Final Report
for the
Comparison of HUD Risk Assessment Methodology to Methods Used at the Bunker Hill Superfund Site in Idaho for the Identification of the Risk from Lead in House Dust

Prepared for:

US Department of Housing and Urban Development

Prepared by:

Panhandle Health District
114 West Riverside
Kellogg, Idaho 83837
208-783-0707

and

TerraGraphics Environmental Engineering, Inc.
121 S. Jackson
Moscow, Idaho 83843
208-882-7858

Grant # IDLTS0096-03

March 20, 2006

Table of Contents

List of Tables

List of Figures

List of Appendices

Appendix A

List of Acronyms

mg/cm^2	milligrams per square centimeter
mg/dl	micrograms per deciliter
mg/ft^2	micrograms per square foot
mg/kg	milligrams per kilogram
mg/m^2	milligrams per square meter
$mg/m^2/day$	milligrams per square meter per day
ANOVA	Analysis of Variance
ATSDR	Agency for Toxic Substances and Disease Registry
bdls	below-detection-limit findings
BHSS	Bunker Hill Superfund Site
BRM	Baltimore Repair and Maintenance
Category 1	Low Risk: no lead paint damage
Category 2	Medium Risk: damaged paint, no soil or dust hazard
Category 3a	High Risk: dust hazard identified
Category 3b	High Risk: soil hazard identified
CDC	Centers for Disease Control
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
USEPA	Unites States Environmental Protection Agency
USEPA-NLLAP	Environmental Protection Agency-National Lead Laboratory Accreditation Program
HEPA	High efficiency particulate air
HHRA	Human Health Risk Assessment for the Coeur d'Alene Basin
HUD	United States Department of Housing and Urban Development
IDEQ	Idaho Department of Environmental Quality
IDHW	Idaho Department of Health and Welfare
LHIP	Lead Health Intervention Program
NAS	National Academy of Sciences
OU	Operable Units
PHD	Panhandle Health District
QAP	Quality Assurance Plan
RAO	Remedial Action Objective
ROD	Record of Decision
ROW	Rights-of-way
SOP	Standard Operating Procedure
XRF	X-ray Fluorescence

EXECUTIVE SUMMARY

Background: The Bunker Hill Superfund Site (BHSS) is located in the Coeur d'Alene River Basin in northern Idaho. Environmental response, public health intervention, and cleanup activities have been underway in the "Box," a 21 square mile area surrounding the former smelter complex, since closure in 1981. The area was the scene of epidemic childhood lead poisoning in the 1970s associated with faulty smelter operations. In 2002, the cleanup was extended to the greater Coeur d'Alene River Basin, expanding about 20 miles upriver and 35 miles downriver of the Box. This cleanup strategy is to remove contaminated soils from children's environment to reduce direct soil exposure and effect concurrent reductions in house dust lead levels. Lead in house dust has long been recognized as a primary source of lead intake and absorption among children in several environments and was identified decades ago as the predominant source of exposure for young children in both the Box and Basin.

Soil remediation in the Box is more than 95% complete and the 350 mg/kg yard soil and 500 mg/kg house dust lead means have been met for all communities. Nearly three in four Box children had blood lead levels exceeding 10 µg/dl in the late 1980s. The incidence of blood lead levels 10 µg/dl or greater is now less than 3% among children tested in the Box. In the Basin, about 15% of the children tested from 1996-1999 had blood lead levels exceeding 10 µg/dl. Between 2% and 5% of Basin children tested showed high blood lead levels in the most recent surveys, although participation has been low. Despite the success of the Box soil cleanup, about 1% of the population has blood lead levels greater than 15 µg/dl, and 5-10% of homes continue to exhibit house dust levels greater than 1,000 mg/kg. Some of the continuing high lead levels in dust and blood are likely associated with lead-based paint. No formal abatement of lead-based paint was accomplished during the cleanup.

Study Description and Objectives: Dust monitoring techniques employed at the BHSS differ substantially from U.S. Department of Housing and Urban Development (HUD) methodologies of lead risk assessment. It is unknown if homes that register hazards in a HUD risk assessment would be identified using the BHSS dust sampling methods. This study was designed to evaluate the risk determined by a HUD lead based paint risk assessment to the risk determined by house dust lead concentrations and loading rates collected at the BHSS. To compare the results of BHSS and HUD risk assessment methods, combined HUD lead-based paint / BHSS soil and dust risk assessments were performed at 75 residential units in three communities: i) the *Box,* a mining/smelting impacted area where remediation is 95% complete; ii) the *Basin,* a mining impacted area where remediation is not complete; and iii) *Background* communities in northern Idaho unaffected by mining.

The study objectives are to: i) compare the HUD and BHSS dust sampling and risk assessment techniques; ii) quantify the relationship between soil and paint lead sources to house dust lead; iii) determine differences in lead levels among the communities; and iv) provide baseline soil, dust and paint lead data in rural Idaho communities.

Selection of the 75 houses was accomplished by door-to-door solicitation. Primary screening criteria were houses built prior to1960 (preferably pre-1940), families with children, and the presence of a vacuum cleaner that could be sampled. To the extent possible, variables relating to house age, condition of paint, family size and activities were kept consistent among all participating households. The majority of homes selected in the Box, Basin, and Background communities were single-family occupied homes built prior to 1970.

HUD Methodology. *Home Visual Assessment:* All painted surfaces and bare soils were assessed at each residence to classify paint condition and overall condition of the building and identify interior or exterior problems that could lead to deteriorating paint. *Paint Sampling:* All painted surfaces were tested using X-ray Fluorescence (XRF) by certified Lead Risk Assessors according to HUD guidelines. XRF results were classified as positive for levels ≥ 1.0 mg/cm^2. Paint chip samples were not collected to avoid using destructive sampling techniques. *Dust Wipe Sampling:* Dust wipe samples were generally collected from floor areas that were likely to be contacted by young children, such as play areas within rooms, room midpoints, areas immediately underneath windows and window sills. *Soil Sampling:* Soil sampling focused on bare soil areas where children were likely to play including outdoor play areas, areas identified as being located within the building's driplines, vegetable gardens, pet sleeping areas, bare pathways, and sandboxes. Soil samples were collected for all driplines, regardless of grass cover status for this study.

