/ft². The percentage of homes estimated to exceed the example floor standard of 100 µg/ft² is 4.04, and the percentage of homes estimated to exceed the example window sill option is 12.5. The percentage of homes estimated to exceed at least one of these example standards of 500 µg/ft² is 13.9. This means that 12.5 + 4.04 – 13.9 = 2.64 percent of homes are estimated to exceed both example dust standards.

Continuing down the rows of column A of Table 6-4, 19.5 percent of the nation's homes would be expected to exceed any of the example standards and paint intervention trigger levels considered in this column:

floor dust-lead loading:	400 µg/ft²
window sill dust-lead loading:	800 µg/ft²
soil-lead concentration:	3,000 µg/g
paint (maintenance):	Greater than 5 ft² of damaged LBP
paint (abatement):	Greater than 20 ft² of damaged LBP.

As mentioned above, a total of 10.3 percent of the homes were projected to exceed at least one of the example dust-lead loading standards. This means that 19.5 – 10.3 = 9.2 percent of the nation's homes are projected to exceed a soil-lead concentration of 3,000 µg/g or exceed 5 ft² of damaged LBP, but not exceed either of the two dust-lead loading standards.

The middle section of Table 6-4 presents estimates, based on the empirical model, of the projected health effect and blood-lead concentration endpoints after implementation of the various example options for the §403 standards. For example, if the proposed §403 rule consists of the standards in column A, 0.442 percent of the nation's children (aged 1-2 years) would be projected, using the empirical model, to have blood-lead concentration at or above 20 µg/dL, and approximately 4.93 percent of children would be projected to have blood-lead concentration at or above 10 µg/dL following promugation of §403. The percentage of children expected to have an IQ score below 70 due to elevated blood-lead concentration is 0.11 percent. The next three rows provide estimates of the percentage of children expected to have IQ decrements greater than or equal to 1, 2, and 3 IQ points. For the example option in column A, the estimates under the empirical model are 37 percent, 9.7 percent, and 3.1 percent, respectively. The next row gives the estimated average IQ decrement associated with elevated blood-lead concentration. Interventions triggered by the first set of standards would be projected to result in (an arithmetic) average IQ decrement of 1.02.

The bottom section of Table 6-4 presents the same information as the middle section, but with the projected health effects determined using the IEUBK model to predict blood-lead concentrations instead of the empirical model. For convenience in making comparisons, the baseline percentages displayed in Table 5-1 (estimated using blood-lead concentration data from NHANES III) are provided in the last column. Additional discussion of the results in Table 6-4 is provided in the next subsection.

6.3.1 Evaluation of Example Dust Standards

To examine the impact of various example options for the dust-lead loading standards on childhood health effect and blood-lead concentration endpoints, Table 6-4 considers six example combinations of floor and window sill dust-lead loadings standards. The last row of the top section of Table 6-4 indicates that the number of homes that would be affected by any of the selected example options ranges from about 20 percent to 53 percent, with the percentage increasing as the example standards decrease.

Examining the associated health effect and blood-lead concentration endpoints in the middle and bottom sections of Table 6-4 reveals that the greatest reduction in health effects is achieved between example options B and C for the IEUBK model and example options C and D for the empirical model, with smaller reductions in health effects achieved between successive lowering of the example standards. The reductions in health effect and blood-lead concentration endpoints diminish and the number of houses impacted increases as the example options decline. This is most clearly evident for the percentage of children with blood-lead concentration at or above 20 µg/dL or 10 µg/dL, and the percentage of children that will have an IQ decrement greater than 2 or 3. For example, based on the empirical model, 4.9 percent of the nation's children would be anticipated to have blood-lead concentration at or above 10 µg/dL under the example option A (floor 400 µg/ft^2; window sill 800 µg/ft^2) while the IEUBK model predicts 3.0 percent. These percentages can be compared with the baseline estimate of 5.75 percent. Under example option C (floor 100 µg/ft^2; window sill 500 µg/ft^2), the projected number of children with blood-lead levels at or above 10 µg/dL decreases to 4.8 percent (empirical model) and 2.3 percent (IEUBK model). For the lowest example dust standards considered in this analysis (option F: floor 25 µg/ft^2; window sill 25 µg/ft^2), the estimated percentage of children with blood-lead concentration at or above 10 µg/dL is reduced to 4.6 percent (empirical model) and 1.7 percent (IEUBK model). However, significantly more homes would be affected by this pair of example standards.

Figure 6-4 shows graphically the percentages of homes that would exceed the example standards given in Table 6-4. For each of the six example sets of standards, Figure 6-4 plots the percentage of homes that would exceed the floor dust standard, the percentage that would exceed the example window sill dust standard, the percentage that would exceed any example dust standard, and the percentage that would exceed any example standard with soil standards and paint intervention triggers held fixed at the levels indicated in Table 6-4.

According to Figure 6-4, the difference between the percentage of homes exceeding example window sill dust standards and the percentage exceeding example floor dust standards is smallest when the example standards are set at 100 and 500 µg/ft^2 (example option C) and largest for the lowest standards (example options E and F), while the difference between the percentage of homes exceeding example window sill dust standards and the percentage exceeding either example dust standard is small for all six example sets. The latter implies that most homes exceeding the floor dust standard once defined also exceed the window sill dust standard, i.e., very few homes that exceed the example option for a floor dust standard did not exceed the corresponding example option for the window sill standard (at least for the pairs of example standards considered in this analysis).

Figures 6-5a and 6-5b contain a total of seven graphs, one for each of the seven health effect and blood-lead concentration endpoints presented in Table 6-4. Each graph in Figures 6-5a and 6-5b illustrates how values for a particular endpoint (as specified along the graph's vertical axis) are affected by each example option for the dust standards. In addition, each graph illustrates how the percentage of homes exceeding at least one example paint intervention

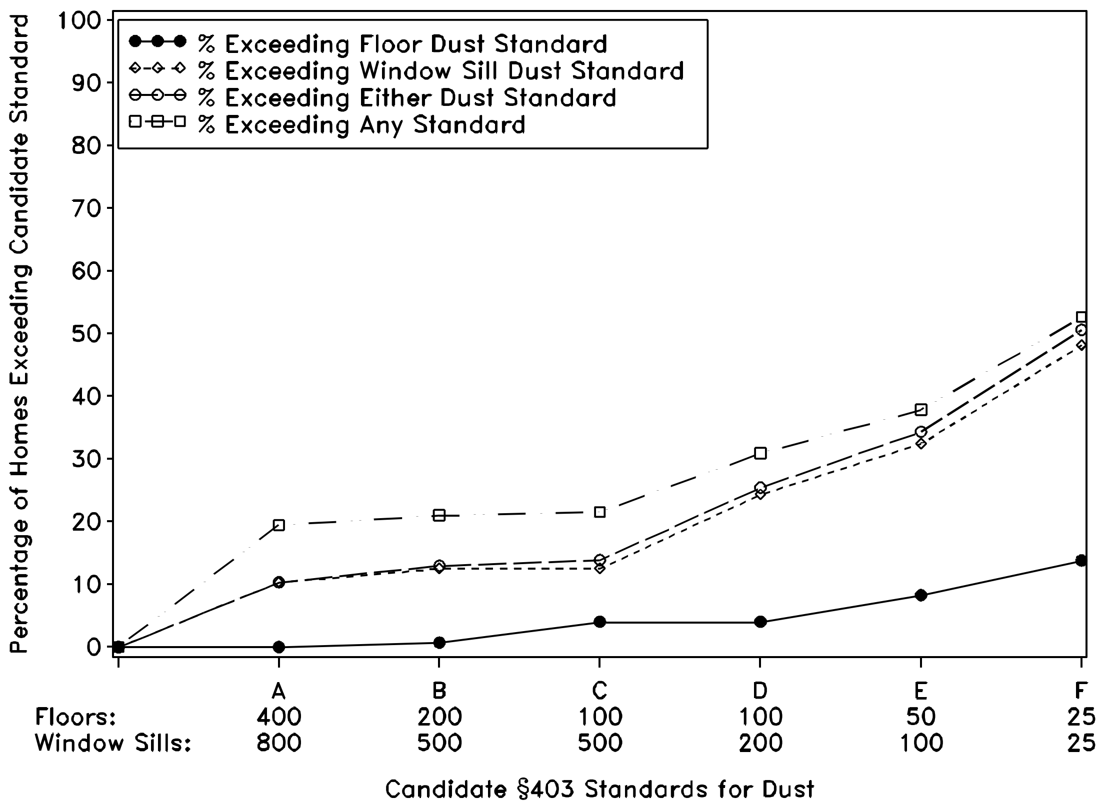


Figure 6-4. Percentage of Homes Exceeding Example Candidate Dust Standards: Soil Standard and Paint Intervention Trigger Held Fixed at Levels Given in Table 6-4.

trigger, or dust or soil standard represented in Table 6-4 (as specified along the graph's horizontal axis) is affected by changes in the example dust standards. Each graph contains two curves: a solid curve illustrating predictions based on the empirical model, and a dashed curve representing predictions based on the IEUBK model. The solid curve is higher than the dashed curve in all graphs, indicating that the empirical model predicts higher values for the endpoints than the IEUBK model. Six letters are plotted on each curve, with each letter corresponding to one of the six example options. The example set of standards associated with a particular letter is specified at the top of Table 6-4 and in the horizontal axis label in Figure 6-4. The dashed horizontal reference lines in Figure 6-4 indicates the baseline risk as determined from NHANES III.

The graphs in Figures 6-5a and 6-5b show the impact of example options for the dust standards on the health effect and blood-lead concentration endpoints, and the number of homes impacted by the example standards. Note the generally consistent shape of each of the curves in these figures. **A sharp decline in the curve indicates a large change in the health effect or blood-lead concentration endpoint, accompanied by a relatively small increase in the number of homes requiring an intervention.** A less steep decline indicates a large increment

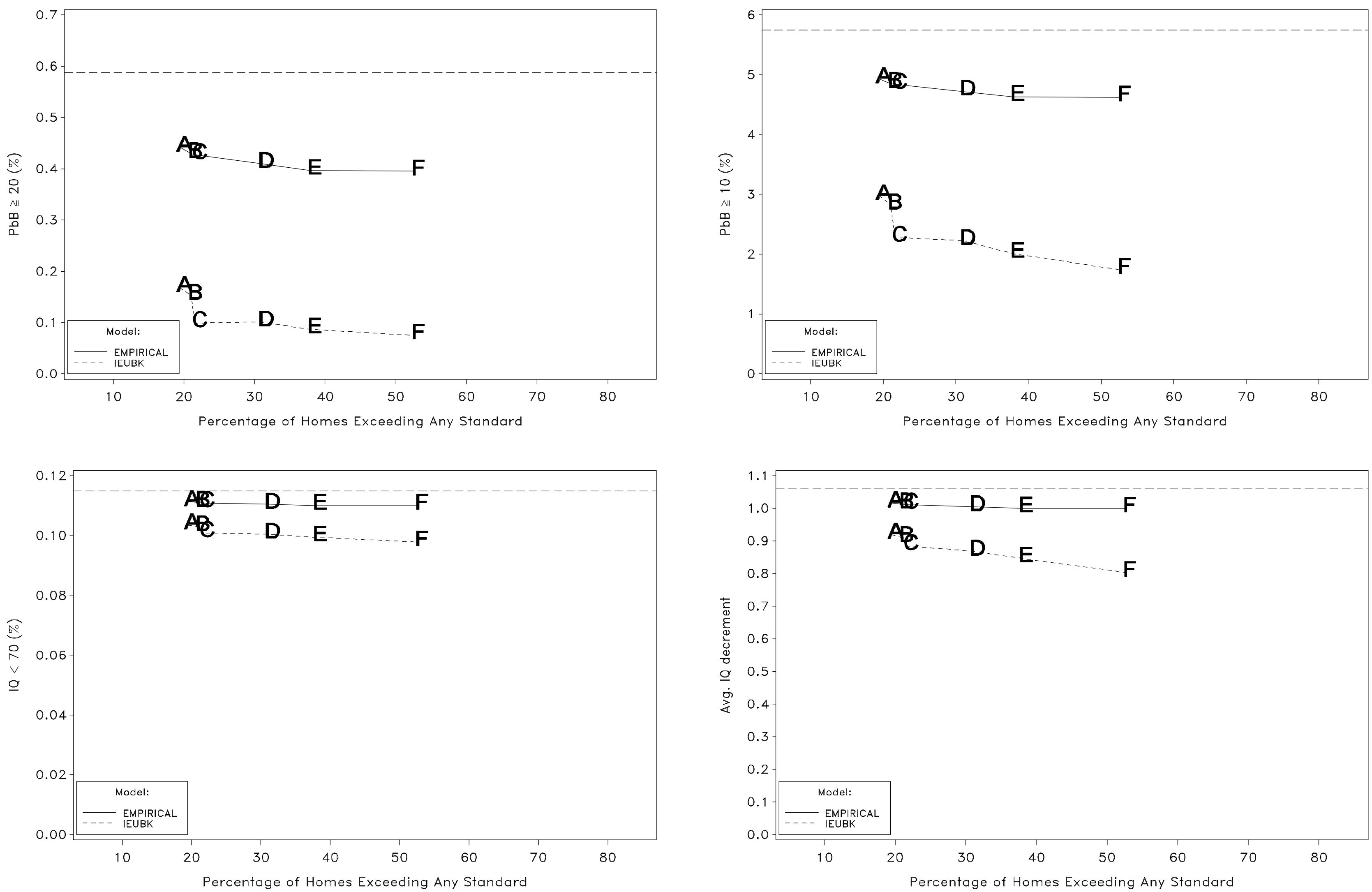


Figure 6-5a. Projected Health Endpoints Based on Various Example Options for Dust Standards, Part 1; Soil Removal 3,000 µg/g, Paint Maintenance 5 ft², Paint Abatement 20 ft². (Dashed reference line represents baseline risk.)

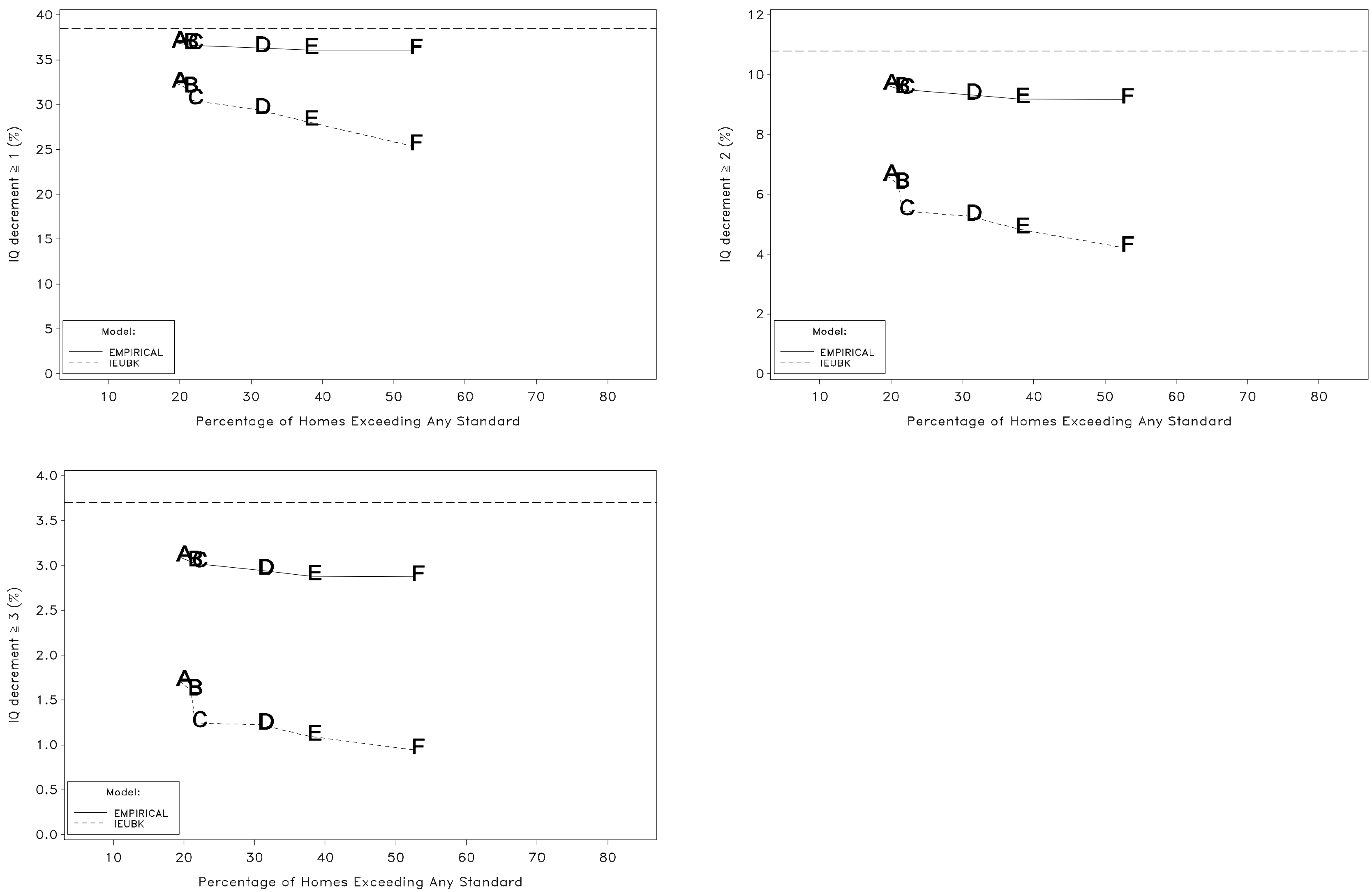


Figure 6-5b. Projected Health Endpoints Based on Various Example Options for Dust Standards, Part 2; Soil Removal 3,000 µg/g, Paint Maintenance 5 ft², Paint Abatement 20 ft². (Dashed reference line represents baseline risk.)

in the number of homes requiring an intervention, accompanied by a small reduction in the endpoint. **<u>In each case, the steepest drop occurs between example options A (floor 400 µg/ft²; window sill 800 µg/ft²) and C (floor 100 µg/ft²; window sill 500 µg/ft²), and then gradually levels off as lower example standards are considered, despite the associated impact on greater and greater numbers of homes.</u>** This pattern is consistent between the empirical and IEUBK models, and across endpoints, with some endpoints reflecting the pattern more drastically than others. However, the estimated reduction in health effect and blood-lead concentration endpoints associated with decreases in example standards is generally smaller under the empirical model compared to the IEUBK model.

In Figures 6-5a and 6-5b, the projected health effect and blood-lead concentration endpoints as a result of implementing §403 with the various example standards can be compared to the baseline (current estimated) values represented by the horizontal reference lines. For example, each example dust standard results in a substantial improvement relative to the baseline for the percentage of children with blood-lead concentration at or above 20 µg/dL or 10 µg/dL, and the percentage of children anticipated to have an IQ decrement greater than 2 or 3 resulting from elevated blood-lead concentration. In contrast, there is little reduction from baseline in the percentage of children predicted to have IQ below 70, in the percentage of children expected to have IQ decrement greater than 1, and in the average IQ decrement, over the range of example standards considered in this analysis.