BHSS Methodology. *Visual Assessment:* The BHSS visual assessment procedure parallels the HUD visual assessment. *Dust Sampling Methods:* Three dust sampling techniques have been applied at the BHSS: vacuum bag dust, floor mat dust, and Baltimore Repair and Maintenance (BRM). Sampling of residents' home vacuum dust has been practiced since 1974 and used as a general representation of lead exposure to individuals inside the home. Since 1996, house dust has been collected using a floor mat technique that measures dust and lead loading rates (mass/area/time) at entryways into the houses. BRM sampling was used at the Site in 2000 and 2001 in a pilot project to determine interior remedial effectiveness. The BRM is a cyclone vacuum device that samples dust accumulation in carpets from random grid locations on the floor. *Soil Sampling:* All 75 homes were also sampled (or had previous soil results) using BHSS methods. As BHSS soil data were available from the CERCLA sampling, no new BHSS soil samples were collected. A clean soil concentration of 100 mg/kg was applied to participating homes in the Box as all of the homes had been previously remediated. BHSS soil samples are collected from several yard and driveway sub-areas, at four depth intervals up to 24 inches. However, only the 0-1 inch depth from different sample locations (e.g., yard, play area, driveway, flower bed, etc.) were used for this study because it is the likely exposure route. As a result, only the 0-1 inch depths were sampled at the Background homes.

Risk Comparison of the HUD and BHSS Methodologies: Both the HUD and BHSS protocols conduct a similar visual inspection to identify potential lead paint hazards in homes. The HUD protocol provides additional testing, assessment, and abatement advice that is unavailable through Superfund.

Both dust protocols consistently identify homes with little or no risk. Overall, with respect to interior dust, the HUD and BHSS protocols agreed on 56 of 74 homes, or 76%. Most of the agreement was for 50 homes that presented no excess risk, 23 of which were in the Background communities, 12 in the Basin and 15 in the Box. When supplemental samples are excluded, the BHSS protocol did not identify window sill hazards in 16% of all Box and Basin homes (4 Box and 4 Basin homes) and 2 homes (8%) in Background communities. The HUD protocol failed to identify dust lead reservoirs in about 12% of homes in the Box and Basin (3 Box and 3 Basin homes), excluding supplemental samples.

These dust results confirm the conclusions of previous investigations that the BRM and wipe techniques are likely the most appropriate for measuring interior loading and current exposure in a house. The entryway mat technique is likely the best indicator of continuing outdoor source contribution to dust lead in the house, and the vacuum bag remains the simplest sampling method for determining the need for intervention.

Determining whether soils presented a hazard was complicated by both supplemental sampling of covered driplines that would not have been sampled under typical HUD protocol and differing risk assessment threshold criteria between HUD and BHSS protocol. Ubiquitous soil lead contamination in the BHSS required sampling rights-of way and covered driplines that typically would not have been included in a HUD assessment. Additionally, the USEPA criteria of 1,200 mg/kg for bare area soils and 400 mg/kg for play area soils used in HUD protocols has been superseded by site-specific cleanup criteria in the BHSS. Adherence to the USEPA/HUD guidelines identified soil hazards that are not considered excessive under the site-specific criteria at the BHSS.

When these supplemental samples were excluded from the comparison, the HUD and BHSS protocols agree on identifying soil hazards at about 70% of homes. This included 15 Box (58%), 15 Basin (62%), and 23 Background (92%) homes. Both are effective at identifying homes with little or no soil risk. Much of the disagreement with respect to soil hazards is associated with the site-specific risk management criteria, as opposed to methodology. The HUD criteria identify soils as hazards based on lead concentrations that are acceptable under site-specific criteria in the Superfund site.

The BHSS protocol relies on yard-wide composite samples, and does not specifically address dripline samples that were identified as potential soil hazards by the HUD method. Driplines have significantly higher concentrations than other sample locations. The percentage of driplines exceeding 400 mg/kg the Basin, Box and Background communities was 28%, 20%, and 3%, respectively, compared to 20%, 4% and 0%, from all other areas around the home. The typical HUD protocol would not have identified hazards at about 33% of homes in the Basin considered as having excess risk by the BHSS criteria. Most of these hazards were identified by the supplemental sampling conducted under the study protocol. The supplemental sampling did not identify the BHSS hazard at 43% of homes from all three areas.

Soil, Paint and Dust Lead Relationships: Correlation matrices and stepwise and general linear regression models were used to quantify soil, paint and dust relationships. Dust lead concentration and loading models were evaluated by the R^2-statistic and variable significance. The soil variable selected for use in these regressions was the average of the HUD soil lead concentrations excluding the dripline results. The dripline results were excluded to maximize independence among the soil and paint variables. This average bare soil variable showed greater significance than all other soil metrics, likely indicating the importance of exposed surface soils to housedust, and was used as the surrogate for all soil lead concentrations.

The quantitative analyses suggest that dust lead concentrations and consequent lead loadings are strongly related to outdoor soil concentrations with some contribution from both exterior and interior paint to mat dust lead loading rate. These results are similar to the findings of the 1996 Coeur d'Alene Basin Exposure Study and the extended analyses of paint and soil exposures conducted in the *Human Health Risk Assessment for the Coeur d'Alene Basin* (HHRA) and the recent supplemental analyses conducted on these data by the National Academy of Science (NAS).

Dust lead concentration from vacuum bags and the BRM methodology are significantly related only to the soil variable and not to paint condition or paint lead concentration. The soil variable explains about 18% and 37% of the variation in dust lead, respectively, for vacuum bags and BRM dusts. The lead concentration in dusts collected from entryway mats is related to both soils and exterior paint condition and concentration. These variables explain about 37% of the variation in entryway mat lead concentration and the results suggest an active pathway into the home from dusts contaminated by both mining industry waste and paint in the soil.

The mat lead loading rate is the best indicator of how much lead may be moving into the home along this pathway. Selected regression analyses show that 28% of the variation in lead loading rate is explained by soil, exterior paint and interior paint. The paint variables continue to show less significance than soil. The strongest relationship was identified for the BRM loadings in the living room carpets. This model shows that soil and interior paint variables explain 41% of the variation in dust lead loading, with a relative soil contribution of 80% and paint 20%. This leads to an overall conclusion that soil likely contributes from 60%-80% of the lead to house dust.

Community Differences and Background Lead Levels in Rural Idaho: This study repeated similar sampling that occurred in 1999, comparing Box and Background homes in demographically similar, non-mining areas of rural northern Idaho. The 1999 study concluded that soils, vacuum bag, and entryway mat dust lead concentrations were significantly higher in the Box than comparable measurements in northern Idaho communities. Dust loading rates were not significantly different, but due to the increased concentration, lead loading rates were higher in the Box. This 2004 HUD investigation confirms those results, although the differences are not as great as in 1999 due to the continuing cleanup in the BHSS.

Soils: Background soil concentrations averaged less than 100 mg/kg with exception of dripline samples. The overall geometric mean for all HUD method samples in Background areas was 88 mg/kg. The mean for driplines from Background homes was 254 mg/kg, while non-dripline Background samples showed a geometric mean of 53 mg/kg lead. Samples collected by the BHSS methodologies in the Background areas showed geometric means ranging from 33 mg/kg to 120 mg/kg for various areas of the property. Overall, mean BHSS soil concentrations were 3-6 times greater than Background concentrations.

Dust: Overall, vacuum bag dust lead levels for Box and Basin communities ranged from 471 mg/kg to 551 mg/kg, respectively, while mean Background vacuum concentrations were 129 mg/kg. Dust mat sampling shows similar trends of lower concentrations and lead loading rates in Background communities compared to BHSS communities. Box homes showed a mean of 391 mg/kg for mat dust, while the Basin was not significantly different from the Box with a mean of 396 mg/kg. The Background homes showed a lower mat dust mean of 79 mg/kg. Lead loading rates were about three times greater in the Basin and Box than those in Background communities; 0.31mg/m^2/day, 0.27 mg/m^2/day and 0.09 mg/m^2/day, respectively. In this study, dust loading rates were higher, but not significantly different in Background homes. Geometric mean dust loading rates were 672 mg/m^2/day, 694 mg/m^2/day and 1,109 mg/m^2/day in Basin, Box and Background homes, respectively. The BRM was the third BHSS dust sampling method. Mean dust loadings were similar among the three communities. However, geometric mean lead concentrations and lead loadings were about four times those observed in the Background communities.

The HUD methodology showed that the percentage of homes with either interior or exterior lead-based paint hazards were similar among the three communities. The dust wipe sampling identified a few additional homes in the BHSS with lead loadings exceeding the USEPA/HUD standard compared to those homes in the Background communities.

SECTION 1.0 INTRODUCTION

1.1 Background

The Bunker Hill Superfund Site (BHSS) is located in the Coeur d'Alene Basin in northern Idaho. The site includes three Operable Units (OU). An approximate 21 square mile area, commonly referred to as the Bunker Hill Box (the Box), contains the original OU1 and OU2 (Figure 1.1). The greater Coeur d'Alene River Basin (the Basin) surrounding the Box is OU3. The Box is home to more than 7,000 people in five residential areas or communities, including the cities of Kellogg, Wardner, Smelterville, Pinehurst, and the unincorporated communities of Page, Ross Ranch, Elizabeth Park, and Montgomery Gulch. Most of the residential neighborhoods and the former smelter complex are located on the valley floor, side gulches, or adjacent hillside areas. Superfund activities were initiated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) following findings of widespread lead poisoning among local children in 1983. Environmental response, public health intervention, and cleanup activities have been underway in the Box since the smelter closure in 1981. Response activities have included health and environmental investigations, public health interventions, emergency removals, and a $200 million comprehensive cleanup plan impacting about 80% of Box homes instituted in 1991.

The cleanup strategy for the Box, adopted in the 1991 Populated Areas (OU1) Record of Decision (ROD), was based on site-specific analysis of the relationship between observed blood lead levels among children and environmental media lead concentrations at the Site. Site-wide Remedial Action Objectives (RAOs) were defined in the Non-populated Areas (OU2) ROD. The blood lead RAOs seek to reduce the incidence of high blood lead levels in the community to the following (USEPA 1991, 1992, 2002);

- less than 5% of children with blood lead levels of 10 micrograms per deciliter (μg/dl) or greater, and
- no individual child exceeding 15 μg/dl (nominally, <1% of population).

These objectives are to be achieved by a strategy that includes:

- remediation of all yards, commercial properties, and rights-of-way (ROW) that have lead concentrations greater than 1,000 milligrams per kilogram (mg/kg);
- achieving a geometric mean yard soil lead concentration of less than 350 mg/kg for each community in the site;
- controlling fugitive dust and stabilizing and covering contaminated soils throughout the site; and
- achieving geometric mean interior house dust lead levels for each community of 500 mg/kg or less, with no individual house dust level exceeding 1,000 mg/kg.