6.3.2 Evaluation of Example Options for the Soil Standard

Table 6-5 presents results for a range of example options (150 to 5,000 µg/g) for the §403 soil standard. In this table, the example floor dust-lead loading standard is set at 100 µg/ft², the example window sill dust-lead loading standard at 500 µg/ft², paint maintenance at 5 ft² of damaged LBP, and paint abatement at 20 ft² of damaged LBP. For each of these example options (A–H), the top section indicates the percentage of homes that would exceed the example soil standard and the percentage of homes that would exceed at least one of the example standards for dust or soil, or the paint intervention triggers specified in Table 6-5. The remaining rows are analogous to those displayed in Table 6-4. Values of health effect and blood-lead concentration endpoints are presented first for the empirical model, and then for the IEUBK model.

Table 6-5 predicts that the number of houses that would exceed at least one of the given example standards ranges from 22 percent to 32 percent. Over the range of example soil standards, the projected post-§403 percentage of children with blood-lead concentration at or above 20 µg/dL ranges from 0.43 percent to 0.31 percent based on the empirical model, and from 0.12 to less than 0.001 percent based on the IEUBK model. The projected percentages of children having blood-lead concentration at or above 10 µg/dL range from 4.9 to 4.0 percent based on the empirical model, and from 2.5 to 0.2 percent based on the IEUBK model. Thus, while the IEUBK model projects lower incidence of elevated blood-lead concentrations for each example standard, both models project substantial reductions in this incidence over the range of example standards.

Table 6-5. Characterization of Impact of Various Example Options for the Soil Standard: Dust and Paint Standards fixed (100 µg/ft² for Floor Dust-Lead Loading, 500 µg/ft² for Window Sill Dust-Lead Loading, 5 ft² Damaged LBP for Paint Maintenance, 20 ft² Damaged LBP for Paint Abatement).

Example Options for Soil Lead Concentration Standard (µg/g)									Baseline
EXAMPLE OPTION CODE	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	
Soil Standard	**5000**	**3000**	**2000**	**1500**	**1000**	**500**	**300**	**150**	
Percentage of Homes Exceeding Soil Standard	0.215	0.746	2.49	3.27	5.82	11.8	16.9	23.9	
Percentage of Homes Exceeding Any Dust, Soil, or Paint Standard	21.5	21.6	21.8	21.8	22.3	25.3	27.8	31.8	
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on Empirical Model)									
PbB≥20 µg/dL (%)	0.433	0.427	0.406	0.397	0.375	0.340	0.318	0.305	0.588
PbB≥10 µg/dL (%)	4.87	4.84	4.70	4.65	4.51	4.26	4.11	4.01	5.75
IQ < 70 (%)	0.111	0.111	0.110	0.110	0.110	0.109	0.108	0.108	0.115
IQ decrement≥1 (%)	36.7	36.6	36.3	36.2	35.9	35.2	34.8	34.5	38.5
IQ decrement≥2 (%)	9.56	9.50	9.30	9.22	9.00	8.62	8.38	8.22	10.8
IQ decrement≥3 (%)	3.05	3.02	2.93	2.89	2.79	2.61	2.50	2.44	3.70
Avg. IQ decrement	1.01	1.01	1.00	1.00	0.994	0.981	0.972	0.967	1.06
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on IEUBK Model)									
PbB≥20 µg/dL (%)	0.119	0.0991	0.0539	0.0408	0.0207	0.00399	0.00171	0.000862	0.588
PbB≥10 µg/dL (%)	2.49	2.28	1.66	1.44	1.02	0.430	0.275	0.188	5.75
IQ < 70 (%)	0.102	0.101	0.0984	0.0975	0.0957	0.0928	0.0918	0.0911	0.115
IQ decrement≥1 (%)	31.1	30.5	28.3	27.3	25.1	20.2	18.0	16.1	38.5
IQ decrement≥2 (%)	5.80	5.44	4.31	3.88	2.99	1.58	1.12	0.839	10.8
IQ decrement≥3 (%)	1.38	1.24	0.858	0.725	0.479	0.174	0.103	0.0663	3.70
Avg. IQ decrement	0.895	0.885	0.848	0.834	0.802	0.741	0.715	0.692	1.06

The percentage of children projected to have IQ scores below 70 is insensitive to changes in the example soil standards based on the empirical model (staying at about 0.11 percent), and ranges from 0.10 percent to 0.09 percent based on the IEUBK model.

Figure 6-6 shows the percentage of homes that would exceed each of the eight example options for the soil standards. The bottom curve indicates the percentage of homes exceeding the soil standard, and the top curve indicates the percentage exceeding any example standard, with the example dust standard and paint intervention triggers held fixed at the levels indicated in the caption of Table 6-5. Relatively small percentages of homes are predicted to exceed example soil standards of 1,500 µg/g or greater.

The seven graphs in Figures 6-7a and 6-7b illustrate how values for a particular health effect or blood-lead concentration endpoint (as specified along the graph's vertical axis) are affected by the various example options for the soil standard. Each graph also illustrates how the percentage of homes exceeding at least one example paint, dust, or soil standard represented in

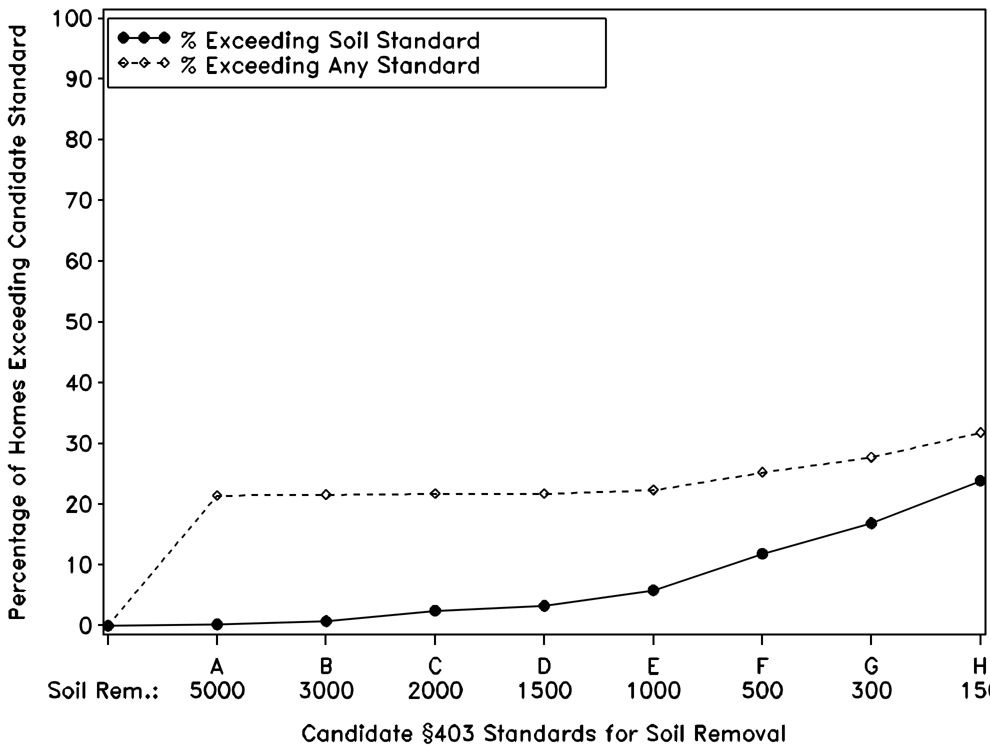


Figure 6-6. Percentage of the Nation's Homes Expected to Exceed Various Example Candidate Soil Standards: Dust Standard and Paint Intervention Triggers Held Fixed at Levels Given in Table 6-5.

Table 6-5 (as specified along the graph's horizontal axis) is affected by changes in the example soil standard. Each graph contains two curves: a solid curve illustrating predictions based on the empirical model, and a dashed curve representing predictions based on the IEUBK model. As seen in Figures 6-5a and 6-5b, the empirical model predicts higher values for the endpoints than the IEUBK model. Each example option is represented in the plots by its letter code (A through H) specified at the top of Table 6-5 and in the horizontal axis label in Figure 6-6.

Results in Figures 6-7a and 6-7b indicate that the IEUBK model predicts significant reduction in percentage of children experiencing IQ decrements greater than or equal to 1, 2, and 3, and blood-lead concentrations across the range of example options A (5,000 µg/g) to F (500 µg/g). The empirical model predicts only small differences. This is due to differences between the soil-lead to blood-lead relationship embodied by the IEUBK model as compared to the empirical model. Specifically, at soil-lead concentrations greater than 1,500 µg/g the IEUBK model generally predicts much higher blood-lead concentrations than the empirical model. Conversely, at the assumed post-intervention soil-lead concentration (150 µg/g) the IEUBK model generally predicts lower blood-lead concentrations. Thus, as the option for soil standard

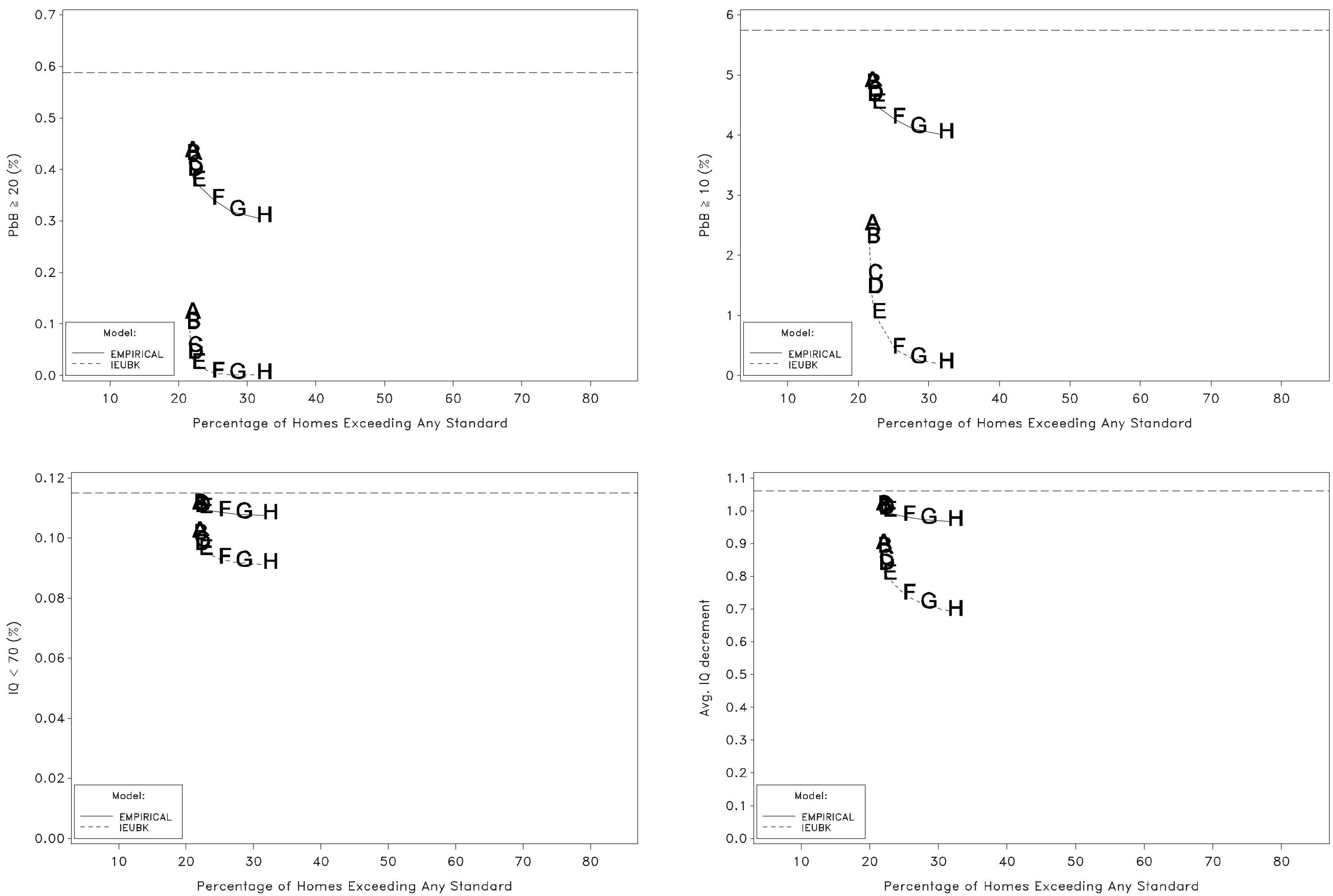


Figure 6-7a. Projected Health Endpoints Based on Various Example Options for the Soil Standard, Part 1; Floor Dust 100 µg/ft², Window Sill Dust 500 µg/ft², Paint Maintenance 5 ft², Paint Abatement 20 ft². (Dashed reference line represents baseline risk.)

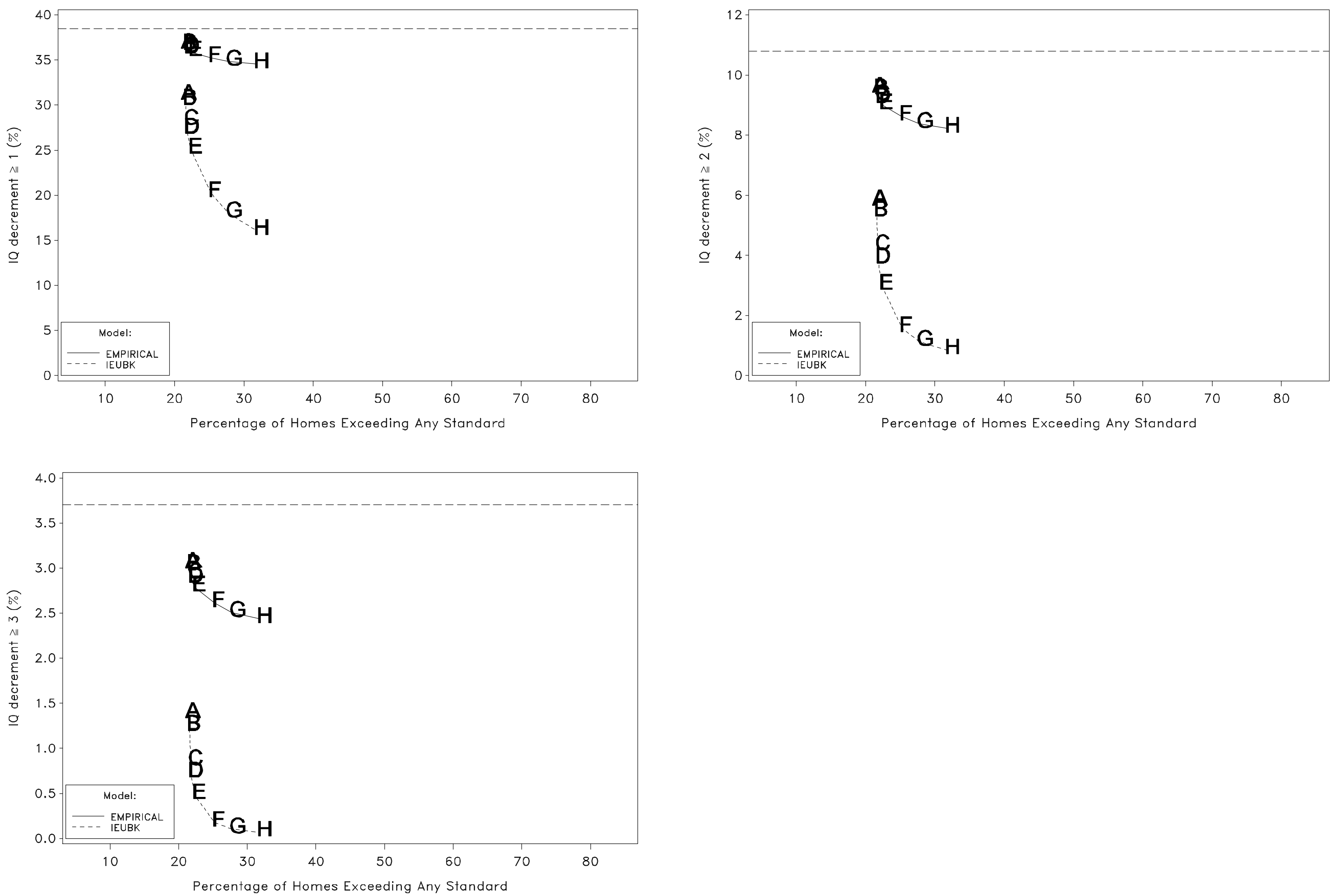


Figure 6-7b. Projected Health Endpoints Based on Various Options for the Soil Standard, Part 2; Floor Dust 100 µg/ft², Window Sill Dust 500 µg/ft², Paint Maintenance 5 ft², Paint Abatement 20 ft². (Dashed reference line represents baseline risk.)

decreases (A–F) and soil-lead concentrations are assumed to be reduced to post-intervention concentrations at more homes, the impact predicted by the IEUBK model is much greater than that predicted by the empirical model. Results presented for percentage of children with IQ less than 70 due to lead exposure and blood-lead concentrations greater than or equal to 20 µg/dL are less sensitive to the model differences discussed above.

Figures 6-7a and 6-7b also indicate that there is very little change in the percentage of homes exceeding any standard between example options A through E. This is indicated by the small horizontal displacement between these letters. Conversely, for example options E through H larger increases in the percentage of homes exceeding any standard are indicated.

In Figures 6-7a and 6-7b, the projected post-§403 health effect and blood-lead concentration endpoints under the various example options can be compared to the baseline (current estimated) endpoints using the horizontal reference lines. Each example option for the soil standard results in a large decrease relative to the baseline for the percentage of children with blood-lead concentration at or above 20 µg/dL or 10 µg/dL, and the percentage of children anticipated to have an IQ decrement greater than 2 or 3 resulting from elevated blood-lead concentration. In contrast, there is little reduction from baseline in the percentage of children predicted to have IQ below 70 or in the percentage of children expected to have IQ decrement greater than 1 over the range of example standards considered.

There is a clear benefit projected for even the largest example soil-lead concentration standard, and there is additional benefit predicted for the lower example standards. There are gains to be made in health effect and blood-lead concentration endpoints for example soil standards as low as 500 µg/g.

6.3.3 Evaluation of Example Options for the Trigger Levels of Paint Intervention

Table 6-6 presents results for a range of paint intervention trigger levels. Example options considered for requiring paint maintenance range from 0 to 10 ft^2 of damaged LBP, and example options for requiring paint abatement range from 5 to 100 ft^2 of damaged LBP. In Table 6-6, the example floor dust-lead loading standard is set at 100 µg/ft^2, the example window sill dust-lead loading standard at 500 µg/ft^2, and the example soil standard at 3,000 µg/g. For each of these options (A–E), the top section of Table 6-6 indicates the percentages of homes that would exceed the trigger levels for interior and exterior paint maintenance, the percentages that would exceed the trigger levels for interior and exterior paint abatement, and the percentage of homes that would exceed at least one of the example standards for dust or soil, or the trigger levels for paint specified in Table 6-6. The remaining rows are analogous to those in Tables 6-4 and 6-5. Estimated values of the health effect and blood-lead concentration endpoints are first presented for the empirical model and then for the IEUBK model.

Table 6-6. Characterization of Impact of Various Options for Paint Intervention Triggers: Example Dust and Soil Standards Fixed (100 µg/ft² for Dust-Lead Loading, 500 µg/ft² for Window Sill Dust-Lead Loading, 3,000 µg/g for Soil Removal).