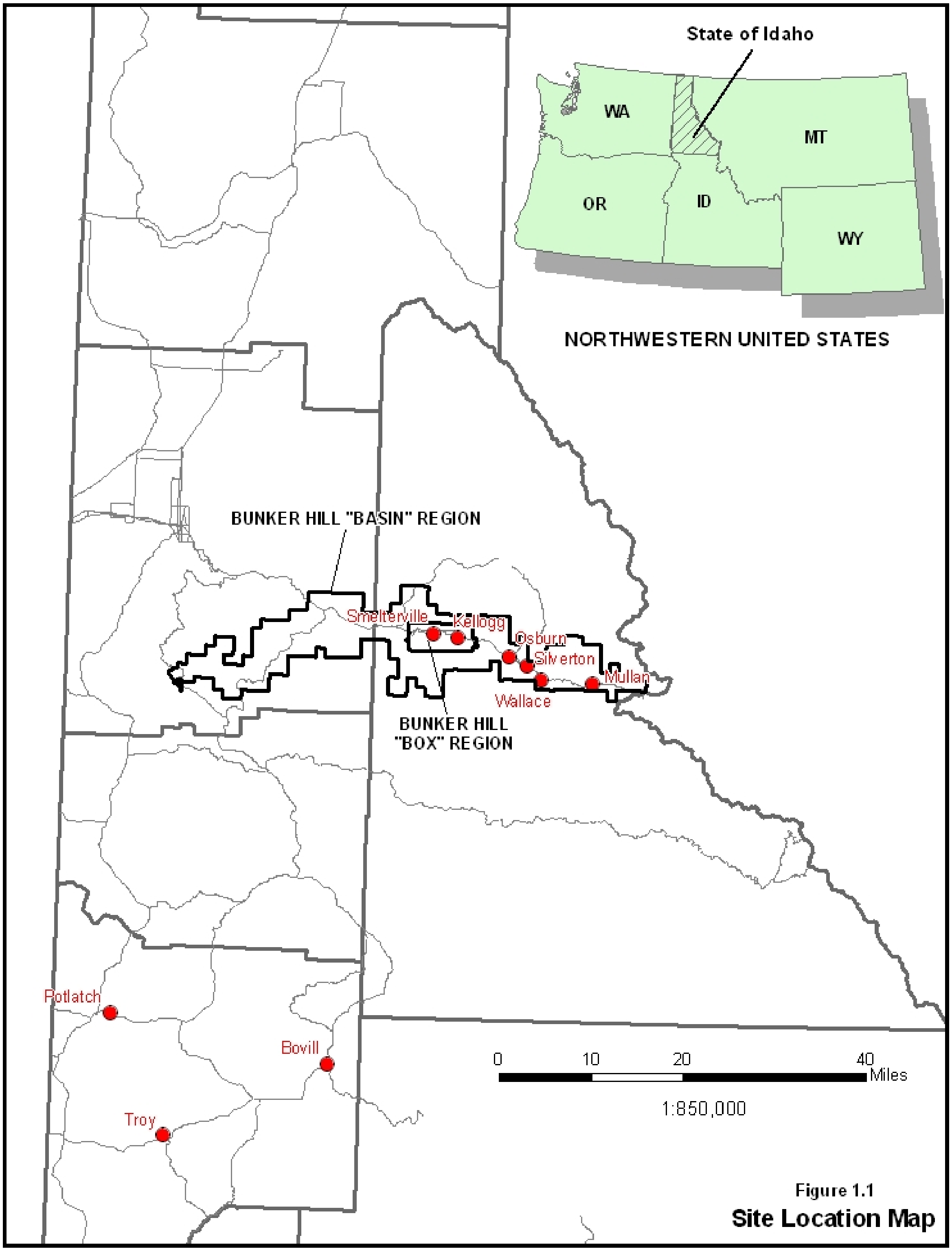


Figure 1.1
Site Location Map

The Lead Health Intervention Program (LHIP) was initiated in the Box in 1985 to minimize lead absorption during the Cleanup through health education, parental awareness, and biological monitoring efforts. The LHIP, sponsored by the Centers for Disease Control (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR), has been implemented by the local Panhandle Health District (PHD) initially through federal grants to the Idaho Department of Health and Welfare (IDHW) and more recently, through state funding provided by the Idaho Department of Environmental Quality (IDEQ). Over the past 18 years, more than 4,000 blood lead samples have been obtained from children living within the Box. Analyses of these data, in conjunction with the Remedial Investigation efforts, resulted in an integrated risk management and cleanup strategy designed to monitor and minimize children's exposures as remediation occurred over several years (TerraGraphics 1997, von Lindern et al. 2003a, TerraGraphics 2004).

Most of the soil and dust RAOs have been achieved in the Box communities. Soil remediation is about 95% complete (>1,800 yards) and the 350 mg/kg community mean soil lead concentration has been achieved. Mean house dust lead levels are below 500 mg/kg lead for all communities (TerraGraphics 2005c).

In Smelterville, where remediation is complete, geometric mean blood lead levels have been reduced from 11.6 µg/dl in 1988 to 2.6 µg/dl in 2002. Nearly three in four children site-wide had blood lead levels exceeding 10 µg/dl in the late 1980s. In 2002, no children reported high blood lead levels in Smelterville. The incidence of blood lead levels 10 µg/dl or greater is now less than 3% among children tested Box-wide (50-60% of the children on-site were tested each year through 2002) (TerraGraphics 2004, and 2005a).

About 1% of the Box population has blood lead levels greater than 15 µg/dl, and about 10% of homes continue to exhibit house dust levels greater than 1,000 mg/kg. Some of the continuing high lead levels in dust and blood are likely associated with lead-based paint. Lead paint hazards were noted in follow-up investigations of high blood lead levels and parents were advised to minimize hazards through cleaning and repairs. However, no formal abatement of lead-based paint was accomplished during the Box cleanup.

The Coeur d'Alene Basin (OU3) ROD was filed in 2002 and extended the BHSS cleanup criteria to other communities in the river basin, expanding about 20 miles upstream and 35 miles downstream of the Box. This includes another 5,000 people and a half-dozen communities. More than 30% of the yards in the Basin have soil lead levels exceeding 1,000 mg/kg and about 15% of the children tested from 1996-99 had blood lead levels exceeding 10 µg/dl, with approximately 25% of the total population tested. Following intervention activities with most of the children identified with high levels and emergency cleanup of 120 homes with high soil lead levels, about 6% of children tested in 2001-2002 showed high blood lead levels. The yard remediation program began in 2003 with 91 homes remediated, and 4% of the children tested showed high blood lead levels. Three hundred thirty-four (334) homes were remediated in 2004, and by this time, about 2% of the children tested showed high blood lead levels. However by 2003, less than 100 children participated (around 80 each year) compared to over 100 children participating in previous years. Environmental media and blood lead monitoring will continue during the Basin cleanup. Figure 1.1 shows both the BHSS and the Basin (TerraGraphics et al. 2001, USEPA 2002, NAS 2005).

Lead in house dust has long been recognized as a primary source of lead intake and absorption among children (Lanphear et al. 1998, PHD 1986). House dusts have been identified as the predominant source of exposure for young children in both the Box and Basin (Yankel et al. 1977, TerraGraphics 2000, TerraGraphics et al. 2001). It is recognized that the success of the overall cleanup strategy in both the Box and the Basin ultimately depends on reduction of interior house dust lead levels to concentrations comparable to post-remedial soils. The Populated Areas ROD states: “All homes with house dust lead concentrations equal to or exceeding 1,000 mg/kg lead will have a one time cleaning of residential interiors after completion of site-wide remedial actions. If interior house dust sampling indicates that house dust lead concentrations exceed a site-wide average of 500 mg/kg lead, the need for additional cleaning will be evaluated” (USEPA 1991, USEPA 1992).

This cleanup strategy was developed in response to studies suggesting that interior dust remediation was not effective in permanently reducing house dust lead concentrations prior to completion of exterior source controls. Interiors of houses that were completely remediated in 1990 were recontaminated by outdoor sources within one year (CH2M HILL 1991). As a result, remediation efforts were directed toward outdoor sources, including residential yard soils, commercial properties, and ROWs. In the interim, monitoring of blood lead levels and interior dust concentrations continued through the LHIP. Parents were counseled regarding household and personal hygiene and were encouraged to clean frequently. Access to high efficiency particulate air (HEPA) vacuums was provided for families not having an available vacuum cleaner.

Soil remediation is nearly complete in the Box with more than 1,800 yards have been cleaned-up. House dust lead exposures to Box children participating in the LHIP have decreased considerably since 1974 when average levels in Smelterville were 11,000 mg/kg. Since fugitive dust control and yard soil removal efforts were initiated in 1988 and 1989, house dust lead exposures have continued to decrease. In 1988, dust exposures to children ranged from 1200 mg/kg lead in Smelterville to 1,500 mg/kg lead in Kellogg. By 2001, these levels ranged from 300 mg/kg to 370 mg/kg, respectively (TerraGraphics 2005a).

The *1999 Five Year Review* conducted for the Populated Areas of the Box concluded that significant reductions in both house dust lead concentrations and blood lead levels have occurred at the Box since 1988, but that interior cleaning should be investigated as a remedial measure that may be necessary to further reduce dust lead concentrations (TerraGraphics 2000, TerraGraphics et al. 2001, USEPA 2000). The Bunker Hill House Dust Pilot Remedial Effectiveness project was undertaken to assess the effectiveness of cleaning and sampling methods and the feasibility of conducting a large-scale interior dust remediation, following completion of exterior remedial actions. Several cleaning methods were tested. Although significant reductions in lead loading and concentration were noted with cleaning, both returned to pre-cleaning levels after 12 months. This confirmed the earlier study suggesting that the outdoor sources of lead must be addressed to provide permanent risk reduction (TerraGraphics et al. 2002). It is expected that a similar percentage of homes in the Basin and the Box will have continuing high dust lead levels associated with lead paint sources following the completion of soil remediation activities.

The relationship between lead paint, house dust and blood lead has long been controversial in the BHSS. Several individuals and mining industry representatives have raised concerns about the effect of interior lead-based paint on children's blood lead levels and expressed the belief that lead-based paint is the primary source of lead in house dust at the site. In response to these concerns, the State of Idaho independently funded the development of the lead paint database and conducted a site-specific quantitative analysis of the blood lead, soil/dust, and paint relationship for the Basin. The subsequent analyses, included in the *Human Health Risk Assessment for the Coeur d'Alene Basin* (HHRA), concluded that both soils and paint are significant sources of lead, but there is uncertainty regarding paint sources due to the relationship between paint condition and socio-economic status that could not be explained with these data. These findings are consistent with the follow-up reports from public health nurses investigating children with high blood lead levels and results from other sites (TerraGraphics 1997, TerraGraphics 2000, TerraGraphics et al. 2001, von Lindern et al. 2003a, von Lindern et al. 2003b, NAS 2005).

The analysis in the HHRA was conducted using the paired blood lead environmental exposure database collected from the homes of children that had participated in the LHIP. This database was unique in that X-ray Fluorescence (XRF) based assessments of lead paint hazards were conducted and measurements of lead loading rates were obtained by placing a floor mat in the home's main entrance. These mats were retrieved after a prescribed period of time and the amount of dust and lead that had accumulated was measured, and adjusted to the lead mass per area per day rate (mg of lead per m^2 of mat per day).

Relationships between blood lead and environmental lead levels were assessed using multivariate analysis. With respect to blood lead levels, the dust lead loading rate alone explained nearly 40% of the variation in the dependent variable. Other environmental variables were significant in combination with dust lead loading rate. Those variables were yard soil lead levels, median exterior paint XRF reading, and interior paint condition. Together with age of the child, these variables explain 60% of the variation in blood lead levels. Considering that this regression model does not address the inherent variance among individuals in a population, accounting for 60% of the variation in observed blood lead levels was considered a strong relationship. Overall, these results suggest that contaminated soils, house dust, and lead-based paint are all related to excess absorption. This is effected through complex exposure pathways, with blood lead levels most related to dust lead loading in the home, followed by independent effects of yard soil lead, interior paint lead condition, and exterior paint lead content. The dust lead pathway is most influenced by outdoor soils, augmented by paint contributions in older homes, especially those in poor condition (TerraGraphics 2001).

The site-specific analysis did provide significant insight into the role of lead paint in lead absorption in the Basin and justified the special State expenditure in developing the database. Children with blood lead levels greater than or equal to 10 µg/dl are exposed to significantly higher soil, dust, and dust lead loading levels than children with blood leads less than 10 µg/dl. Lead-based paint plays a minor, but significant, role in affecting these blood lead levels. Children living in houses with an interior lead paint hazard are exposed to increased dust lead concentrations and dust lead loading rates compared to those not exposed to a lead paint hazard.

A disproportionate number of children with high blood lead levels come from homes with an identified lead paint hazard (i.e., 30% of children with high blood lead levels come from the 11% of homes identified with an interior lead paint hazard). However, the majority of children with high blood lead levels (70%) come from homes with no identified lead paint hazard. This resulted in soil remediation and paint abatement as necessary components in the Comprehensive Cleanup Plan for the Basin. The recent National Academy of Sciences (NAS) review of the HHRA in the Coeur d'Alene Basin concluded that reasonable methods were employed to apportion risks due to sources other than mining wastes, and that " ... although lead from old house paint probably contributed to exposure of some children, lead contaminated soil was the primary contributor to health risk from lead." (TerraGraphics 2001, NAS 2005).

1.2 Study Description and Objectives

1.2.1 Description and Study Hypothesis

With respect to lead paint hazards at the BHSS there is a need to i) assess the contribution of paint and residual soil contamination to lead in dust, ii) identify baseline or background levels of lead in dust in similar-aged homes outside the mining district, iii) identify homes that have a significant lead paint hazard, and iv) provide an effective abatement to minimize the hazard.

In the Box, this is being accomplished through continued monitoring of house dust lead levels in home vacuum cleaners and floor mats, responding to those homes with concentrations above the threshold criteria. In the Basin, it has been proposed to monitor house dust lead levels using the same methodologies as the Box throughout the soil remediation phase and to respond to those homes exceeding a specified lead loading criteria. Both of these techniques have been applied historically and a large and useful empirical database has accumulated. In the Box, the significance of soil sources has diminished while lead paint sources have likely remained about the same. As most of the soil problems are resolved, paint becomes a more prominent issue among the last homes exhibiting a lead hazard. A similar result is expected in the Basin as soil remediation proceeds.

The BHSS dust monitoring techniques differ substantially from the United States Department of Housing and Urban Development (HUD) methodologies that rely on XRF and dust wipes. The BHSS methods collect large volume samples by vacuum and directly measure the lead in dust media exposing children. Both vacuum bag and entryway mat techniques measure lead in dust from all sources (soil, paint or other), and are less expensive and resource demanding than other methods. In the Basin HHRA described above, results of both dust monitoring and HUD XRF results were related to blood lead levels.