Example Options for Paint Standard (ft² damaged LBP)						Baseline
EXAMPLE OPTION CODE	**A**	**B**	**C**	**D**	**E**	
Paint Maintenance Trigger (Interior or Exterior)	**10**	**5**	**2**	**1**	**0**	
Paint Abatement Trigger (Interior or Exterior)	**100**	**40**	**20**	**10**	**5**	
Percentage of Homes Exceeding Interior Paint Maintenance Trigger	2.80	4.37	3.03	2.75	1.08	
Percentage of Homes Exceeding Exterior Paint Maintenance Trigger	3.84	4.80	4.20	3.22	1.15	
Percentage of Homes Exceeding Interior Paint Abatement Trigger	0.453	0.980	2.43	3.25	5.35	
Percentage of Homes Exceeding Exterior Paint Abatement Trigger	3.03	4.46	5.77	6.87	9.26	
Percentage of Homes Exceeding Any Dust, Soil, or Paint Trigger	20.2	21.6	22.2	22.5	22.8	
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on Empirical Model)						
PbB≥20 (%)	0.437	0.428	0.426	0.425	0.423	0.340
PbB≥10 (%)	4.90	4.85	4.83	4.82	4.81	4.26
IQ<70 (%)	0.111	0.111	0.111	0.111	0.111	0.109
IQ decrement≥1 (%)	36.8	36.7	36.6	36.6	36.6	35.2
IQ decrement≥2 (%)	9.59	9.52	9.50	9.49	9.46	8.62
IQ decrement≥3 (%)	3.07	3.03	3.02	3.02	3.00	2.61
Avg. IQ decrement	1.01	1.01	1.01	1.01	1.01	0.981
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on IEUBK Model)						
PbB≥20 (%)	0.162	0.0991	0.0973	0.0966	0.0947	0.588
PbB≥10 (%)	2.92	2.28	2.26	2.24	2.22	5.75
IQ<70 (%)	0.103	0.101	0.101	0.101	0.101	0.115
IQ decrement≥1 (%)	32.2	30.5	30.4	30.3	30.2	38.5
IQ decrement≥2 (%)	6.52	5.44	5.40	5.37	5.32	10.8
IQ decrement≥3 (%)	1.67	1.24	1.23	1.22	1.21	3.70
Avg. IQ decrement	0.917	0.885	0.883	0.882	0.880	1.06

Figures 6-8 and 6-9 display the percentage of homes that would exceed the different trigger levels of paint intervention for interior and exterior paint, respectively. In each of these figures, the difference between the percentage of homes exceeding either intervention trigger level and the percent exceeding the paint abatement trigger represents the percentage of homes that have enough damaged LBP to exceed the paint maintenance trigger but not the abatement trigger.

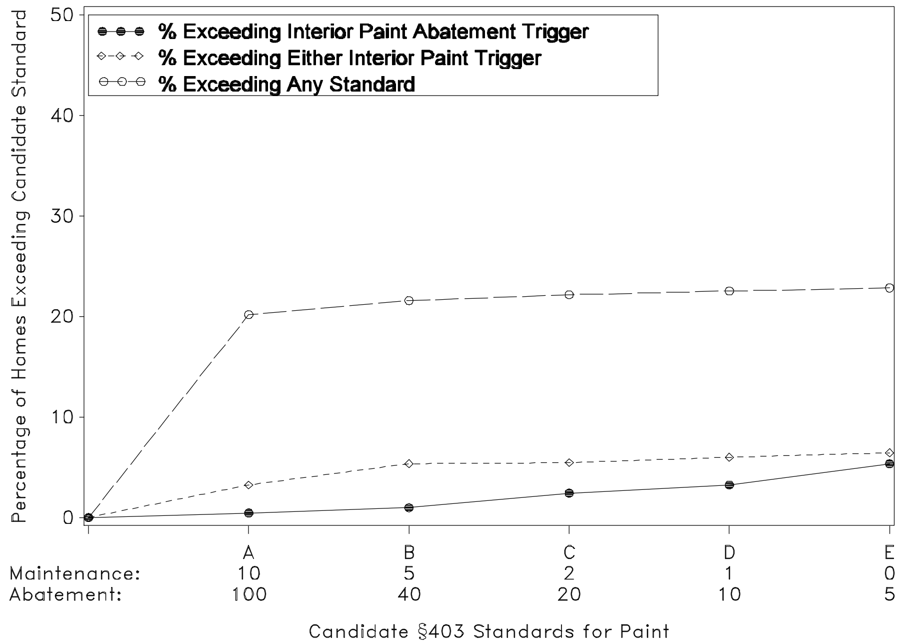


Figure 6-8. Percentage of Homes Exceeding Candidate Interior Paint Intervention Triggers: Dust and Soil Example Standards Held Fixed at Levels Given in Table 6-6.

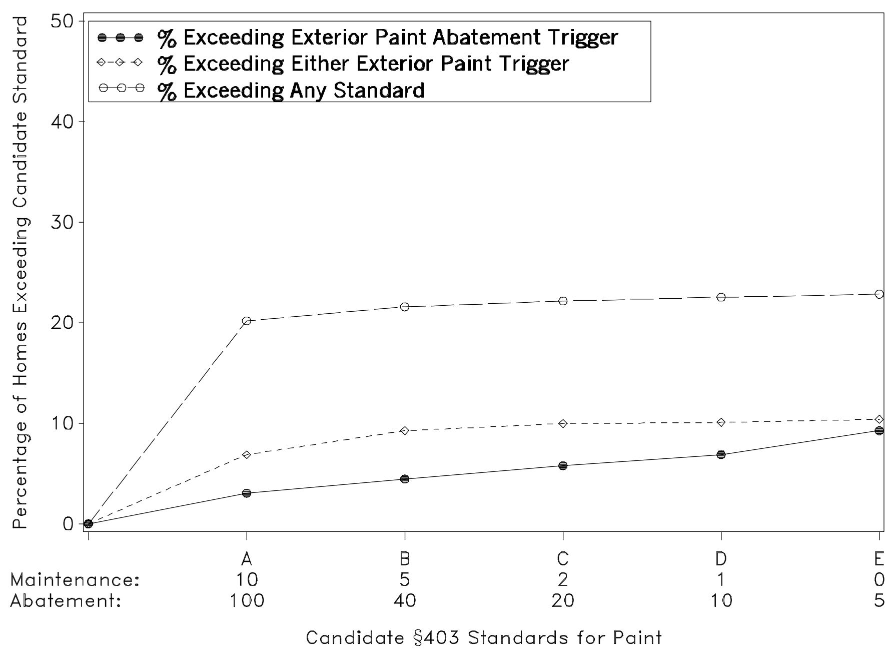


Figure 6-9. Percentage of Homes Exceeding Candidate Exterior Paint Intervention Triggers: Dust and Soil Example Standards Held Fixed at Levels Given in Table 6-6.

These figures show that relatively few homes exceeded even the lowest example option considered for the paint intervention triggers. Therefore, there is very little change in the percentage of homes that would exceed any of the combinations of trigger levels for paint from the lowest to the highest square footages of deteriorated LBP. However, this analysis is based on the limited data available on deteriorated lead-based paint in the HUD National Survey.

The seven graphs in Figures 6-10a and 6-10b illustrate how values for a particular health effect or blood-lead concentration endpoint (as specified along the graph's vertical axis) are affected by the various example options for the pair of paint trigger levels. Each graph also illustrates how the percentage of homes exceeding at least one paint intervention trigger level or dust or soil example standard represented in Table 6-6 (as specified along the graph's horizontal axis) is affected by changes in the paint intervention trigger levels. Each graph contains two curves: a solid curve illustrating predictions based on the empirical model, and a dashed curve representing predictions based on the IEUBK model. As was seen in previous figures, the empirical model predicts higher values for the endpoints than does the IEUBK model. Each example option for the pair of paint intervention trigger levels is represented in the plots by its letter code (A through E) specified at the top of Table 6-6 and in the horizontal axis label in Figures 6-8 and 6-9 (a given set of paint intervention triggers is assumed to hold for both the interior and exterior).

With the exception of example option A, the graphs in Figures 6-10a and 6-10b show very little variation across the various paint intervention trigger levels. The percentage of homes exceeding the example options for §403 standards ranged only from 20 percent at the highest paint intervention trigger considered (option A) to 23 percent at the lowest paint intervention trigger (option E). The values of health effect and blood-lead concentration endpoints, although less than their baseline pre-§403 respective values, are very similar for paint intervention trigger options B through E. For instance, the percentage of children with a blood-lead concentration at or above 20 µg/dL ranges from 0.10 percent at option B to 0.99 percent at option E, based on the IEUBK predicted blood-lead concentrations. Example option A for the paint intervention trigger (maintenance 10 ft^2; abatement 100 ft^2) provided noticeably higher health effect and blood-lead concentration endpoints than the next example option (option B: maintenance 5 ft^2; abatement 40 ft^2). The limited ranges for the predicted health effect and blood-lead concentration endpoints and for the percentages of homes exceeding the intervention triggers, particular among options B through E might be due to the following:

1. It is very difficult to study the effects of an individual environmental medium on childhood blood-lead concentration. As discussed in Section 3.1, deteriorated or damaged LBP is a source of lead contamination for both soil and household dust. Thus, most of the homes that exceed a paint intervention trigger also exceeded either the dust or soil example standards, and therefore, much of the post-§403 benefits expected to result from the paint intervention triggers overlap with risk reductions expected to result from the dust and soil example standards.

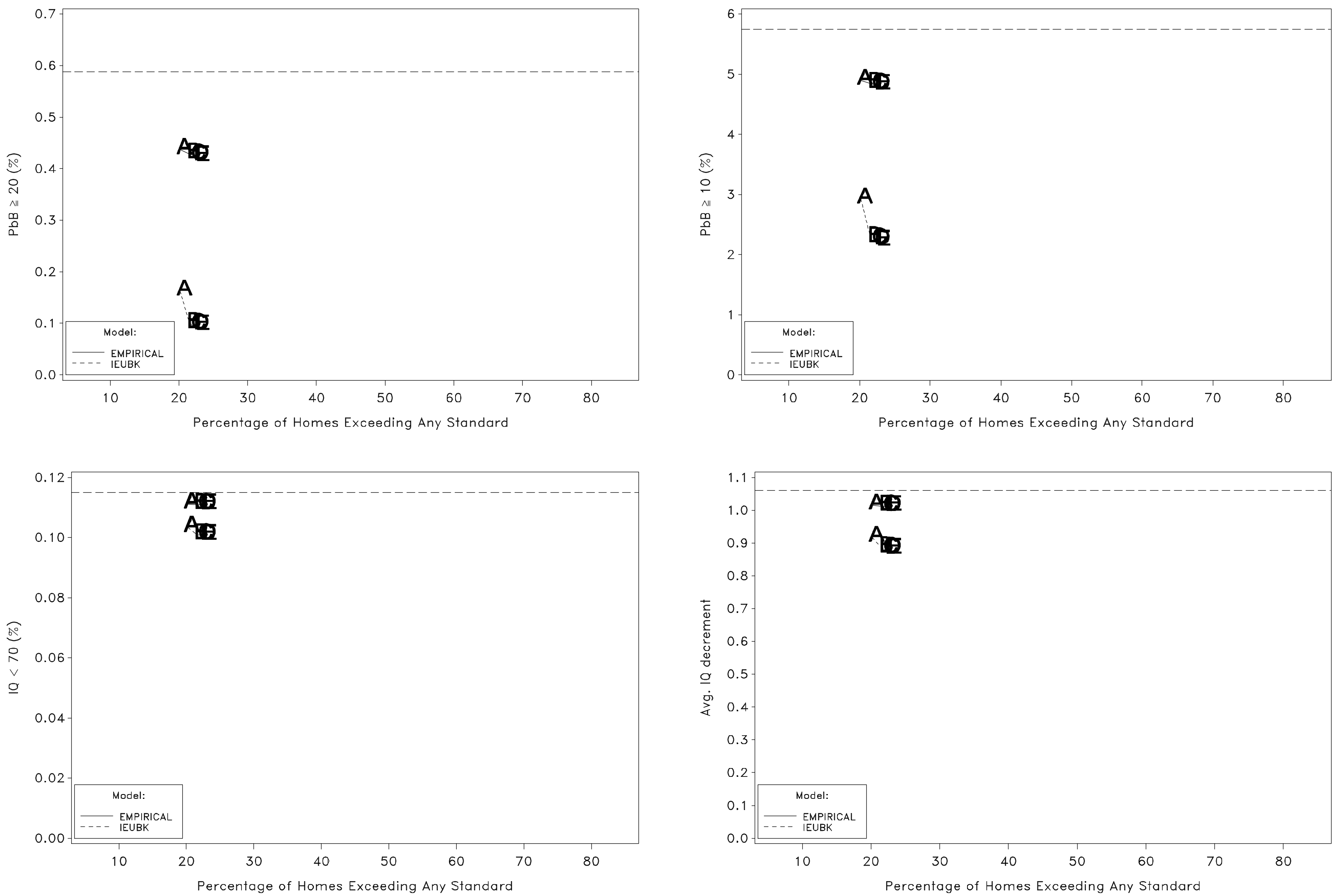


Figure 6-10a. Projected Health Endpoints Based on Various Options for Paint Intervention Triggers Part 1; Floor Dust 100 µg/ft², Window Sill Dust 500 µg/ft², Soil Removal 3,000 µg/g. (Dashed reference line represents baseline risk.)

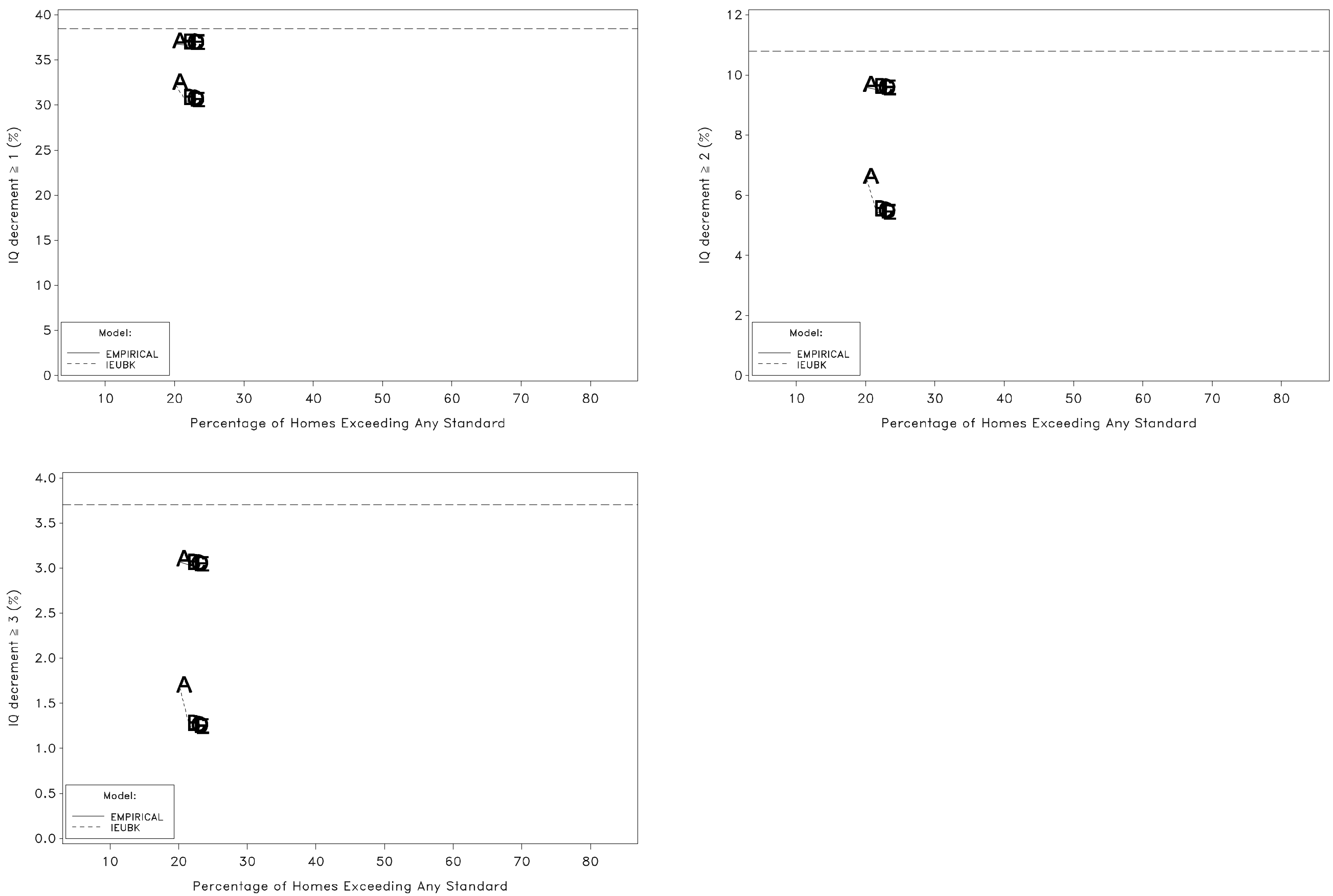


Figure 6-10b. Projected Health Endpoints Based on Various Options for Paint Intervention Triggers, Part 2; Floor Dust 100 µg/ft², Window Sill Dust 500 µg/ft², Soil Removal 3,000 µg/g. (Dashed reference line represents baseline risk.)

2. Not all surfaces were examined for the presence of damaged or deteriorated LBP in the HUD National Survey. In general, only two interior rooms and one exterior surface were examined.

3. The tools available for assessing the impact of damaged lead-based paint are limited. Both the empirical and IEUBK models for predicting blood-lead concentrations based on environmental-lead levels are limited in their usage of paint-lead measurements. IEUBK model-predicted blood-lead concentrations are adjusted for the contribution of paint ingested due to pica using the procedures, developed only for the purposes of this analysis, presented in Section 4.1.3. The empirical model was developed from data collected in the Rochester Lead-in-Dust Study, which does not express the amount of damaged LBP in the same manner as the HUD National Survey. Pica for paint also plays a role in this model, and the estimate of the prevalence of pica for paint used in this risk analysis may be somewhat inaccurate.

6.3.4 Evaluation of the Effects of Varying Example Standard Options for All Media

Analyses summarized in Tables 6-4 through 6-6 permit an assessment of the impact on the nation's housing and health effects of children for various example standard or trigger options for an individual environmental medium. A range of example standards for one environmental medium is considered while the example standards for the other media are held fixed at a specified level. However, those results do not show the effect of varying the example standards simultaneously for dust, soil, and paint. Table 6-7 presents results when the example standards for all media are varied over the ranges previously considered in this chapter. Table 6-7 is structured similarly to Tables 6-4 through 6-6. Each column represents a unique combination of example standards displayed at the very top in the shaded rows. For example, column A in Table 6-7 represents an option in which the candidate example standards are 400 µg/ft² for floor dust-lead loading, 800 µg/ft² for window sill dust-lead loading, 5,000 µg/g for soil-lead concentration, and with 10 ft² of damaged lead-based paint prompting paint maintenance, and 100 ft² prompting paint abatement. Below the example options for standards are presented the estimated percentage of homes that exceed one or more of the example standards. The first row in this section provides the estimated percentage of homes that would exceed the example floor dust standard. Analogous information is provided in the next seven rows for the window sill dust standard, the soil standard, and the interior and exterior paint maintenance triggers, and interior and exterior paint abatement triggers. Finally, the last row of this section provides the estimated percentage of the nation's homes that would exceed one or more of the example standards or intervention triggers.

The third and fourth sections of Table 6-7 provide the estimated post-§403 health effect and blood-lead concentration endpoints, based on the empirical model and the IEUBK model, respectively. The rows in these two sections are analogous to those in Tables 6-4 through 6-6.

Table 6-7. Characterization of Impact of Various Sets of Candidate Example Dust and Soil, and Paint Intervention Triggers.