However, it is not known if homes that register hazards in a HUD risk assessment would be identified in the BHSS dust sampling methods, or what house dust lead concentrations or loadings would be found in such homes. There is little information regarding house dust lead levels in typical homes outside the mining district that do (or do not) show a lead hazard under the HUD protocols. A small study conducted using the mat and vacuum methods in similar socio-economic status communities unaffected by the mining district showed typical levels around 200 mg/kg in pre-1970 housing and 50 mg/kg in newer homes (Spalinger et al. in-press). However, no HUD lead risk assessments were performed in this effort.

To compare the results of BHSS and HUD risk assessment methods, combined HUD lead-based paint /BHSS risk assessments were performed at 75 residential units in the Box, Basin, and similar home-age and socio-economic status communities outside the mining district. The hypothesis to be tested is: *The hazards identified by the HUD Lead- Based Paint Risk Assessment methodology are reflected in the house dust monitoring techniques used to assess residential lead dust exposures at the Bunker Hill Superfund Site*.

The three communities that were targeted have varied mining/smelting exposure scenarios described below:

Box: Mining/Smelter impacted area where remediation is complete. Smelterville and northern Kellogg, located in the Bunker Hill Superfund Site OU1, are both previously highly lead-contaminated communities where all exterior populated areas soils have been completely remediated by Superfund efforts. Both communities have experienced an order-of-magnitude drop in blood, soil and dust lead levels. Although average house dust lead levels have significantly dropped in these communities over the past 20 years, a small number (10%) of homes remain above action levels established for the Site (house dust lead concentrations ≥1,000 mg/kg). The majority of homes in Smelterville and Kellogg are single-family occupied homes built prior to 1970 with median family incomes of about $31,000 (US Census 2000).

Basin: Mining impacted area where remediation is not complete. Mining has also impacted the upper Coeur d'Alene Basin communities of Osburn, Silverton, Mullan, and Wallace, located in the BHSS OU3. More than 80% of the homes sampled are currently undergoing soil remediation on some portion of the property exhibiting soil lead concentrations ≥1,000 mg/kg (over 1,600 homes sampled to date) (TerraGraphics 2004). Another 1,200 to 1,300 properties are expected to be sampled this year to continue with Superfund efforts. The majority of homes in Mullan, Osburn and Wallace are also single-family occupied homes built prior to 1970 with median family incomes of about $35,000 (US Census 2000).

Background: Communities in northern Idaho unaffected by mining. The northern Idaho towns of Potlatch, Bovill, and Troy were selected for this project based on 2000 census data because they have similar housing age and socio-economic characteristics as the BHSS towns. Potlatch and Bovill were also part of a background survey conducted in 1999, which compared house dust and soil lead levels to those at the BHSS. Some homes in these communities have soil, dust, and questionnaire data, which previously showed significantly lower lead levels than those observed in the Box. The median family incomes in Potlatch, Bovill, and Troy were about $42,000 with most homes constructed before 1970 (US Census 2000).

1.2.2 Objectives

This project was designed to evaluate and compare the risk determined by HUD lead-based paint risk assessment to the risk determined by house dust lead concentrations and loading rates collected at the BHSS. The objectives of this project are as follows:

- To quantitatively compare the number of houses that show an exposure risk from lead in house dust by the HUD Risk Assessment methods to the BHSS monitoring methods, and to compare and discuss any observed differences or similarities among the four dust sampling techniques.

- To quantify the relationship between soil and paint to house dust.

- To determine differences in environmental media lead levels among the three types of communities sampled, if any.

- To provide baseline data regarding house dust lead levels and lead paint conditions in rural Idaho communities and their relation to BHSS homes.

SECTION 2.0 METHODS

A detailed description of the following methods and sampling protocols is located in the *Quality Assurance Plan (QAP) For Comparison of HUD Risk Assessment Methodology to Methods Used at the Bunker Hill Superfund Site in Idaho for the Identification of Risk from Lead in House Dust - Revision No. 2* (PHD and TerraGraphics, 2004).

2.1 Screening Questionnaire and Home Selection

A screening process was carried out in order to recruit homes that warranted full risk assessments. Selection of the 75 houses was accomplished by door-to-door solicitation. Residents agreeing to participate were administered a questionnaire to determine if they satisfied the screening criteria. The primary criteria, in order of importance, were houses built prior to1960 (preferably pre-1940), families with children, and the presence of a vacuum cleaner that could be sampled. To the extent possible, variables relating to house age, condition of paint, family size and activities were kept consistent among all participating households. The questionnaire is for informational purposes and documents the participants' involvement with lead-based activities, occupations, or home renovations.

2.2 HUD Risk Assessment Methodology

The HUD methodology for performing risk assessments was developed to target priority lead-based paint hazards in federal housing and eliminate child lead exposures. In many ways, the HUD method is best suited for large, urban, multi-dwelling housing complexes. The rural nature and predominance of single-family housing, coupled with widespread lead contamination, complicates comparisons of the HUD and BHSS methods.

For this study, the primary purposes of the risk assessments were to identify lead-based paint hazards that currently exist in the dwelling, the potential lead hazards that should be routinely monitored, options for correcting and controlling priority hazards, and to use information obtained during the HUD risk assessment process to compare with lead risk assessment methodologies employed at the BHSS. For this reason, a combination lead-based paint inspection and risk assessment was performed for every participating home, regardless of the likelihood of lead-based paint hazards. However, a full risk assessment generally would not be conducted when an assessor found little risk in the preliminary screen.

In the HUD methodology, the risk assessor's experience and judgment are critical in defining the potential hazards present. As a result, the risk assessor and property owner first define what level of assessment is to be performed in evaluating a dwelling. At this step of the evaluation, the risk assessor may, with homeowner input, recommend conducting one of the following:

1) A Lead-based Paint Inspection: This is an on-site surface-by-surface inspection that determines if and where lead-based paint exists. This is not a risk assessment method because it does not identify lead-based paint hazards. It is appropriate if the owner wants only to know if and where lead paint exists. Only rarely would dust or soil samples be collected during a paint inspection.