Example Options for Standards/Triggers							Current Interim Guidance	Baseline
EXAMPLE OPTION CODE	A	B	C	D	E	F	I	
Floor Dust-Lead Loading (µg/ft²)	400	200	100	100	50	25	100	
Window Sill Dust-Lead Loading (µg/ft²)	800	500	500	200	100	25	500	
Soil-Lead Concentration (µg/g)	5000	3000	2000	1500	1000	500	5000	
Paint Maintenance (interior and exterior) (ft² damaged LBP)	10	10	5	2	1	0	2	
Paint Abatement (interior and exterior) (ft² damaged LBP)	100	40	20	10	10	5	10	
Percentage of Homes Exceeding Example Standards/Triggers								
Floor Dust	0.00	0.694	4.04	4.04	8.28	13.8	4.04	
Window Sill Dust	10.3	12.5	12.5	24.3	32.5	48.1	12.5	
Soil	0.215	0.746	2.49	3.27	5.82	11.8	0.215	
Interior Paint Maintenance	2.80	2.27	2.92	2.22	2.75	1.08	2.22	
Exterior Paint Maintenance	3.84	2.41	3.49	3.09	3.22	1.15	3.09	
Interior Paint Abatement	0.453	0.980	2.43	3.25	3.25	5.35	3.25	
Exterior Paint Abatement	3.03	4.46	5.77	6.87	6.87	9.26	6.87	
Percentage of Homes Exceeding Any Standard	17.5	19.5	21.8	31.2	38.4	53.7	22.0	
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on Empirical Model)								
PbB≥20 (%)	0.458	0.439	0.406	0.381	0.350	0.317	0.431	0.588
PbB≥10 (%)	5.03	4.91	4.70	4.53	4.33	4.09	4.86	5.75
IQ < 70 (%)	0.112	0.111	0.110	0.110	0.109	0.108	0.111	0.115
IQ decrement≥1 (%)	37.1	36.8	36.3	35.9	35.4	34.7	36.7	38.5
IQ decrement≥2 (%)	9.79	9.62	9.30	9.04	8.71	8.34	9.54	10.8
IQ decrement≥3 (%)	3.16	3.08	2.93	2.81	2.66	2.49	3.04	3.70
Avg. IQ decrement	1.02	1.02	1.00	0.995	0.984	0.971	1.01	1.06
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on IEUBK Model)								
PbB≥20 (%)	0.290	0.235	0.0539	0.0409	0.0164	0.00198	0.117	0.588
PbB≥10 (%)	3.92	3.51	1.66	1.39	0.841	0.250	2.47	5.75
IQ < 70 (%)	0.107	0.106	0.0984	0.0971	0.0945	0.0909	0.102	0.115
IQ decrement≥1 (%)	34.5	33.5	28.3	26.2	22.5	15.1	31.0	38.5
IQ decrement≥2 (%)	8.09	7.45	4.31	3.71	2.52	0.978	5.76	10.8
IQ decrement≥3 (%)	2.37	2.08	0.858	0.702	0.392	0.0976	1.37	3.70
Avg. IQ decrement	0.964	0.943	0.848	0.816	0.764	0.666	0.894	1.06

A total of seven example options for the standards are assessed in Table 6-7. Environmental-lead levels are highest for example option A (floor: 400 µg/ft²; window sill: 800 µg/ft²; soil: 5,000 µg/g; paint maintenance: 10 ft² damaged LBP; paint abatement: 100 ft² damaged LBP) and are lowest for example option F (floor: 25 µg/ft²; window sill: 25 µg/ft²; soil: 500 µg/g; paint maintenance: 0 ft² damaged LBP; paint abatement: 5 ft² damaged LBP). In addition, example option I corresponds to the interim standards presented in the interim rule (floor: 100 µg/ft²; window sill: 500 µg/ft²; soil: 5,000 µg/g; paint maintenance: 2 ft² damaged LBP; paint abatement: 10 ft² damaged LBP). For comparison purposes, the baseline values for the health and blood-lead concentration endpoints are displayed in the last column of the table.

The last row of the second section indicates that the percentage of homes affected by the various example sets of standards ranges from 17.5 percent to 53.7 percent. This is a wider range than was observed for any of the individual environmental medium. This is because the example options considered in these tables represent a broader range of example standards than what was considered in the analyses illustrating the effect of varying the standard for a single medium.

Over this range of example standards, the percentage of children expected to have blood-lead concentration at or above 20 µg/dL ranged from 0.46 to 0.32 percent based on the empirical model and from 0.29 to 0.002 percent based on the IEUBK model. The percentage of children with blood-lead concentration at or above 10 µg/dL ranged from 5.0 to 4.1 percent based on the empirical model and from 3.9 to 0.3 percent based on the IEUBK model. The percentage of children expected to have an IQ below 70 as a result of lead exposure ranged from 0.112 to 0.108 percent based on the empirical model, and from 0.107 to 0.091 percent based on the IEUBK model.

The seven graphs in Figures 6-11a and 6-11b illustrate how values for a particular health effect or blood-lead concentration endpoint (as specified along the graph's vertical axis) are affected by the example options in Table 6-7. Each graph also illustrates how the percentage of homes exceeding at least one example standard (as specified along the graph's horizontal axis) changes among the different sets of example standards. Each graph contains two curves: a solid curve illustrating predictions based on the empirical model, and a dashed curve representing predictions based on the IEUBK model. As was seen in previous figures, the empirical model predicts higher values for the endpoints than does the IEUBK model. Each example set of standards is represented by its letter code (A through F) specified at the top of Table 6-7.

In Figures 6-11a and 6-11b, the incremental reduction in the estimated health effect or blood-lead concentration endpoint for each unit change in the number of homes affected is represented by the slope of the line connecting any two plotted points. For each graph, the slope is steepest between example options A and C. This property was also present in the graphs (Figures 5a, 5b, 7a, 7b, 10a, and 10b) illustrating the effects of changes in example standards for the individual environmental medium.

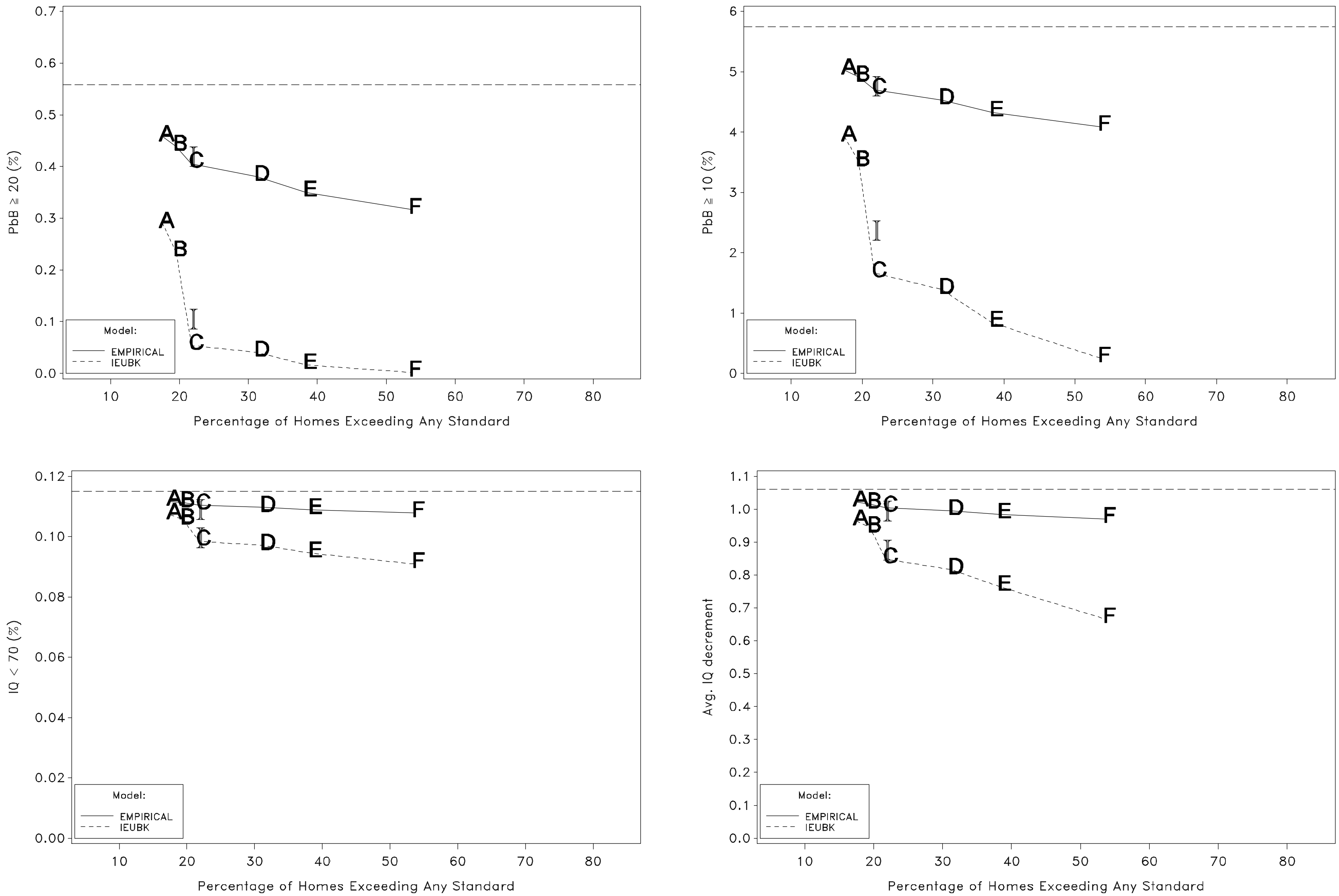


Figure 6-11a. Projected Health and Blood-Lead Concentration Endpoints Based on Various Example Sets of Options for Dust and Soil Standards, and Paint Intervention Triggers, Part 1. (Dashed reference line represents baseline risk.)

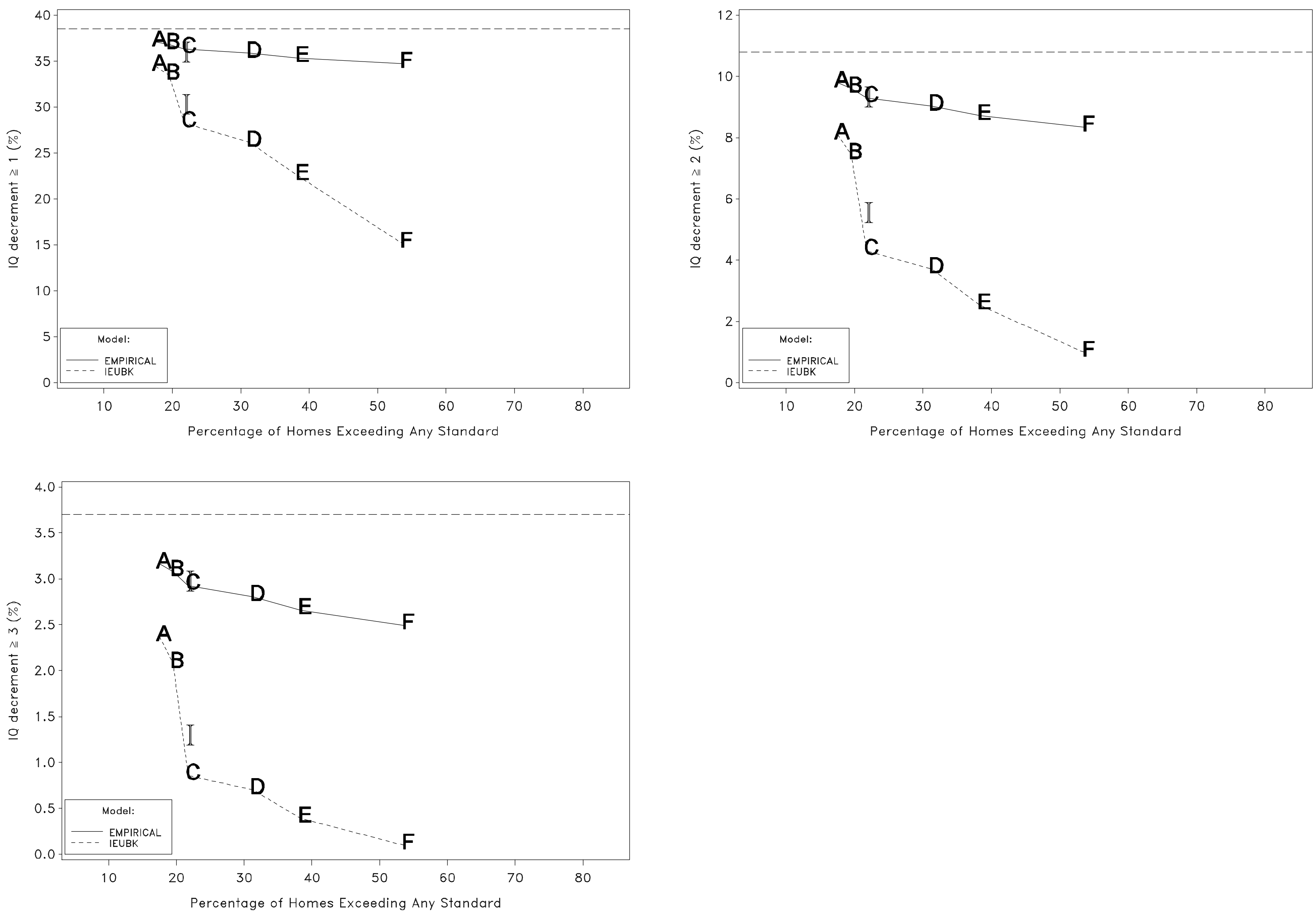


Figure 6-11b. Projected Health Endpoints Based on Various Example Sets of Options for Dust and Soil Standards, and Paint Intervention Triggers, Part 2. (Dashed reference line represents baseline risk.)

There is, again, a generally consistent shape to each of the curves in Figures 6-11a and 6-11b. In each case, the steepest drop occurs between example options A and C. This pattern is consistent between the empirical and IEUBK models; however, incremental changes predicted by the empirical model are generally less than those predicted by the IEUBK model. While example option C is estimated to affect about the same number of homes as the current interim guidance (21.8 compared to 22.0 percent), the estimated health effect and blood-lead concentration endpoints for the interim standards are generally higher. However, the actual difference in the endpoints between the two sets of example standards may be inconsequential relative to the uncertainty in the estimated endpoints.

As also observed when considering each medium individually, an option that establishes even a relatively high example standard for all environmental media results in a substantial improvement relative to the baseline for the percentage of children at or above 20 µg/dL or 10 µg/dL, and the percentage of children anticipated to have an IQ decrement greater than 2 or 3 resulting from elevated blood-lead concentration. However, even varying the example set of standards encompassing all environmental media results in little change in the percentage of children predicted to have an IQ below 70 due to elevated blood-lead concentration or in the percentage of children expected to have an IQ decrement greater than 1 due to elevated blood-lead concentration.

6.3.5 Risk Reduction Details for an Illustrative Set of Standards

This section provides a more detailed characterization of projected health effect and blood-lead concentration endpoints associated with a particular illustrative set of dust and soil standards, and paint intervention triggers. The illustrative standards considered are 100 µg/ft² for floor dust-lead loading, 500 µg/ft² for window sill dust lead loading, 2,000 µg/g for soil-lead concentration removal, 5 ft² damaged LBP for paint maintenance, and 20 ft² damaged LBP for paint abatement (i.e., option C of Table 6-7).

Under these illustrative standards, Figure 6-12 displays the projected post-§403 distribution of blood-lead concentrations in children aged 1-2 years based on the empirical model and the IEUBK model in both histogram and cumulative distribution function (cdf) format. The pre-§403 (baseline) distribution is also presented in Figure 6-12. The histogram indicates the general shape of the distribution of blood-lead concentrations, while the cdf provides the probability that a child has a blood-lead concentration below any specified value. The cdf enables the reader to easily estimate the percentage of children having blood-lead concentrations within any particular interval of concentrations.

Qualitatively, the distribution associated with the IEUBK-predicted, post-§403 blood-lead concentrations appears to the left of the corresponding distribution based on the empirical model, which does not appear to be substantially different than the baseline (pre-§403) distribution. The IEUBK model-predicted distribution of blood-lead concentrations indicates that the reduction in the number of children with elevated blood-lead concentration under the illustrative set of standards is more substantial than that based on the empirical model.

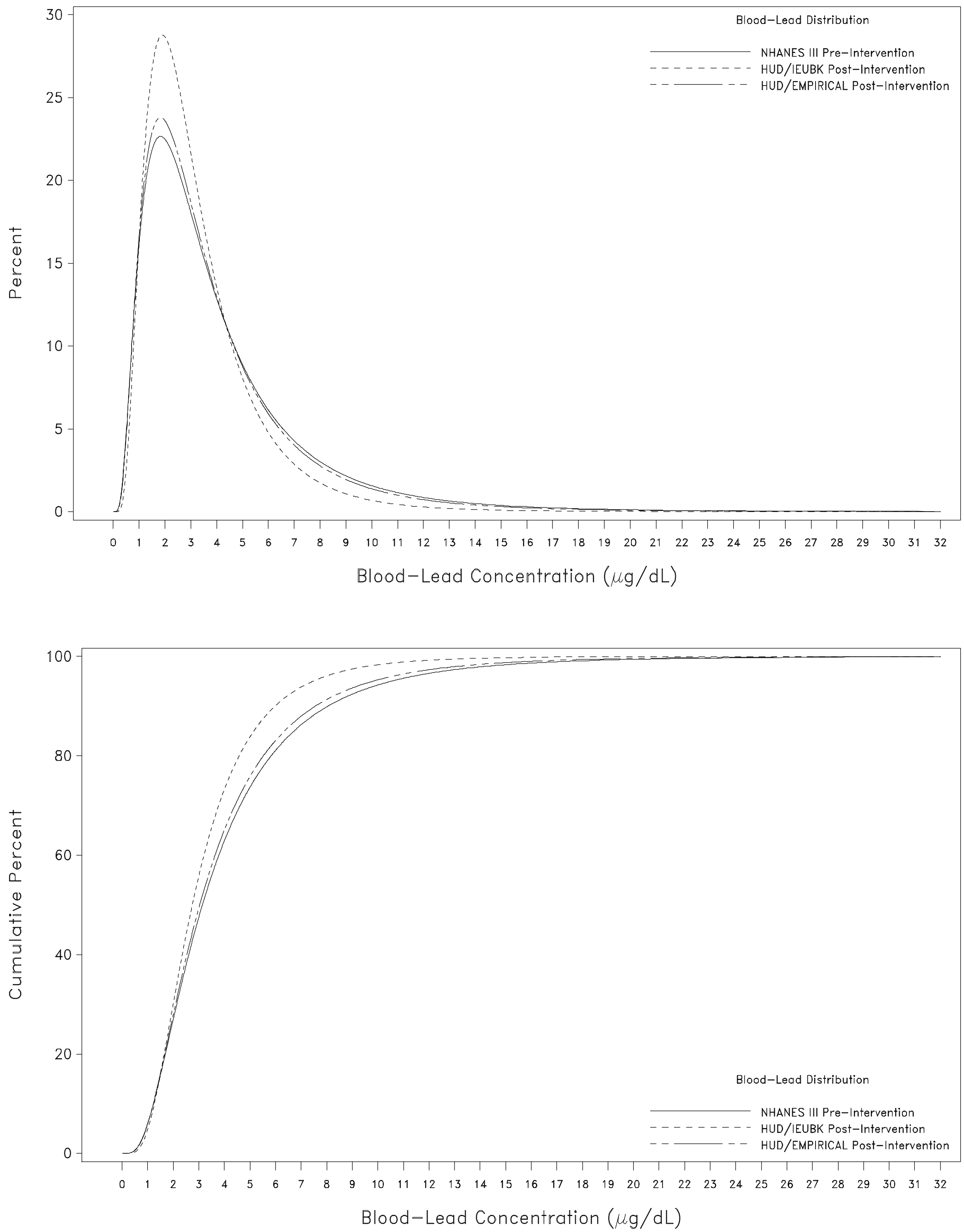


Figure 6-12. Projected Post-Intervention Blood-Lead Concentration Distributions Based on Empirical and IEUBK Models at Standards of Floor Dust-Lead – 100 µg/ft²; Window Sill Dust-Lead – 500 µg/ft²; Soil-Lead Concentration – 2,000 µg/g; Paint Maintenance – 5 ft² Damaged LBP; and Paint Abatement – 20 ft² Damaged LBP.

Table 6-8 compares the baseline distribution of blood-lead concentrations and health effect endpoints to the post-§403 distribution based on the empirical and IEUBK models for the illustrative set of standards considered in this section: 100 µg/ft² for floor dust-lead loading, 500 µg/ft² for window sill dust-lead loading, 2,000 µg/g for soil-lead concentration, 5 ft² damaged LBP for paint maintenance, and 20 ft² damaged LBP for paint abatement. The top half of Table 6-8 characterizes the distribution of children's blood-lead concentrations. Estimated numbers and percentages of children with blood-lead concentration in various intervals are provided. The bottom half of Table 6-8 estimates various health endpoints under the baseline and post-§403 projections for this example set of standards.

Table 6-8. Estimated Distribution of Health Effect and Blood-Lead Concentration Endpoints Prior to and After the Proposed §403 Rule for an Illustrative Set of Standards.[1]

PbB (µg/dL)	Pre-§403		Post-§403 (Empirical Model)		Post-§403 (IEUBK Model)	
	# Children[2]	Percent	# Children[2]	Percent	# Children[2]	Percent
Total	7,960	100	7,960	100	7,960	100
0 ≤ PbB < 1	477	5.99	475	5.96	385	4.83
1 ≤ PbB < 3	3,310	41.6	3,460	43.4	4,060	51.0
3 ≤ PbB < 5	2,080	26.1	2,110	26.5	2,230	28.0
5 ≤ PbB < 10	1,640	20.6	1,550	19.5	1,150	14.5
10 ≤ PbB < 15	325	4.08	275	3.46	112	1.41
15 ≤ PbB < 20	85.9	1.08	66.7	0.838	16.3	0.205
20 ≤ PbB < 25	27.9	0.350	20.1	0.252	3.19	0.0401
PbB ≥ 25	18.9	0.238	12.2	0.154	1.10	0.0138
Inferred Health Effects						
IQ < 70	9.13	0.115	8.79	0.110	7.84	0.0984
IQ decrement ≥ 1	3,060	38.5	2,890	36.3	2,250	28.3
IQ decrement ≥ 2	863	10.8	741	9.30	343	4.31
IQ decrement ≥ 3	294	3.70	233	2.93	68.3	0.858
Average IQ decrement	1.06		1.00		0.848	
	# Houses	Percent	# Houses	Percent	# Houses	Percent
Houses Affected	0	0	21,600	21.8	21,600	21.8

[1] 100 µg/ft² for floor dust lead loading, 500 µg/ft² for window sill dust-lead loading, 2,000 µg/g for soil-lead concentration, 5 ft² damaged LBP for paint repair, and 20 ft² damaged LBP for paint abatement.
[2] Numbers of children aged 1-2 years in thousands.

6.4 SENSITIVITY AND UNCERTAINTY ANALYSES FOR RISK MANAGEMENT ANALYSES

There are numerous procedures and assumptions discussed and presented that contribute to the final results in this chapter. Sensitivity analyses address the extent to which variations in key assumptions and approaches affect the estimated outcomes, thereby contributing to overall uncertainty in the results. As it was not feasible to consider variations in all aspects of the analysis, the sensitivity analysis considered approaches and assumptions which had the potential for producing the largest expected deviation. The alternative approaches considered in the sensitivity analysis and the comparison of their findings with the final results had to be manageable within the context of the sensitivity analysis. Table 6-9 summarizes seven factors addressed by the sensitivity analysis for risk management analyses where alternative approach(es) were considered; these alternative approaches are included in Table 6-9. Sections 6.4.1 through 6.4.8 present the sensitivity analyses under each of these factors.

An eighth factor considered in the sensitivity analysis was the method for determining post-intervention dust-lead concentrations (Section 6.1.3). However, instead of presenting results under one or more alternative assumptions (as was done with the seven factors in Table 6-9), graphs and tables were prepared that illustrate how results calculated under this method compare to those from published studies. Section 6.4.5 presents these findings.

There is also uncertainty in the estimated post-§403 health effect and blood-lead concentration endpoints due to the variability in the data used to obtain these estimates. Standard errors associated with post-intervention estimates of the health effect and blood-lead concentration endpoints are presented in Section 6.4.9 for three sets of example options for the standards.

6.4.1 Uncertainty in Converting Dust-Lead Loadings for Comparison to Standards

Because the §403 dust-lead loading standards will be defined in terms of lead loadings for dust samples collected with wipe collection techniques, and because dust samples in the HUD National Survey were collected using a Blue Nozzle vacuum, it was necessary to convert the HUD National Survey dust-lead loadings (for both floors and window sills) to wipe dust-lead loadings in the risk management analysis. Different formulas were used (Section 4.3; Table 6-9) to predict a wipe dust-lead loading from a Blue Nozzle vacuum dust-lead loading, depending on the age of the house and whether a floor or window sill was sampled. These formulas assume that the expected value of the log-transformed wipe dust-lead loading (log(Wipe)) given a Blue Nozzle vacuum dust-lead loading of “Vac,” takes the form

$$\alpha + \beta*\log(\text{Vac}).$$

Table 6-9. Procedures for Which Alternative Assumptions Were Considered in the Sensitivity Analysis Addressing Risk Management.

Procedure	Approach Taken in the Risk Management Analyses	Alternative(s) Considered in the Sensitivity Analysis
Convert Blue Nozzle vacuum dust-lead loadings reported in the National Survey to wipe dust-lead loadings, so that the area-weighted geometric mean for a housing unit can be compared to example dust-lead loading standards	As indicated in Section 4.3, convert each Blue Nozzle vacuum dust-lead loading ("Vac") to a wipe dust-lead loading ("Wipe") using the following formulas: Floors: Pre-1940: Wipe = $5.66(Vac)^{0.809}$ 1940-1959: Wipe = $4.78(Vac)^{0.800}$ 1960-1979: Wipe = $4.03(Vac)^{0.707}$ Window Sills: Wipe = $2.95*(Vac)^{1.18}$	Alt. #1 (low estimate): Assign the lower 90% confidence bound on the estimated wipe dust-lead loading obtained from the adjacent formulas to each sample result. Alt. #2 (high estimate): Assign the upper 90% confidence bound on the estimated wipe dust-lead loading obtained from the adjacent formulas to each sample result. (Section 6.4.1)
Convert the specified post-intervention wipe dust-lead loadings of 40 µg/ft² for floors and 100 µg/ft² for window sills to Blue Nozzle dust-lead loadings for input to the empirical model	As indicated in Section 4.3, convert the wipe dust-lead loading to a Blue Nozzle vacuum dust-lead loading ("BN") as follows: Floors: BN = $0.185*(40)^{0.931}$ = 5.7 µg/ft² Window Sills: BN = $0.955*(100)^{0.583}$ = 14.0 µg/ft²	Alt. #1 (low estimate): Assign the lower 90% confidence bound on the estimated Blue Nozzle vacuum dust-lead loading obtained from the adjacent formulas. Alt. #2 (high estimate): Assign the upper 90% confidence bound on the estimated Blue Nozzle vacuum dust-lead loading obtained from the adjacent formulas. (Section 6.4.2)
Determine a post-§403 blood-lead concentration distribution under the empirical model as a function of post-intervention dust-lead loadings	Consider post-intervention dust-lead loadings of 40 µg/ft² for floors and 100 µg/ft² for window sills	Consider the following alternative post-intervention dust-lead loadings: -- 20 µg/ft² for floors and 50 µg/ft² for window sills -- 100 µg/ft² for floors and 250 µg/ft² for window sills (Section 6.4.3)
Determine a method for characterizing the post-§403 distribution of blood-lead concentration, and comparing health effects between pre- and post-§403.	Apply the methods in Section 6.3 to obtain pre- and post-intervention distributions.	Rather than predicting post-§403 blood-lead concentration as a function of environmental-lead levels, use the average efficacy observed in abatement studies with an adjustment for bone-lead stores. (Section 6.4.4)
When predicting the post-intervention values of the blood-lead distribution and health effect endpoints, determine an appropriate value for the geometric standard deviation (GSD) of the blood-lead concentrations associated with a given environmental-lead exposure scenario	Assume a GSD of 1.6	Alt. #1: Assume a GSD of 1.4 Alt. #2: Assume a GSD of 1.9 Alt. #3: Assume a GSD of 2.1 Section 6.4.6
When using the IEUBK model to predict post-intervention values of the blood-lead distribution and health effect endpoints, determine an appropriate value for daily dietary lead intake for a child aged 1-2 years (an input parameter to the IEUBK model)	Assume daily dietary lead intake is 5.78 µg (the IEUBK model's default value for children aged 1-2 years)	Alt. #1: Daily dietary lead intake = 1.29 µg Alt. #2: Daily dietary lead intake = 3.53 µg Section 6.4.7

Table 6-9. Procedures for Which Alternative Assumptions Were Considered in the Sensitivity Analysis Addressing Risk Management. (Continued)

Procedure	Approach Taken in the Risk Management Analyses	Alternative(s) Considered in the Sensitivity Analysis
When using modeling techniques to predict post-intervention values of the blood-lead distribution and health effect endpoints, adjust model-based results to reflect the effects of paint pica tendencies on blood-lead concentration	Make assumptions on the prevalence of paint pica and the effects of paint pica on blood-lead concentration that are documented in Section 4.1.3 and Appendix D1	Alt. #1: Make no adjustment for paint pica effects Alt. #2: Assume a lower prevalence of paint pica and lower effects of paint pica on blood-lead concentration than that used in the risk analysis Alt. #3: Assume a higher prevalence of paint pica and higher effects of paint pica on blood-lead concentration than that used in the risk analysis Section 6.4.8

where values of α and β are provided in Table 6-9. Assuming lognormality, upper and lower one-sided 90% confidence bounds on the expected value of log(Wipe) are

$$\text{(predicted value of log(Wipe))} \pm 1.3 * SE(\alpha + \beta * \log(Vac))$$

where SE($\alpha + \beta$ * log (Vac)) is the standard error of the expected value of log(Wipe). Upper and lower 90% confidence bounds on the untransformed expected wipe dust-lead loadings are obtained by exponentiating the bounds for the expected log-transformed loading.

The confidence bounds were used to define two alternative sets of converted dust-lead loadings in the sensitivity analysis:

Alternative set #1: Wipe dust-lead loading equals the lower 90% confidence bound on the expected wipe dust-lead loading obtained from the formulas in Table 6-9.

Alternative set #2: Wipe dust-lead loading equals the upper 90% confidence bound on the expected wipe dust-lead loading obtained from the formulas in Table 6-9.

Note that alternative set #1 is a low estimate of the converted loading value, while alternative set #2 is a high estimate. Under both sets, area-weighted arithmetic mean dust-lead loadings for both floors and window sills were calculated for each HUD National Survey unit. The means were used to determine whether candidate dust-lead loading standards were exceeded for a given unit. In this part of the sensitivity analysis, numbers and percentages of units exceeding various combinations of example environmental-lead standards were calculated under each set of converted dust-lead loadings.

Table 6-10 considers numbers of units exceeding an example floor dust-lead loading standard of 100 µg/ft², exceeding an example window sill dust-lead loading standard of 500 µg/ft², either of these two example standards, or any of the example standards for dust, soil, or paint. These numbers were calculated for the wipe-equivalent dust-lead loadings used in the risk management analyses, Alternative set #1, or Alternative set #2.

Table 6-10. Number (and Percentage) of Units in the 1997 National Housing Stock Projected to Exceed Various Combinations of Example Standards, As Determined from Three Different Sets of Converted Dust-Lead Loadings.

Example Standards, or Combination of Standards	Number (%) of Units Exceeding the Example Standard(s)		
	Approach Used in Risk Management Analyses[1]	Using Low Alternative Estimates for Converted Dust-Lead Loading[2]	Using High Alternative Estimates for Converted Dust-Lead Loading[2]
Floor-dust standard of 100 µg/ft²	4,010,000 (4.04%)	2,320,000 (2.34%)	5,750,000 (5.80%)
Window sill-dust standard of 500 µg/ft²	12,400,000 (12.5%)	9,760,000 (9.83%)	12,900,000 (13.0%)
Floor- or window sill- dust standard	13,800,000 (13.9%)	11,600,000 (11.7%)	15,800,000 (16.0%)
At least one dust or soil standard, or paint intervention trigger[3]	21,600,000 (21.8%)	20,300,000 (20.5%)	23,500,000 (23.6%)

[1] See Section 4.3 on the methods for performing conversions from Blue Nozzle vacuum to wipe dust-lead loadings.
[2] Low and high estimates correspond to the lower 90% confidence bound and upper 90% confidence bound, respectively, for the estimates considered in the second column of this table.
[3] Example soil standard and paint intervention triggers are as follows: soil-lead concentration of 2,000 µg/g for soil removal, 5 ft² of deteriorated lead-based paint for paint maintenance, and 20 ft² of deteriorated lead-based paint for paint abatement.

Effect on risk analysis: The largest variation between the two alternative sets of dust-lead loadings occurred when considering only the example floor-dust standard. Under Alternative set #2 (high converted values), 5.75 million units exceed the example floor-dust standard of 100 µg/ft², compared to four million units under the set of converted values used in the risk management analyses, and 2.32 million units under Alternative set #1 (the low converted values). This finding implies that the risk management analysis may be underestimating the numbers of homes exceeding example standards by as much as 50%. However, a dust-cleaning intervention is triggered if either the floor or window sill dust-lead loading standard is exceeded. The impact of the uncertainty in the dust-lead loading conversion equation was smaller for the number of homes in which either the example floor dust standard or window sill dust standard was exceeded. The number of units triggering an intervention by exceeding either example dust standard ranged from a low estimate of 11.6 million to a high estimate of 15.8 million, which is a 16% decrease or increase, respectively, from the estimate of 13.8 million units calculated in the risk management analysis.

6.4.2 Uncertainty in Converting Wipe Dust-Lead Loadings to Blue Nozzle Dust-Lead Loadings for Determining Post-Intervention Blood-Lead Distributions Using the Empirical Model

As described in Section 4.2, the empirical model is a multi-media regression model developed especially for this risk analysis to predict the geometric mean blood-lead concentration of children 1-2 years old as a function of environmental-lead levels at a child's primary residence. Because data from the HUD National Survey are utilized to predict children's blood-lead concentrations, the dust-lead loadings for floors and window sills inputted to the empirical model are assumed to represent dust samples collected using the Blue Nozzle vacuum method (i.e., the method used in the HUD National Survey). However, the dust-lead loading on floors and window sills following dust-cleaning interventions were specified in terms of a wipe dust-lead loading (Table 6-2). Thus, a means of converting post-intervention dust-lead loadings from wipe to Blue Nozzle vacuum loadings was necessary.

Two formulas were used (Table 6-9) to predict a Blue Nozzle vacuum dust-lead loading as a function of a wipe dust-lead loading, depending on whether a floor or window sill was sampled. These formulas indicate that the expected value of the log-transformed Blue Nozzle dust-lead loading (log(BN)) given a wipe dust-lead loading of "Wipe" takes the form

$$\alpha + \beta * \log(\text{Wipe})$$

where estimates of α and β are provided in Table 6-9. Therefore, assuming lognormality, upper and lower one-sided 90% confidence bounds on the expected value of log(BN) are

$$(\text{predicted value of } \log(\text{BN})) \pm 1.3 * \text{SE}(\alpha + \beta * \log(\text{Wipe}))$$

where $\text{SE}(\alpha + \beta * \log(\text{Wipe}))$ is the standard error of the expected value of log(BN). Upper and lower 90% confidence bounds on the expected untransformed Blue Nozzle dust-lead loading are obtained by exponentiating the corresponding bounds for the expected log-transformed Blue Nozzle dust-lead loading.

Using the two conversion formulas in Table 6-9, the converted Blue Nozzle floor dust-lead loading corresponding to a wipe dust-lead loading of 40 µg/ft², is 5.7 µg/ft² and the converted Blue Nozzle window sill dust-lead loading corresponding to a wipe dust-lead loading of 100 µg/ft² is 14.0 µg/ft². In the sensitivity analysis, two alternatives to the converted Blue Nozzle dust-lead loadings of 5.7 µg/ft² for floors and 14.0 µg/ft² for window sills were considered:

<u>Alternative #1</u>: Lower 90% confidence bounds associated with the converted values: 4.5 µg/ft² for floors and 12.4 µg/ft² for window sills.

<u>Alternative #2</u>: Upper 90% confidence bounds associated with the converted values: 7.3 µg/ft² for floors and 15.8 µg/ft² for window sills.

Thus, Alternative #1 represents low estimates of the converted loadings, while Alternative #2 represents high estimates. Table 6-11 presents the resulting health effects under each of these two alternatives, as well as under the converted loadings employed in Section 6.3.

Table 6-11. Empirical Model-Predicted Post-§403 Health Effect and Blood-Lead Concentration Endpoints for Children 1-2 Years of Age, As Calculated Under Three Assumptions on Post-Intervention Blue Nozzle Vacuum Dust-Lead Loading[1]

Health Effect and Blood-Lead Concentration Endpoints	Post-Intervention Blue Nozzle Dust-Lead Loading		
	Values Used in the Risk Management Analyses (5.7 µg/ft² for floors, 14.0 µg/ft² for window sills)	Alternative #1 (4.5 µg/ft² for floors, 12.4 µg/ft² for window sills)	Alternative #2 (7.5 µg/ft² for floors, 15.8 µg/ft² for window sills)
PbB≥20 (%)	0.406	0.400	0.412
PbB≥10 (%)	4.70	4.67	4.74
IQ < 70 (%)	0.110	0.110	0.111
IQ decrement≥1 (%)	36.3	36.2	36.4
IQ decrement≥2 (%)	9.30	9.24	9.36
IQ decrement≥3 (%)	2.93	2.90	2.96
Avg. IQ decrement	1.00	1.00	1.01

[1] Health effects are calculated assuming the following:
- Example dust-lead loading standards of 100 µg/ft² for floors and 500 µg/ft² for window sills
- Example soil-lead concentration standard of 2,000 µg/g
- Paint maintenance is performed if more than 5 ft², but less than 20 ft² of deteriorated lead-based paint exists.
- Paint abatement is performed if more than 20 ft² of deteriorated lead-based paint exists.
- Blue Nozzle dust-lead loadings for floors and window sills equal to the minimum of the average pre-intervention Blue Nozzle loading and the loading specified in the column heading.
- Soil-lead concentrations equal to 150 µg/g after soil removal intervention
- 0 ft² of deteriorated lead-based paint after all paint interventions

Effect on risk analysis: For each alternative, deviation from the results for the risk management analyses was negligible.