2) A Hazard Screen: This is a very limited type risk assessment applied to housing in good condition. The purpose of a hazard screen is to determine if a full risk assessment should be performed. A risk assessor may choose this option after determining there is not a high likelihood of lead-based paint hazards based on discussions with owner and the visual assessment of the property.
3) A Risk Assessment: This is an on-site investigation of a dwelling during which the risk assessor looks for lead-based paint hazards primarily based on the likelihood of dust from lead-based paint. Risk assessments include investigation into the age, history, management and maintenance of a dwelling. Visual assessments and limited sampling of soils, dusts, and paints are performed. Reporting identifies the lead-paint hazards, and also identifies appropriate hazard control measures (abatement or interim controls) based upon the site conditions and the owner's ability to implement control options.
4) A Combination Lead-Based Paint Inspection and Risk Assessment. In this case, both lead-based paints and lead-based paint hazards are identified.
5) Bypass Hazard Identification: In this case, the initial steps of inspection or risk assessment are skipped and remediation of the hazard is performed.
6) A Re-Evaluation: A Re-Evaluation is performed when a previous risk assessment determines that that lead-based paint hazards are likely to appear. HUD offers guidance for determining the frequency and need for re-evaluations based on the likelihood for a lead hazard to appear.

During this study, owner consultation was abbreviated because the houses were pre-screened to help ensure that lead-based paint would be found. The initial stage at which the risk assessor and the owner would determine the most appropriate investigation methods based upon the overall condition of the property was bypassed and a combination risk assessments/lead-based paint inspection was performed at every property. This led to the inclusion of some properties that likely would not have been candidates for risk assessment under the typical HUD protocol.

The HUD risk assessment methodology was further modified to group homes in risk categories in order to compare HUD and BHSS risk assessment methods. HUD risk assessments are site-specific. When lead is found, the risk assessor determines if a significant hazard does or does not exist. Because HUD data will be presented in this report in aggregate, it was necessary to group homes in risk categories based on the following three-tiered approach. This three-tiered ranking system still identifies all lead-based hazards required by the HUD methodology and attaches an additional category of risk to facilitate comparison of the HUD and BHSS methodologies.

1) Low Risk: Only lead paint in good condition was found. Normal maintenance, using lead-safe work practices, is usually adequate to avoid lead exposures in this condition.
2) Medium Risk: Damaged lead paint was observed, but no lead dust hazards were found. Maintenance and repair of the damaged areas using lead-safe work practices is usually adequate to avoid lead exposures. In some cases, interim controls or abatement may be required to control the hazard.
3) High Risk: Lead dust or soils were found and are likely to be an exposure hazard. In the case where lead dust or soils are found, more immediate response is warranted. Immediate implementation of interim controls or abatement would be required under the

HUD model. The highest risk tier, Level 3, is also annotated as 3a, referring to dust hazards, and 3b, referring to soil hazards.

As a final step in the HUD risk assessment, recommendations were made to homeowners regarding necessary and possible actions to reduce exposure to lead paint, such as Abatement or Interim Controls. Abatement is a total elimination of the hazard in accordance with federal standards and includes complete removal of all lead-based paint from a component, encapsulation or enclosure, removal and replacement of the lead-based paint coated component, permanent soil covering, and/or soil removal and replacement. Abatement provides a higher margin of safety than interim controls, but results in increased cost.

Interim controls are measures that temporarily reduce exposure to lead-based paint hazards and require ongoing monitoring. Some of the methods used for interim controls are paint film stabilization, friction and impact point reduction treatments, dust removal, soil covering using non-permanent methods, temporary containment, management in place, and/or occupant and management education. Interim Controls are initially less costly than abatement, but there is a higher risk of recontamination.

2.3 HUD Sampling and Survey Methods

2.3.1 Visual Assessment

A visual assessment was conducted at each dwelling to locate potential lead-based paint hazards and evaluate the magnitude of the hazard. The overall purpose of a visual assessment is to classify paint condition, identify interior or exterior problems that can lead to deteriorating paint conditions, identify areas of bare soil, and characterize the overall condition of the building. All the painted surfaces on the property are visually inspected to determine paint condition.

In cases where a certified HUD Lead Paint Inspection had already been conducted, the visual assessment was focused on painted surfaces known to contain lead-based paint and the areas surrounding them (i.e., floors and window sills). No dwellings in this study had previous inspections. In dwellings where no inspection had been conducted, any painted surface that had not been replaced after 1977 was tested using the XRF because it is assumed these contain lead-based paint. All surfaces were tested in this study.

During the visual assessment, paint condition is classified as intact, fair or poor using Form 5.3 or 5.7 of *Guidelines for Evaluation and Review of Lead-Based Paint in Housing* (HUD 1995 and updates). The assessor's classification is guided by assessment of paint condition on large surfaces of building components.

- <u>Intact</u> paint refers to a painted surface on which the paint is entirely intact. Intact paint is regarded as being in good or excellent condition.
- <u>Fair</u> paint condition for interior paint indicates that 10% or less of the component/painted surface or less than 2 square feet of the painted surface has damaged paint.
- <u>Fair</u> paint condition for exterior paint indicates that 10% or less of the component/painted surface or less than 20 square feet of the painted surface has damaged paint.

- Poor paint condition for interior paint indicates that more than 10% of the component/painted surface or more than 2 square feet has damaged paint.
- Poor paint condition for exterior paint indicates that more than 10% of the component/painted surface or more than 20 square feet has damaged paint.

All bare soil at residences were also noted during the visual assessment. Bare soil can be in the form of sandboxes, the ground under swings or play equipment, patio areas, foundation driplines, bare ground in driveways or under porches or any other location reasonably assumed to be a child's play area. All bare areas, regardless of surface area, were sampled for this study.

2.3.2 Environmental Sampling

Once a visual assessment was performed, a sampling strategy was devised and sampling performed. During the combination risk assessments/lead-based paint inspection, the following sampling methods were followed, as described in the *Quality Assurance Plan (QAP) for Comparison of HUD Risk Assessment Methodology to Methods used at the Bunker Hill Superfund Site in Idaho for the Identification of Risk from Lead in House Dust (Revision No. 2)* (PHD 2004).

2.3.2.1 Niton X-ray Fluorescence (XRF) Sampling

XRF sampling was performed as a non-destructive method of determining the location of lead paint in the home using a Niton Model # 300 Series XRF machine. The XRF operator was a certified Lead Risk Assessor and was trained in the use of any XRF instrument used during the assessment.

Paint sampling occurred at each house according to HUD guidelines for Lead Paint Inspection and complied with the Performance Characteristic of the Niton XRF. XRF analysis on paint was conducted after dust sampling was completed in order to minimize the possibility of cross-contamination of dust and paint samples. For most risk assessment purposes, only those painted surfaces considered to be in poor condition are typically tested during a risk assessment. In this study, XRF testing was done on all painted surfaces and/or components. XRF results were classified as positive when lead levels were greater than or equal to 1.0 milligrams per square centimeter (mg/cm^2) and negative when lead levels were less 1.0 mg/cm^2.