6.4.3 Alternative Assumptions on Post-Intervention Dust-Lead Loadings

Assumed post-intervention environmental-lead levels used in the risk analysis were provided in Table 6-2. The sensitivity analysis considered alternatives to the assumed post-intervention wipe dust-lead loading following dust cleaning, interior paint abatement, and soil removal, in order to observe how the health effect and blood-lead concentration estimates under the empirical model were affected by assumptions on post-intervention dust-lead loadings. Two sets of alternative post-intervention wipe dust-lead loadings for floors and window sills were considered:

- 20 µg/ft² for floors and 50 µg/ft² for window sills, and
- 100 µg/ft² for floors and 250 µg/ft² for window sills.

(The loadings used in the risk management analyses were 40 µg/ft² for floors and 100 µg/ft² for window sills.) The sensitivity analysis did not address alternative soil-lead concentration values following soil removal (150 µg/g), or amounts of deteriorated lead-based paint following paint interventions (0 ft²).

Note that assumptions on post-intervention dust-lead loadings affect estimates of the distribution of post-§403 blood-lead concentration and the health effect endpoints only when these estimates are determined by the empirical model (Section 4.2). The IEUBK model (Section 4.1) uses post-intervention dust-lead concentration as input, and the methods used to determine post-intervention dust-lead concentrations are not affected by assumptions on post-intervention dust-lead loadings (Section 6.1.3). Therefore, health effect and blood-lead concentration endpoints are estimated only under the empirical model here.

Table 6-12 summarizes the post-intervention estimates of childhood health effect and blood-lead concentration endpoints (based on the empirical model) under the alternative post-intervention dust-lead loadings. Results in Table 6-12 were calculated assuming the following example dust and soil standards and paint intervention triggers:

- Dust-lead loadings (under wipe sampling techniques) of 100 µg/ft² for floors and 500 µg/ft² for window sills
- Soil-lead concentration of 2,000 µg/g
- Paint maintenance is performed if more than 5 ft², but less than 20 ft² of deteriorated lead-based paint exists
- Paint abatement is performed if more than 20 ft² of deteriorated lead-based paint exists.

Effect on risk analysis: Table 6-12 indicates that the health effect and blood-lead concentration endpoints most affected by changes in the observed post-intervention dust-lead loadings are those indicating the most extreme effects (e.g., IQ decrement of at least 3, blood-lead concentration of at least 20 µg/dL). The percentage of children with blood-lead concentration at or above 20 µg/dL differs from the estimate reported in the risk analysis by approximately 4 to 6 percent under the two alternative post-intervention dust-lead loadings, while an approximate 3 percent difference is observed for the percent of children with blood-lead concentrations at or above 10 µg/dL. Virtually no difference in the estimated percentage of children with IQ less than 70 or in average IQ decrement in a child as a result of lead exposure is observed between the two alternatives.

Table 6-12. Empirical Model-Predicted Post-§403 Percentages of Children Aged 1-2 Years Experiencing Specific Health Effect and Blood-Lead Concentration Endpoints, Under Various Assumptions on Post-Intervention Dust-Lead Loading.

Health Effect and Blood-Lead Concentration Endpoints	0 ft² Deteriorated Lead-Based Paint after all Paint Interventions Soil-Lead Concentration after Soil Removal Intervention = 150 µg/g		
	Dust-Lead Loading[1]: Floors = 20 µg/ft² Window Sills = 50 µg/ft²	Dust-Lead Loading[1]: Floors = 40 µg/ft² Window Sills = 100 µg/ft²	Dust-Lead Loading[1]: Floors = 100 µg/ft² Window Sills = 250 µg/ft²
PbB ≥ 20 (%)	0.388	0.406	0.429
PbB ≥ 10 (%)	4.59	4.70	4.85
IQ < 70 (%)	0.110	0.110	0.111
IQ decrement ≥ 1 (%)	36.0	36.3	36.7
IQ decrement ≥ 2 (%)	9.12	9.30	9.53
IQ decrement ≥ 3 (%)	2.85	2.93	3.04
Avg. IQ decrement	0.998	1.00	1.01

[1] After dust cleaning, soil removal, or interior paint abatement this analysis assumes the following example dust and soil standards and paint intervention triggers:

- Dust-lead loadings (under wipe techniques) of 100 µg/ft² for floors and 500 µg/ft² for window sills
- Soil-lead concentration of 2,000 µg/g
- Paint maintenance is performed if more than 5 ft², but less than 20 ft² of deteriorated lead-based paint exists
- Paint abatement is performed if more than 20 ft² of deteriorated lead-based paint exists.

Shaded cells correspond to results for example option C in Table 6-7.

6.4.4 Alternative Approach to Determining a Post-Intervention Blood-Lead Concentration Distribution Using Directly-Measured Blood-Lead Concentration Changes

An alternative to the approach presented in Section 6.2 to characterizing a post-intervention blood-lead concentration distribution was performed utilizing published results on the effectiveness of lead hazard intervention strategies among children exposed to residential lead hazards. This approach is desirable since blood-lead concentrations are a more direct measure of intervention effectiveness than are environmental-lead levels. The scientific literature reports the results of a range of non-medical intervention strategies conducted to reduce the lead exposure of children residing at the targeted residences (USEPA, 1995b). The strategies included lead-based paint abatement, interior dust abatement via routine cleaning procedures, elevated soil-lead abatement, and intensive educational efforts (USEPA, 1995b). The effectiveness of these strategies as measured by declines in children's blood-lead concentrations may be used to estimate the post-intervention blood-lead concentration distribution. As such, this approach represents a somewhat independent (of many of the procedures and data used in risk management) estimation of a post-intervention distribution.

As summarized in USEPA, 1995b, the intervention strategies reported 18–34% declines in the blood-lead concentrations of exposed children six to twelve months following the conduct of the intervention. Lead-based paint abatement (of all deteriorated LBP), biweekly dust abatement (of areas with elevated dust lead), soil abatement (removal and replacement of top 6"), and intensive education (visit by semi-professional outreach worker) reported comparable declines of approximately 25% one year following conduct of the intervention (USEPA, 1995b). Each of these four intervention studies reported significantly greater declines among the study population than among a suitable control population—no control population was studied for the educational intervention associated with the 34% decline—providing reassurance that the interventions themselves were responsible for much of the reported declines. For the purpose of this sensitivity analysis, therefore, the average decline in children's blood-lead concentration resulting from an intervention was taken to be 25%[1].

This degree of effectiveness may not be suitable for estimating the post-intervention blood-lead distribution since the reported declines were for children already exposed (i.e., already exhibiting elevated blood-lead concentrations due to exposure to the targeted lead source). By contrast, the promulgation of §403 will prompt preventive interventions (primary prevention) conducted prior to any lead exposure to resident children. Measures of secondary prevention effectiveness may not be representative of primary intervention effectiveness because lead present in blood is a combination of current environmental exposure and internal reservoirs of lead stored in bone and soft tissue (Gulson et al., 1995; Smith et al., 1996; Rabinowitz et al., 1976; Manton, 1985). The reported declines in exposed children's blood-lead concentrations, therefore, may underestimate the primary prevention effectiveness of an intervention (Gulson et al., 1995).

A methodology was developed to estimate the impact of body lead burdens on measures of secondary intervention effectiveness to adjust the reported secondary prevention effectiveness (see Appendix F2). For a two-year-old exposed child, it is estimated that a secondary intervention prompting a 25% decline in blood-lead concentration at one year following intervention would actually prompt 33% declines were the intervention primary in character (Table F2-1 of Appendix F2). Based on this result, a 33% efficacy will be utilized for the purposes of this portion of the sensitivity analysis. As a comparison, the IEUBK model indicates a 41% primary prevention efficacy when lead-based paint hazards are eliminated and dust- and soil-lead levels are lowered to background levels (Section 5.2).

It is worth noting that the scientific literature also includes two recent journal articles regarding the percentage of lead in blood that may be attributed to body lead stores (Gulson et al., 1995; Smith et al., 1996). Such results, of course, have relevance to this aspect of the sensitivity analysis. Both articles indicate that between 40-70% of lead in an adult's blood may be attributed to mobilized bone-lead stores. The fact that these studies examined adults is critical because the percentage of blood lead attributable to bone-lead stores varies considerably with age

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[1] In all four studies, the control population did exhibit some decline which may be attributed to increased awareness of environmental lead and its hazards. As similar awareness may be expected to accompany §403 prompted interventions, it was not deemed necessary to adjust the reported study population declines by the declines associated with the control populations.

(Rabinowitz, 1991). Higher percentages are associated with older individuals (Rabinowitz, 1991). Thus, the population of 1-2 year olds considered in this risk analysis may have lower percentages of their blood lead attributable to mobilized bone lead. Greater primary prevention efficacy is reported for, say, 7 year old children than for 2 year old children (Table F2-1 in Appendix F2). If the methodology used in this alternative approach is used to make inferences on adults, it too suggests that 40-70% of blood lead is attributable to mobilized bone-lead stores.

This alternate approach to estimating a post-intervention national distribution of blood-lead concentrations for 1997 children aged 1-2 years was implemented based on the estimated 33% decline in blood-lead concentration following an intervention. This alternative estimate of primary prevention effectiveness, which adjusts the blood-lead changes for body-lead stores and hereafter is denoted the 'adjusted blood-lead effects model', was then compared to post-intervention distributions based on the IEUBK model and the empirical model.

The methodology for this comparison is summarized as follows:

1. Environmental-lead levels for each HUD National Survey unit were used as input to the IEUBK and empirical models to predict the geometric mean blood-lead concentration for children aged 1-2 years old exposed to environmental-lead levels similar to that in the National Survey unit. The contribution of pica was estimated using the methodology documented in Section 4.1.3.

2. For each unit in the HUD National Survey, lead levels in paint, dust, and soil were compared to the following example dust and soil standards and paint intervention triggers (example option C in Table 6-7):

   - 100 µg/ft² for floor dust-lead loading and 500 µg/ft² for window sill dust-lead loading,

   - 2,000 µg/g for soil-lead concentration,

   - Paint maintenance is performed if more than 5 ft², but less than 20 ft² of deteriorated lead-based paint exists,

   - Paint abatement is performed if more than 20 ft² of deteriorated lead-based paint exists.

3. For each HUD National Survey unit, if an intervention was triggered, then the post-intervention geometric mean blood-lead concentration was set equal to 67% of the geometric mean computed in (1). If an intervention was not triggered, then the post-intervention geometric mean blood-lead concentration equaled the geometric mean calculated in (1).

4. The geometric mean blood-lead concentration calculated in (3) and an assumed geometric standard deviation of 1.6 were used to generate a distribution of blood-lead

concentrations for each unit in the HUD National Survey. The distributions were then combined over all of the HUD National Survey units to yield estimated post-intervention blood-lead concentrations under the IEUBK model or the empirical model (Appendix E2).

Table 6-13 summarizes the health effect and blood-lead concentration endpoint values as estimated in the baseline risk characterization (Section 5.1.1), in the risk management analysis (Section 6.3), and under the adjusted blood-lead effects model. The table also includes the geometric mean and geometric standard deviation of the blood-lead distributions.

Effect on risk analysis: According to Table 6-13, the post-intervention geometric mean blood-lead concentrations under the adjusted blood-lead effects model were estimated to be 2.89 and 2.88 µg/dL for the IEUBK and empirical models, respectively. The IEUBK model-predicted geometric mean reported in the risk management analysis is slightly lower (2.74 µg/dL), while that predicted using the empirical model is slightly higher (3.03 µg/dL). Under the IEUBK model, the estimated percentages of children with blood-lead concentration at or above 10 or 20 µg/dL are greater using the adjusted blood-lead effects approach than those predicted in the risk management analysis. This results from the differences in the geometric standard deviations of blood-lead concentrations between the two approaches (1.97 and 1.84). Under the empirical model, percentages of children with blood-lead concentrations at or above than 10 or 20 µg/dL are less using the adjusted blood-lead effects approach than those predicted in the risk management analysis. This results from the differences in the geometric mean blood-lead concentrations between the two approaches.

6.4.5 Uncertainty in Assumptions Made in Determining Post-Intervention Dust-Lead Concentrations

As the IEUBK model requires dust-lead levels to be input as concentrations for predicting the geometric mean blood-lead concentration associated with a given exposure scenario (Section 4.1), it was necessary to develop a method for determining (interior) floor dust-lead concentrations that result from interventions performed under §403 rules. This method was presented in Section 6.1.3. In this section, uncertainty associated with key assumptions made in this method is characterized.

To determine post-intervention floor dust-lead concentrations, the following two assumptions were made:

1. an 80% reduction in floor dust-lead concentration results whenever a paint intervention is conducted (regardless of any other type of intervention that may be conducted)
2. the amount of floor-dust lead that is attributable to soil is equal to 80% of the amount of lead in the soil.

Table 6-13. Estimated Post-§403 Health and Blood-Lead Concentration Endpoints Based on the Risk Assessment Approach and the Adjusted Blood-Lead Effects Approach.

Health Effect and Blood-Lead Concentration Endpoints	Baseline (Section 5.1.1)	Post-§403 Estimates Under the Adjusted Blood Lead Effects Model		Post-§403 Estimates Under the Risk Management Analysis	
		IEUBK Model	Empirical Model	IEUBK Model	Empirical Model
PbB ≥ 20 (%)	0.588	0.213	0.302	0.0539	0.406
PbB ≥ 10 (%)	5.75	3.33	3.89	1.66	4.70
IQ < 70 (%)	0.115	0.105	0.107	0.0984	0.110
IQ decrement ≥ 1 (%)	38.5	33.0	33.4	28.3	36.3
IQ decrement ≥ 2 (%)	10.8	7.16	7.94	4.31	9.30
IQ decrement ≥ 3 (%)	3.70	1.96	2.37	0.858	2.93
Avg. IQ decrement	1.06	0.934	0.949	0.848	1.00
Geom. Mean PbB (GSD)	3.14 (2.09)	2.89 (1.97)	2.88 (2.03)	2.74 (1.84)	3.03 (2.04)

Example dust and soil standards were set at: 100 µg/ft² for floor dust-lead loading, 500 µg/ft² for window sill dust-lead loading, and 2,000 µg/g for soil-lead concentration. Paint maintenance is performed if more than 5 ft², but less than 20 ft², of deteriorated lead-based paint exists. Paint abatement is performed if more than 20 ft² of deteriorated lead-based paint exists.

GSD = geometric standard deviation.

To investigate the uncertainty associated with Assumption #1, post-intervention floor dust-lead concentrations measured in two studies were compared to those preicted by the algorithm in Section 6.1.3. The two studies were the Boston phase of the Urban Soil Lead Abatement Demonstration Project (USLADP; Section 3.2.2.4) and the Baltimore Repair and Maintenance (R&M) study (Section 3.2.2.1). These studies were selected because pre- and post-intervention floor dust-lead concentrations were measured and because they assessed the efficacy of paint interventions (among other interventions). The algorithm presented in Section 6.1.3 was used to predict the post-intervention dust-lead concentration (i.e., an 80% reduction from pre-intervention levels) for "study group" units in the Boston USLADP and "R&M Level III" units in the Baltimore R&M study. Figures 6-13 and 6-14 plot the predicted versus observed average post-intervention floor dust-lead concentrations in these units for the Boston USLADP and Baltimore R&M study, respectively. The solid line in both plots indicates equality. In both plots, the line of equality appears to be a good fit to the data points, indicating that the 80% reduction in dust-lead concentration from pre-intervention conditions is a good estimate of the post-intervention dust-lead concentration. However, there is considerable variability between the data points and this line, indicating that while the assumption is good when considering an average across all units, it may not be appropriate in certain units.

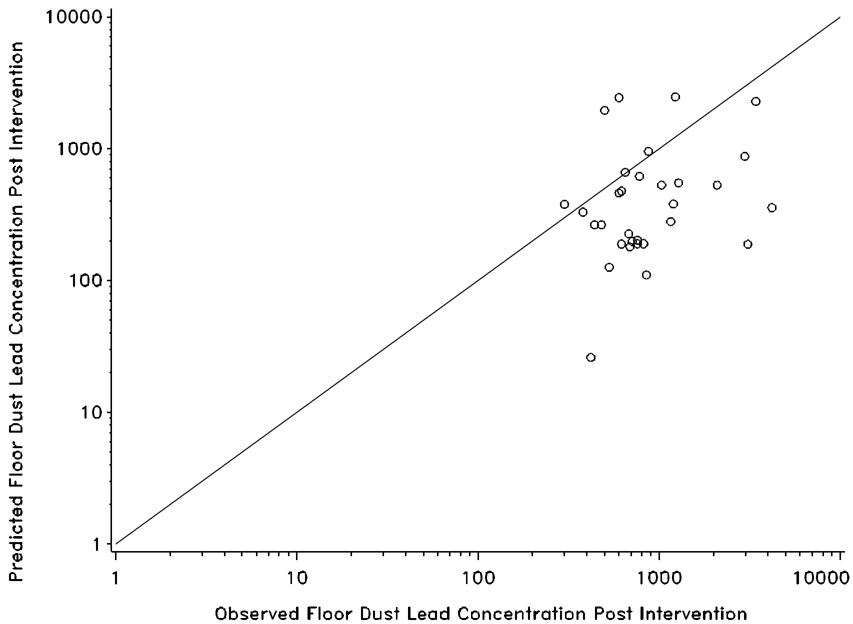

Figure 6-13. Predicted Versus Observed Average Post-Intervention Floor Dust-Lead Concentration (µg/g) (Boston USLADP Study Group Homes).

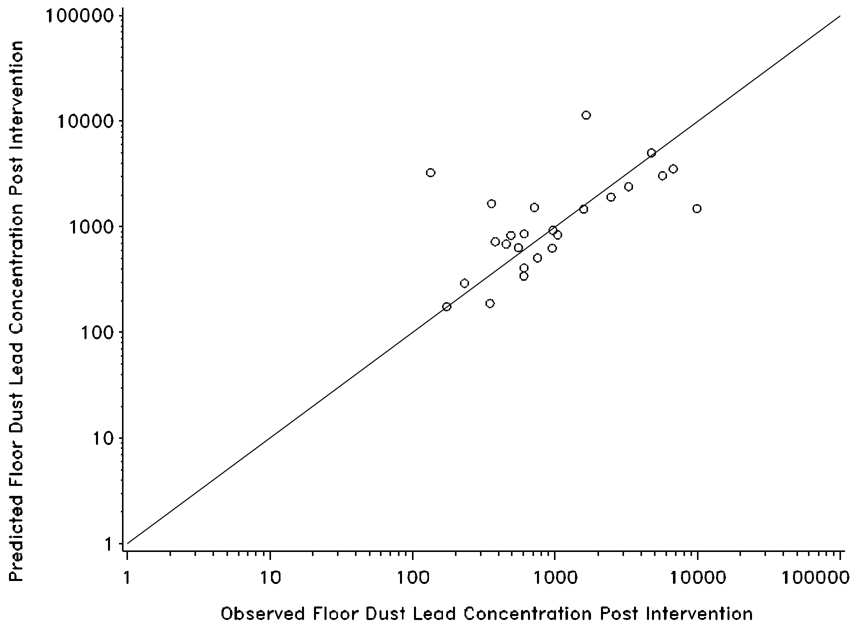

Figure 6-14. Predicted Versus Observed Average Post-Intervention Floor Dust-Lead Concentration (µg/g) (Baltimore R&M Level III Homes).

To investigate the extent to which floor dust-lead concentration declines following interventions, Tables 6-14 and 6-15 present geometric mean concentrations at specific times following intervention and how these geometric means have declined from pre-intervention values. Table 6-14 show results for Baltimore R&M study units according to housing type/group. This table shows that 80% declines are typical for R&M III study units (which had the most intensive intervention strategies) throughout the months following intervention. Similar results are seen in the "study group" of units in Table 6-15, which shows results for the Boston USLADP.

Table 6-14. Geometric Mean Post-Intervention Floor Dust-Lead Concentration (µg/g), and Percent Difference from Pre-Intervention Levels, for the Baltimore R&M Study.

	Modern Urban Units		Previously Abated Units		R&M I Units		R&M II Units		R&M III Units	
% Months Post-Intervention	Geom. Mean	% Diff. from Pre-Int.	Geom. Mean	% Diff. from Pre-Int.	Geom. Mean	% Diff. from Pre-Int.	Geom. Mean	% Diff. from Pre-Int.	Geom. Mean	% Diff. from Pre-Int.
Pre-intervention	85.8	—	736.4	—	1,413	—	1,930	—	3,970	—
06	92.1	7.3%	876.5	19.0%	846.7	-40.1%	621.9	-67.8%	931.1	-76.5%
12	55.1	-3.5%	715.1	-2.9%	769.8	-45.5%	684.0	-64.6%	578.6	-85.4%

18	72.1	-16.0%	731.2	-0.7%	490.9	-65.3%	484.3	-74.9%	718.2	-81.9%
24	45.0	-47.6%	523.9	-28.9%	716.9	-49.3%	332.4	-82.8%	547.3	-86.2%
30	65.1	-24.1%	531.5	-27.8%	—	—	—	—	442.7	-88.8%

Table 6-15. Geometric Mean Post-Intervention Floor Dust-Lead Concentration (µg/g), and Percent Difference from Pre-Intervention Levels, for the Boston USLADP.

Study Phase	# Months Post-Intervention	Study Group		Control Group A		Control Group B	
		Geom. Mean	% Diff. from Pre-Int.	Geom. Mean	% Diff. from Pre-Int.	Geom. Mean	% Diff. from Pre-Int.
1	Pre-Intervention	6,623	—	4,202	—	5,178	—
Recontamination No. 1	6	3,108	-53.1%	1,458	-65.3%	1,493	-71.2%
Recontamination No. 2	11	1,294	-80.5%	1,300	-69.1%	1,886	-63.6%

Pre-intervention data from the Baltimore phase of the USLADP were used to investigate Assumption #2. Figure 6-15 plots (pre-intervention) floor dust-lead concentration versus (pre-intervention) fine soil-lead concentration for units in this phase. The solid line in Figure 6-15 represents a lower bound on dust-lead concentration when assuming that the soil contributes 80% of the mass of dust. Only 12% of the units have data which fall below this line, which is within range of what can be expected under Assumption #2 given the measurement errors in soil-lead and dust-lead concentrations. Figure 6-15 also contains lines that represent soil contributions of 20%, 40% and 60% of the total mass of floor dust.

Post-intervention dust-lead concentrations measured in the Baltimore USLADP were compared to those predicted by the algorithm in Section 6.1.3. Because paint interventions were not conducted in the Baltimore USLADP, this comparison provides an assessment of assumption 2. Figure 6-16 plots predicted post-intervention floor dust-lead concentration versus measured concentration, with the solid line representing equality. This plot does not indicate a particular bias in the prediction procedure for these units, supporting the approach taken for units with no paint interventions. However, large differences between the observed and predicted post-intervention concentrations are present for certain units.

6.4.6 Alternative Estimates for the Geometric Standard Deviation of Blood-Lead Concentrations

The sensitivity of pre-§403 model-based estimates of the health effect and blood-lead concentration endpoints to various assumptions on the GSD for childhood blood-lead concentrations was presented in Section 5.4.6. Three alternative GSD values were considered: 1.4, 1.9, and 2.1. In this section, post-§403 estimates of the health effect and blood-lead concentration endpoints are estimated (under a single set of example options for standards, using both the IEUBK and empirical models) under these same alternative GSD values. See Section 5.4.6 for additional details on how the alternative GSD values were selected and on interpreting the GSD in this risk analysis.

Effect on risk analysis: For the three alternative GSD values, as well as for the GSD of 1.6 used in the risk analysis, Table 6-16 presents the estimated post-§403 health effect and blood-lead concentration endpoints for the example standards specified in the footnote to the table. As was seen in Table 5-14, post-§403 risks increase as the assumed GSD increases (i.e., larger percentage of children with blood-lead concentrations greater than or equal to 10 or 20 µg/dL). The IEUBK model is considerably more sensitive than the empirical model to the GSD value. For example, the probability of a child having a blood-lead concentration at or above 10 µg/dL increases by 41% under the IEUBK model (from 1.46% to 2.07%) when the GSD increases from 1.4 to 2.1, compared to only a 7% increase under the empirical model (from 4.56% to 4.88%). The probability of a child having a blood-lead concentration at or above 20 µg/dL more than doubles under the IEUBK model (from 0.0404% to 0.0865%), while only a 16% increase is observed under the empirical model (from 0.378% to 0.440%). Higher sensitivity to the GSD value was also observed for the IEUBK model versus the empirical model for the IQ parameters.

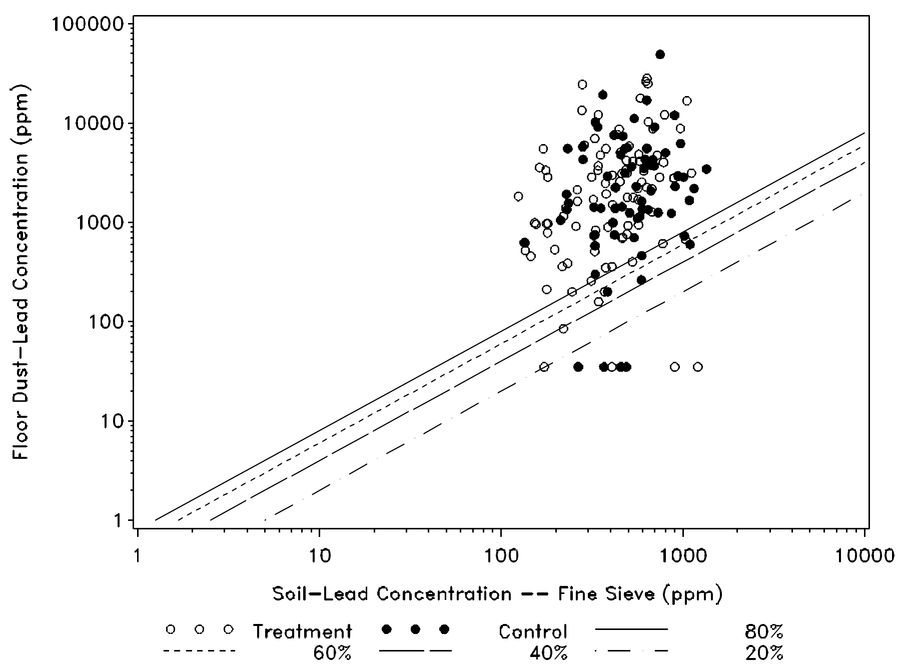

Figure 6-15. Average Floor Dust-Lead Concentration Versus Average Fine Soil-Lead Concentration (Baltimore USLADP Homes).

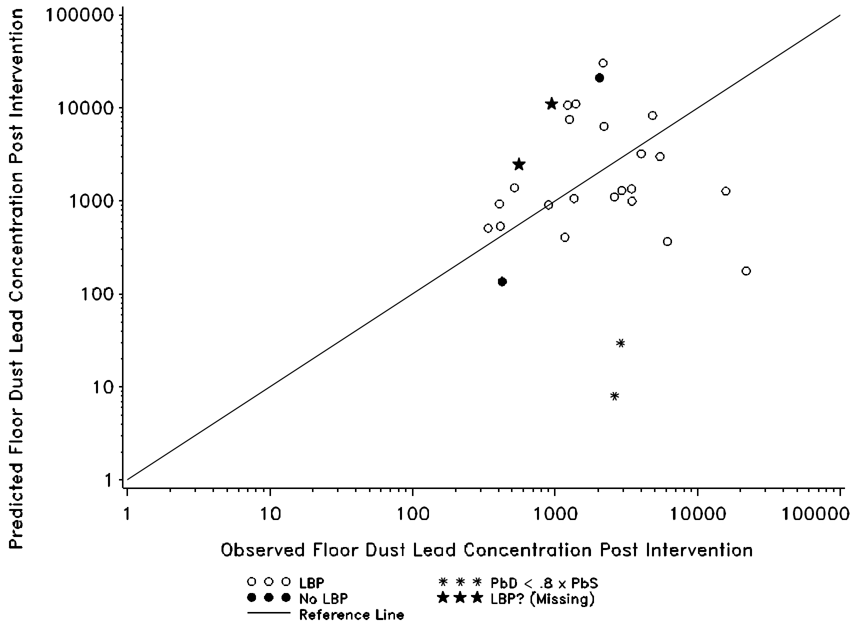

Figure 6-16. Predicted Versus Observed Average Post-Intervention Floor Dust-Lead Concentration (µg/g) (Baltimore USLADP Treatment Group Homes).

Table 6-16. Sensitivity Analysis on the Estimated Post-§403 Health Effect and Blood-Lead Concentration Endpoints for Children Aged 1-2 Years, Under Three Alternative Values (1.4, 1.9, 2.1) for the Geometric Standard Deviation (GSD) of the Blood-Lead Concentration Distribution and Under the Value Used in the Risk Analysis (1.6).[1]

Health Effect and Blood-Lead Concentration Endpoints	Predictions Using the IEUBK Model				Predictions Using the Empirical Model			
	GSD = 1.4	GSD = 1.6	GSD = 1.9	GSD = 2.1	GSD = 1.4	GSD = 1.6	GSD = 1.9	GSD = 2.1
PbB ≥ 20 (%)	0.0404	0.0539	0.0742	0.0865	0.378	0.406	0.430	0.440
PbB ≥ 10 (%)	1.46	1.66	1.93	2.07	4.56	4.70	4.83	4.88
IQ < 70 (%)	0.0977	0.0984	0.0994	0.0999	0.110	0.110	0.111	0.111
IQ decrement ≥ 1 (%)	27.8	28.3	28.8	29.1	36.2	36.3	36.4	36.5
IQ decrement ≥ 2 (%)	3.94	4.31	4.77	5.01	9.11	9.30	9.47	9.53
IQ decrement ≥3 (%)	0.731	0.858	1.03	1.12	2.82	2.93	3.02	3.06
Average IQ decrement (# points)	0.841	0.848	0.857	0.862	1.00	1.00	1.01	1.01

[1] The specified GSD represents variability associated with blood-lead concentrations in children aged 1-2 years who are exposed to the same set of environmental-lead levels. Health effects are calculated assuming the following:
- Example dust-lead loading standards of 100 µg/ft^2 for floors and 500 µg/ft^2 for window sills
- Example soil-lead concentration standard of 2000 µg/g
- Paint maintenance is performed if more than 5 ft^2, but less than 20 ft^2 of deteriorated lead-based paint exists
- Paint abatement is performed if more than 20 ft^2 of deteriorated lead-based paint exists

Shaded cells correspond to results presented in Table 6-7 (under example options "C"). Only IQ decrement and occurrences of IQ < 70 that result from exposure to lead-based paint hazards are considered in calculating health effect endpoints.

6.4.7 Alternative Estimates for Daily Dietary Lead Intake Assumed in Fitting the IEUBK Model

Section 5.4.7 considered how alternative values for daily dietary lead intake in children aged 1-2 years affected IEUBK model-based, pre-§403 estimates of the health effect and blood-lead concentration endpoints. The alternative values were 1.29 µg and 3.53 µg, compared to the value of 5.78 µg considered in the risk analysis. In this section, post-§403 health effect and blood-lead concentration endpoints are estimated (using the IEUBK model, under a single set of example options for standards) under these same alternative assumptions on daily dietary lead intake. See Section 5.4.7 for details on how the alternative values were selected.

Effect on risk analysis: Under the two alternative daily diet intake values (as well as the default value used in the risk analysis), Table 6-17 presents the IEUBK model-predicted post-§403 health effect and blood-lead concentration endpoints for the example standards provided in the footnote to the table. The probability of a child having a blood-lead concentration at or above 20 µg/dL is reduced by 34% (from 0.0539% to 0.0355%) when daily dietary lead intake decreases from 5.78 µg to 1.29 µg, while the probability of a child having a blood-lead concentration at or above 10 µg/dL is reduced by 20% (from 1.66% to 1.32%).

Table 6-17. Sensitivity Analysis on the IEUBK Model-Predicted Post-§403 Health Effect and Blood-Lead Concentration Endpoints for Children Aged 1-2 Years, Under Two Alternative Values (1.29 µg, 3.53 µg) for the Daily Lead Dietary Intake Parameter and Under the Value Used in the Risk Analysis (5.78 µg).[1]

Health Effect and Blood-Lead Concentration Endpoints	IEUBK Model-Predicted Post-§403 Estimates		
	Lead intake: 1.29 µg/day	Lead intake: 3.53 µg	Lead intake: 5.78 µg
PbB ≥ 20 (%)	0.0355	0.0497	0.0539
PbB ≥ 10 (%)	1.32	1.43	1.66
IQ < 70 (%)	0.0970	0.0967	0.0984
IQ decrement ≥ 1 (%)	26.4	24.6	28.3
IQ decrement ≥ 2 (%)	3.62	3.67	4.31
IQ decrement ≥3 (%)	0.658	0.744	0.858
Average IQ decrement (# points)	0.821	0.791	0.848
Geometric mean blood-lead conc. (µg/dL)	2.68	2.53	2.74

[1] Health effects are calculated assuming the following:
- Example dust-lead loading standards of 100 µg/ft^2 for floors and 500 µg/ft^2 for window sills
- Example soil-lead concentration standard of 2000 µg/g
- Paint maintenance is performed if more than 5 ft^2, but less than 20 ft^2 of deteriorated lead-based paint exists
- Paint abatement is performed if more than 20 ft^2 of deteriorated lead-based paint exists

Shaded cells correspond to results presented in Table 6-7 (under example options "C"). Only IQ decrement and occurrences of IQ < 70 that result from exposure to lead-based paint hazards are considered in calculating health effect endpoints.

In general, the impact of varying the daily dietary lead intake on the estimated endpoints is minimal. For example, the geometric mean post-§403 blood-lead concentration for daily dietary lead intakes of 1.29 and 5.78 µg were 2.74 and 2.68 µg/dL, respectively. The post-§403 geometric mean is computed by multiplying the pre-§403 geometric mean (determined by NHANES III) by the ratio of the model-predicted geometric means (see appendix F1 and Step 3 in Section 6.2). The ratio (post-§403 geometric mean divided by pre-§403 geometric mean) is determined by fitting the IEUBK model to pre- and post-§403 environmental-lead data. Because changing the daily dietary lead intake has a similar effect on the IEUBK model-predicted pre- and post-§403 geometric means, the ratio of the IEUBK model-predicted geometric means is robust to variations in the daily dietary lead intake.

6.4.8 Alternative Assumptions on Paint Pica Tendencies in Children and the Effect of Paint Pica on Blood-Lead Concentration

Section 5.4.8 considered alternative assumptions on the method for obtaining a model-predicted geometric mean blood-lead concentration for children with a history of ingesting paint chips. This section considers how these alternative assumptions affect estimated post-§403 health effect and blood-lead concentration endpoints. Results of this sensitivity analysis are presented separately for each model.

6.4.8.1 Empirical Model

When applying the empirical model to characterize the distribution of blood-lead concentration in children aged 1-2 years, it is assumed that 9% of children residing in housing units with deteriorated lead-based paint ingest paint chips in some manner. The sensitivity analysis considers three alternatives to this assumed percentage: 0%, 6%, and 14%. The assumption of 0% is equivalent to making no adjustment for paint pica, while the assumptions of 6% and 14% correspond to the lower and upper limits of an approximate 95% confidence interval on the percentage of children with paint pica tendencies in the Rochester Lead-in-Dust study.

Effect on risk analysis: Table 6-18 presents the post-§403 health effect and blood-lead concentration endpoints, as estimated by the empirical model, under the three alternative assumptions on the percentage of children with paint pica tendencies in units with deteriorated lead-based paint (the assumed set of example options for the standards is provided in a footnote to the table). Values under the 9% assumption used in the risk analysis are also included in this table for comparison purposes.

Results in Table 6-18 indicate that as the assumed pica percentage increases, the estimated endpoints decrease. The reason for this trend will be explained in terms of the estimated geometric means given in the last row. The post-§403 geometric mean is computed by multiplying the pre-§403 geometric mean (determined by NHANES III) by the ratio of the model-predicted geometric means (see Appendix F1 and Step 3 in Section 6.2). A total of 55 housing units in the HUD National Survey contained deteriorated lead-based paint. Upon conducting paint interventions under the example standards considered in Table 6-18, only 9 housing units continued to contain deteriorated lead-based paint. Therefore, increasing the percentage of children in such housing who have paint pica tendencies increases the pre-§403 model-predicted geometric mean more than the post-§403 model-predicted geometric mean. Therefore, increasing the percentage of children with paint pica decreases the ratio of the model-predicted geometric means and consequently reduced the post-§403 geometric mean.

The change in the estimated endpoints (based on the empirical model) is generally small. The percentage of children with blood-lead concentration greater than or equal to 20 µg/dL increased by 6.9% (from 0.406% to 0.434%) when the 9% assumption was decreased to 0%; the percentage increase in other endpoints is even less. When the assumption is increased from 9% to 14%, a 3.7% decline in the percentage of children with blood-lead concentration greater than or equal to 20 µg/dL (from 0.406% to 0.391%) is observed.

Table 6-18. Sensitivity Analysis on the Empirical Model-Predicted Post-§403 Health Effect and Blood-Lead Concentration Endpoints for Children Aged 1-2 Years, Under Three Alternative Values (0%, 6%, 14%) for the Percentage of Children with Paint Pica Tendencies, and Under the Value Used in the Risk Analysis (9%).[1]

Health Effect and Blood-Lead Concentration Endpoints	0%	6%	9%	14%
PbB ≥ 20 (%)	0.434	0.415	0.406	0.391
PbB ≥ 10 (%)	4.87	4.76	4.70	4.61
IQ < 70 (%)	0.111	0.111	0.110	0.110
IQ decrement ≥ 1 (%)	36.7	36.4	36.3	36.2
IQ decrement ≥ 2 (%)	9.55	9.38	9.30	9.17
IQ decrement ≥3 (%)	3.05	2.97	2.93	2.86
Average IQ decrement (# points)	1.01	1.01	1.00	1.00
Geometric mean blood-lead concentration (µg/dL)	3.048	3.038	3.034	3.026

[1] Health effects are calculated assuming the following:

- Example dust-lead loading standards of 100 µg/ft^2 for floors and 500 µg/ft^2 for window sills
- Example soil-lead concentration standard of 2000 µg/g
- Paint maintenance is performed if more than 5 ft^2, but less than 20 ft^2 of deteriorated lead-based paint exists
- Paint abatement is performed if more than 20 ft^2 of deteriorated lead-based paint exists

Shaded cells correspond to results presented in Table 6-7 (under example options "C"). Only IQ decrement and occurrences of IQ < 70 that result from exposure to lead-based paint hazards are considered in calculating health effect endpoints.

6.4.8.2 IEUBK Model

The approach to accounting for the effects of paint pica on geometric mean blood-lead concentrations estimated from the IEUBK model is more complex than that for the empirical model, due to the greater number of assumptions going into the approach. Assumptions in the risk analysis are as follows:

- 9% of children aged 1-2 years have paint pica tendencies
- 0.03% of children aged 1-2 years living in housing units containing damaged lead-based paint have recently ingested paint chips.
- children aged 1-2 years who recently ingested paint chips have a blood-lead concentration of 63 µg/dL.
- children aged 1-2 years who ingested paint chips at some time, but not recently, have a 3 µg/dL increase in their geometric mean blood-lead concentration from children who do not ingest paint chips.

In the sensitivity analysis, three sets of alternative assumptions were considered:

Alternative set #1: Assumes 0% of children have paint pica tendencies. (This is equivalent to making no adjustment for paint pica.)

Alternative set #2: Assumes that pica tendencies have a lower impact than that observed in the risk analysis:

- 6% of children aged 1-2 years have paint pica tendencies (the lower bound of a 95% confidence interval on the percentage in the Rochester Lead-in-Dust study).
- 0.01% of children aged 1-2 years living in housing units containing damaged lead-based paint have recently ingested paint chips.
- children aged 1-2 years who recently ingested paint chips have a blood-lead concentration of 55 µg/dL (a low estimate based on information from McElvaine et al., 1992).
- children aged 1-2 years who ingested paint chips at some time, but not recently, have a 15% increase in their geometric mean blood-lead concentration from children who do not ingest paint chips (the lower bound of a 95% confidence interval on the percentage increase as estimated from the Rochester Lead-in-Dust study).

Alternative set #3: Assumes that pica tendencies have a larger impact than that observed in the risk analysis:

- 14% of children aged 1-2 years have paint pica tendencies (the upper bound of a 95% confidence interval on the percentage in the Rochester Lead-in-Dust study).
- 0.10% of children aged 1-2 years living in housing units containing damaged lead-based paint have recently ingested paint chips.
- children aged 1-2 years who recently ingested paint chips have a blood-lead concentration of 63 µg/dL.
- children aged 1-2 years who ingested paint chips at some time, but not recently, have a 100% increase in their geometric mean blood-lead concentration from children who do not ingest paint chips (the upper bound of a 95% confidence interval on the percentage as estimated from the Rochester Lead-in-Dust study).

Effect on risk analysis: Table 6-19 presents estimated post-§403 endpoints, as estimated by the IEUBK model under the three alternative sets of assumptions, as well as under the set of assumptions used in the risk analysis. As seen in Table 6-18, the estimated endpoints decrease as the prevalence of paint pica and the effect of paint pica on blood-lead concentration increases. The reason for the decreasing trend is similar to that explained in the previous subsection.

According to Table 6-19, the set of pica assumptions considered in the risk analysis yields estimated endpoints closer to those under the low-end alternative sets (sets #1 and #2) than under the high-end alternative set #3. The percent increase in the estimated endpoints between the risk analysis assumptions and alternative set #1 is no higher than 9%, while percent declines between the risk analysis assumptions and alternative set #3 are as high as 35% (e.g., the percentage of children with blood-lead concentrations at or above 20 µg/dL declines from 0.0539% to 0.0348%). Therefore, if assumptions on the prevalence and health effects of pica are actually greater than those considered in the risk analysis, the post-§403 estimated endpoints may be less than those estimated in the risk analyses.

6.4.9 Standard Errors for Health Effect and Blood-Lead Concentration Endpoints Due to Sampling Variability

The health effect and blood-lead concentration endpoints presented in Tables 6-4 to 6-7 are based on models for predicting blood-lead concentration from environmental lead measured in the HUD National Survey, conversions between various types of measured data, assumed relationship between IQ point loss and blood-lead concentration, and assumptions on the post-intervention environmental-lead levels. Earlier subsections investigated the sensitivity of the risk analysis to assumptions on conversions, relationship between IQ point loss and blood-lead concentration, and post-intervention environmental-lead levels by modifying the assumptions and recalculating the health effect and blood-lead concentration endpoints. In this section, uncertainty in the estimated post-§403 health effect and blood-lead concentration endpoints as a result of sampling variability in the HUD National Survey and NHANES III is characterized.

As described in Section 3.3, the HUD National Survey collected samples from 284 homes. The environmental-lead levels in these homes are used to represent a sample of the environmental-lead levels in the nation's housing. If a different set of 284 homes was sampled, then the estimated health effect and blood-lead concentration endpoints would be different. For three sets of example options for the §403 standards, statistical analyses were conducted to characterize the variability in the estimated post-§403 health effect and blood-lead concentration endpoints due to the sampling variability of the 284 homes. For each set of example standards, standard errors were computed for each of the estimated health effect and blood-lead concentration endpoints based on a Monte Carlo (bootstrap) analysis (Efron and Tibshirani, 1993). The standard errors were derived by recomputing the endpoints for each of 1,000 different samples of size 284 drawn with replacement from the 284 homes. For each of the 1,000 samples generated, a sample was taken with replacement from the 987 children aged 1-2 years in the NHANES III, Phase 2 data. Then, for each of these 1,000 sets of samples, the same procedures used in the risk management analyses (Section 6.2) were applied to compute each of the endpoints.

Table 6-19. Sensitivity Analysis on the IEUBK Model-Predicted Post-§403 Health Effect and Blood-Lead Concentration Endpoints for Children Aged 1-2 Years, Under Three Alternative Sets of Assumptions on Paint Pica Effects, and Under the Set of Assumptions Used in the Risk Analysis.[1]

Health Effect and Blood-Lead Concentration Endpoints	Pica Assumptions in the Risk Analysis	Pica Alternative Set #1 (no adjustment)	Pica Alternative Set #2 (low adjustment)	Pica Alternative Set #3 (high adjustment)
PbB ≥ 20 (%)	0.0539	0.0586	0.0568	0.0348
PbB ≥ 10 (%)	1.66	1.74	1.71	1.34
IQ < 70 (%)	0.0984	0.0988	0.0986	0.0972
IQ decrement ≥ 1 (%)	28.3	28.6	28.5	27.1
IQ decrement ≥ 2 (%)	4.31	4.45	4.40	3.69
IQ decrement ≥ 3 (%)	0.858	0.904	0.887	0.663
Average IQ decrement (# points)	0.848	0.853	0.852	0.830
Geometric mean blood-lead concentration (µg/dL)	2.74	2.755	2.752	2.715

[1] Health effects are calculated assuming the following:

- Example dust-lead loading standards of 100 µg/ft² for floors and 500 µg/ft² for window sills
- Example soil-lead concentration standard of 2000 µg/g
- Paint maintenance is performed if more than 5 ft², but less than 20 ft² of deteriorated lead-based paint exists
- Paint abatement is performed if more than 20 ft² of deteriorated lead-based paint exists

Shaded cells correspond to results presented in Table 6-7 (under example options "C"). Only IQ decrement and occurrences of IQ < 70 that result from exposure to lead-based paint hazards are considered in calculating health effect endpoints.

Table 6-20 displays the standard errors for the estimated health effect and blood-lead concentration endpoints under each of the three sets of example standards, along with estimates of the standard errors of these estimates. Approximate 95% confidence intervals for the estimated endpoints can be computed by adding and subtracting two times the standard error to the respective endpoint. For instance, under the first set of standards presented in Table 6-20, the lower bound of the 95% percent confidence interval for the percentage of homes exceeding any of the standards is 17.5 – (2 * 2.1) = 13.3%, while the upper bound is 17.5 + (2 * 2.1) = 21.7%.

In general, the standard errors displayed in Table 6-20 are quite small. This suggests that other sources are likely to have a larger impact on overall uncertainty than the sampling variability in the HUD National Survey and in NHANES III. Other sources include uncertainty associated with the conversion equations, assumptions on post-intervention environmental-lead levels, the ability of the models (IEUBK and empirical) to predict blood-lead concentration from environmental levels, the relationship between IQ point loss and blood-lead concentration, the

Table 6-20. Estimates of Standard Errors Associated with Estimated Post-§403 Health Effect and Blood-Lead Concentration Endpoints and with Number of Homes Exceeding Standards, for Three Sets of Example Options for the §403 Standards.

Example Options for Standards						
Floor Dust-Lead Loading	400		100		25	
Window Sill Dust-Lead Loading	800		500		25	
Soil-Lead Concentration	5000		2000		500	
Paint Maintenance Trigger	10		5		0	
Paint Abatement Trigger	100		20		5	
	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
STANDARD/TARGET	**Percentage of Homes Exceeding Example Standards***					
Floor Dust	0.00	0.00	4.04	1.13	13.8	1.7
Window Sill Dust	10.3	1.7	12.5	1.9	48.1	2.7
Soil Removal	0.215	0.273	2.49	0.87	11.8	1.8
Interior Paint Maintenance	2.80	0.92	2.92	0.94	1.08	0.59
Exterior Paint Maintenance	3.84	1.11	3.49	1.05	1.15	0.59
Interior Paint Abatement	0.453	0.382	2.43	0.87	5.35	1.26
Exterior Paint Abatement	3.03	0.97	5.77	1.34	9.26	1.61
Exceeding Any Standard	17.5	2.1	21.8	2.3	53.7	2.7
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on Empirical Model)**						
PbB≥20 (%)	0.458	0.094	0.406	0.088	0.317	0.074
PbB≥10 (%)	5.03	0.53	4.70	0.52	4.09	0.49
IQ<70 (%)	0.112	0.002	0.110	0.002	0.108	0.002
IQ decrement≥1 (%)	37.1	1.3	36.3	1.3	34.7	1.3
IQ decrement≥2 (%)	9.79	0.78	9.30	0.78	8.34	0.75
IQ decrement≥3 (%)	3.16	0.39	2.93	0.38	2.49	0.35
Avg. IQ decrement	1.02	0.03	1.00	0.03	0.971	0.027
Predicted Health Effect and Blood-Lead Concentration Endpoints (Based on IEUBK Model)**						
PbB ≥ 20 (%)	0.290	0.081	0.0539	0.0429	0.00198	0.00354
PbB≥10 (%)	3.92	0.56	1.66	0.59	0.250	0.167
IQ<70 (%)	0.107	0.002	0.0984	0.0024	0.0909	0.0011
IQ decrement≥1 (%)	34.5	1.5	28.3	2.3	15.1	2.6
IQ decrement≥2 (%)	8.09	0.87	4.31	1.12	0.978	0.469
IQ decrement≥3 (%)	2.37	0.40	0.858	0.367	0.0976	0.0801
Avg. IQ decrement	0.964	0.030	0.848	0.038	0.666	0.031

* Standard error estimates for percentage of homes affected by standards are based on 2,000 bootstrap replicates.
** Standard error estimates for health effects are based on 1,000 bootstrap replicates.

assumption of lognormality in blood-lead concentration, and uncertainty in sample mean and sample standard deviation (on a log scale) associated with blood-lead concentration. In addition, these standard errors were computed assuming simple random sampling and do not account for the complex survey design employed in the HUD National Survey.

6.5 CONCLUSION

The primary purpose of the risk management analyses is to develop and apply methodology for analyzing example options for the §403 standards. To that end, various example options for the §403 standards for lead in paint, dust, and soil were evaluated in this chapter. The example options were assessed by predicting the incremental risk reductions expected to result after interventions are conducted in response to the proposed §403 rule.

Estimating the impact of the proposed §403 rule on health effect and blood-lead concentration endpoints for children aged 1-2 years is a very complicated and challenging problem. A series of technical analyses were conducted to address this problem. The following four points summarize the analyses conducted.

- First, estimating the impact of the proposed §403 rule required estimating the distribution of environmental-lead levels expected to result from promulgation of the §403 standards. This was accomplished by assuming that homeowners would take actions in response to the various example standards. Predicting the actual responses of homeowners to the proposed rule is a difficult problem. For the purposes of the risk management analyses, a set of six interventions were defined and utilized for the analyses of various example options for the §403 standards: one dust intervention, one soil intervention, two exterior paint interventions, and two interior paint interventions. The effectiveness and duration of effectiveness of each of the six interventions is defined in terms of environmental-lead levels. To the extent possible, the assumed efficacies and durations are based on data in the scientific literature.

- Second, determining the impact of the various example options for the proposed §403 standards required estimating the numbers and percentages of homes affected by each example option for the §403 standards for lead in paint, dust, and soil. The HUD National Survey is the most complete and extensive set of data on lead levels in paint, dust, and soil in the nation's housing. However, this study was conducted over six years ago, collected measures of dust lead that required extensive conversions, was limited to homes built prior to 1979, and involved only 284 homes. A detailed and involved methodology was developed to update the numbers of homes to 1997, convert the dust lead measures, and estimate environmental-lead levels in homes built post-1979.

- Third, estimating the impact of the proposed §403 rule required estimating the distribution of blood-lead concentrations for children aged 1-2 expected to result from example options for the §403 standards. Even if the distribution of environmental-lead levels for example options for the proposed §403 standards could be determined, estimating the distribution of blood-lead concentrations associated with the post-§403 environmental-lead levels is a very complicated problem. There are many factors other than the measured amount of lead in the child's home that contribute to a child's blood-lead concentration: nutrition, activity patterns, and lead exposures at day cares, schools, and at play areas outside of the home. More factors are listed in Section 4.1.2. Predicting a blood-lead concentration distribution associated with a specific set of environmental exposures is a difficult problem. Predicting the national distribution of blood-lead concentrations across a wide range of environmental exposures for children aged 1-2 years is an order of magnitude more complex.

Two different types of models were used to predict blood-lead concentrations: EPA's IEUBK model and an empirical model developed for this study. The IEUBK model has been studied extensively, has been utilized at a wide number of sites, and has undergone peer review by EPA's Science Advisory Board. However, the application of the IEUBK model in this study differs from those it was developed for. The empirical model was developed specifically for this study based on the data collected in a single study (Lanphear et al, 1995). It has not undergone peer review, has not been applied elsewhere, and has not been studied in much depth. The two models function and behave very differently, and that is why two different models were used.

A detailed and involved methodology was developed to predict the distribution of blood-lead concentrations for children aged 1-2 years associated with distributions of environmental-lead levels expected to result for various example options for the proposed §403 standards. It is essential that we recognize that the predicted post-§403 blood-lead distributions may not be very accurate, are not very robust, and should not be used as indicators of what will happen in the future following promulgation of the §403 standards for lead in paint, dust, and soil. On the other hand, the predicted post-§403 blood-lead distributions are useful for making relative comparisons among example options for the §403 standards.

! Fourth, characterizing health benefits associated with the reduction of lead-based paint hazards under various example options for the proposed §403 standards required estimation of health effects from blood-lead concentrations. Seven health effect and blood-lead concentration endpoints were used to characterize the health benefits associated with various example options for the proposed §403 standards for lead in paint, dust, and soil. The prediction of health effects related to IQ scores from blood-lead distributions is based on the best available data and tools. Nevertheless, as stated above for blood-lead concentration, predicted post-§403 health effect and blood-lead concentration endpoints are meant to be used only for making relative comparisons between example options for the §403 standards.

Tables, developed from these four analyses, that predict the health effect and blood-lead concentration endpoints for children aged 1-2 years in the year 1997 following proposal of the §403 rule for example standards are presented in this chapter. The primary conclusion from these analyses is that health benefits tend to be most sensitive, and numbers of affected housing units least sensitive to changes in the example standards on dust-lead loadings and soil-lead concentration when these example standards are at the upper end of the ranges considered. At the lower end of the ranges of the example dust and soil standards, health benefits are less sensitive, while the numbers of affected housing units are highly sensitive.

For example, consider again the plots displayed in Figure 6-11a for the various example standards. The percentage of children aged 1-2 years predicted to have a blood-lead concentration greater than or equal to 10 µg/dL, based on the IEUBK model predictions, following promulgation of the example option labeled as point A (3.9%) is twice as large as that for the example option labeled as point C (1.7%). However, the percentages of homes affected by the two example options (17.5% and 21.8%) are similar. On the other hand, the percentage of children aged 1-2 years predicted to have a blood-lead concentration greater than or equal to 10 µg/dL following promulgation of the example option E (0.84%) is very similar to that predicted for the example option F (0.25%) even though the percentages of homes affected by the two example options are substantially different (38.4% and 53.7%).

A secondary conclusion of the analyses is that there are relatively small differences in the selected endpoints and percentages of homes affected among the example options considered for the paint intervention trigger levels. However, this conclusion must be interpreted with caution, as the available data on deteriorated lead-based paint in the nation's housing stock were considered very limited, and the models are limited in their ability to handle paint as a predictor variable. Because there is not sufficient data and information to perform a quantitative analysis of example options for the paint intervention triggers, it may be best to only qualitatively evaluate these options.

When comparing values of the health effect and blood-lead concentration endpoints between baseline (pre-§403) and post-§403 (under the example standards studied) conditions, the largest differences occurred for the percentages of children with blood-lead concentration at or above 10 or 20 µg/dL and the percentages of children with IQ decrement of greater than or equal to 2 or 3. Smaller declines from baseline were observed in the percentage of children with IQ score less than 70, the percentage of children with IQ decrement of greater than 1, and average IQ decrement in a child. Across all endpoints, larger differences from baseline were observed under the IEUBK model than under the empirical model.

The major limitation associated with how example options for environmental-lead standards were investigated in this chapter is the limited amount of data available for estimating pre- and post-§403 environmental-lead levels. This includes a lack of nationally-representative dust-lead loading data (representing both pre- and post-§403 conditions) where samples were collected by wipe techniques. This data limitation constitutes one of the major data gaps and limitations for the risk management analyses. To help alleviate this limitation, sensitivity analyses were conducted to examine the impact of changes in post-intervention environmental-lead levels on risk reductions and on determining wipe-equivalent dust-lead loadings for comparisons to example standards and for determining a post-intervention blood-lead concentration distribution. Two conclusions from the sensitivity analysis on dust-lead loading data were as follows:

- Estimated numbers of housing units in which dust cleanings are triggered based on pre-intervention dust-lead loadings may be biased by as many as one million units in either direction due to necessary conversions of these loadings to wipe equivalents.

- Deviating the assumptions on post-intervention (wipe) dust-lead loadings (40 µg/ft² for floors and 100 µg/ft² for window sills) most notably affected estimated endpoints representing extreme effects (i.e., high blood-lead levels, large IQ decrements).

One component of the sensitivity analysis examined an alternative approach to estimating health effect and blood-lead concentration endpoints which does not require specifying post-intervention environmental-lead levels (Section 6.4.5). This approach narrowed the extent to which the IEUBK and empirical models differed in their estimates of post-intervention health effect and blood-lead concentration endpoints.

The analyses of various example options for the §403 standards clearly indicates that the risks to children's health associated with exposures to lead in paint, dust, and soil can be reduced. The standards established by the proposed §403 rule (once defined) will help reduce the health risks to our nation's children. Depending on the methodology utilized, an illustrative example for the §403 standards (floor dust-lead loading of 100 µg/ft², window sill dust-lead loading of 500 µg/ft², soil-lead concentration of 2000 µg/g, paint maintenance warranted at 5 ft² deteriorated LBP, and paint abatement at 20 ft² deteriorated LBP) indicates that the percentage of children aged 1-2 years with a blood-lead concentration at or above 10 µg/dL ranged from 1.83 to 4.85 % compared to the current baseline estimate of 5.75%. This corresponds to approximately 70 to 300 thousand fewer children aged 1-2 years old with a blood-lead concentration at or above 10 µg/dL. Reductions in other health measures would also be achieved. In addition, reductions in health measures would also be achieved for children of other age groups.