During the lead-based paint inspection, all room equivalents inside the dwelling were tested. The exterior was assigned a separate room equivalent. Substrates are noted (i.e., brick, concrete, drywall, metal, plaster, or wood). Each sample location and room was identified. A sketch of the home's floor plan was created to aid with sample location identification. Calibrations were performed before and after each home was sampled.

2.3.2.2 Paint Chip Sampling

Paint chip sampling is typically performed as a quality control measure and to help determine lead concentrations in paint that produced indeterminate results by XRF. No paint chip samples were collected for this study. The primary reason paint chip samples were not collected during this risk assessment was to avoid using destructive sampling techniques, since sampling destroys surfaces where the sample is collected. Without paint chip sampling, it is possible that some paints are improperly identified as lead-based or non-lead-based paints. This is primarily true in cases where XRF results are near the 1.0 mg/cm^2 level.

2.3.2.3 Dust Wipe Sampling

Dust wipe samples were collected and analyzed to identify locations where a lead dust hazard may exist. Dust was collected on a wipe from a pre-measured area in locations likely to have leaded dust. The results give mass loading in micrograms/area. Elevated dust sample levels are any lead in dust over 40 micrograms/square foot for floors; and over 250 micrograms/square foot for window sills.

The selected area to be sampled was based on visual observations and results of resident interviews and use patterns. Dust wipe samples were generally collected from areas that were likely to be contacted by young children, such as play areas within rooms, high-traffic walkways, room midpoints, or areas immediately underneath windows. Dust was collected through two different procedures. In the first procedure, a plastic template assisted sampling of wide or flat locations of approximately 30 cm by 30 cm. For the smaller locations, such as a window sill or a doorjamb, the confined area sampling procedure was utilized. For confined area sampling procedure, the area to be measured was marked with adhesive tape and cleaned using a prepackaged wipe.

Dust samples were collected from each home from the following locations, when possible:

- the floor of the child's principal play area, TV room, or living room,
- the interior window sill of the most frequently opened window in the child's principal play area,
- the kitchen floor,
- the window sill of the kitchen window,
- the floor of the bedroom of the youngest child (older than 6 months),
- the interior window sill of the bedroom of the youngest child (older than 6 months),
- the floor of the bedroom of the next oldest child, if any, and
- the window sill of the bedroom of the next oldest child, if any (if inaccessible, an interior window sill sample would be collected).

The QAP projected that approximately 500 dust wipe samples would be collected during the study. This estimate was based on the assumption that most participating homes were resident to at least two children. However, approximately 300 dust wipe samples were actually collected during the study. Several of the participating homes were not resident to two children and some were not resident to any children. For this reason, floor and window sill dust wipes could not be collected from a child's bedroom or play area. Additionally, several of the homes did not have window sills from which to collect samples.

2.3.2.4 Soil Sampling

Soil data were collected according to HUD protocols from participating homes. Soil sampling was conducted to determine whether the soil outside of the dwelling poses a significant hazard to children, and was focused in bare soil areas where it was determined that children were likely to play. The concentration of lead in the soil was determined as well as the use pattern (i.e., the frequency of contact and use of soil) for different soil locations and conditions.

HUD guidance states that "except for play areas, yard or soil areas containing a total of less than 9 square feet of bare soil are not considered to be hazardous and will not be sampled." However, upon recommendation by HUD and due to the focus of this study, samples were collected from bare soil areas less than 9 square feet that were determined by the HUD risk assessor to have the potential for exposure.

Bare soil areas that were sampled include outdoor play areas, areas identified as being located within the building's dripline, vegetable gardens, pet sleeping areas, bare pathways, and sandboxes. In addition, soils may have been collected from other locations if there was a reasonable expectation that lead contamination occurred in those locations. Soil sampling followed the protocol established in Appendix 13.3 of the HUD Guidelines and ASTM E 1727-99 and sieved to -80 mesh (HUD 1995 and updates). At the request of HUD, soil samples were collected for all driplines, regardless of cover.

In a child's play area bare soil with greater than 400 mg/kg lead is considered elevated; and for bare soil in other locations 1,200 mg/kg is considered elevated. All bare soils regardless of location should be abated when lead levels are over 5,000 mg/kg.

2.4 Bunker Hill Superfund Site (BHSS) Methodologies

Media sampled using the BHSS methodology included dust from vacuum cleaner bags and floor mats, Baltimore Repair and Maintenance (BRM) samples, and soil samples. The BHSS soil database was used to pair the latest known soil concentration at the 50 houses participating in the Superfund Site. For the 25 houses outside the BHSS, soil samples were collected following similar protocols as those used in the BHSS. The QAP contains more detailed descriptions of the following sampling protocols (PHD and TerraGraphics 2004).

2.4.1 Paint Assessment

The BHSS paint assessment procedure parallels the HUD visual assessment.

2.4.2 Dust Sampling

House dusts have been monitored at the BHSS as part of the LHIP offered by the Panhandle Health District since 1974. House dust lead concentrations have been determined for houses site-wide with young children by collecting a sample from the homeowner's vacuum cleaner bag during the annual blood lead census in July/August as a measure of exposure. Since 1996, house dust lead concentrations have also been sampled by a floor mat sampling technique. This method also measures an index of dust and lead loading rates at entryways into the houses (mass/area/time). This same dust mat technique was recently used by (Farfel et al. 2001) in pre-1950 and new urban houses. BRM sampling was used at the Site in 2000-2001 in Smelterville homes as part of a pilot project to determine interior remedial effectiveness (TerraGraphics et al. 2002). The BRM was shown to be most useful in determining remedial effectiveness on carpeted surfaces and was a more controlled dust sample compared to the vacuum bag or mat because it is not dependent on homeowner cleaning habits and is not left unattended for three to four weeks. These same house dust sampling methods were employed for this project.

2.4.2.1 Vacuum Dust Sampling

The vacuum dust sample is a general representation of lead exposure to individuals inside the home. Prior to sample collection the field technician verified that the vacuum had not been used anywhere outside the home since the bag was last changed. No sample was collected from vacuum cleaners that did not meet this criterion.

2.4.2.2 Floor Mat Dust Sampling

A carpeted floor mat for dust collection was placed at all homes participating in the study to quantify lead concentration, lead loading rate, and dust loading rate. Except for unusual circumstances, floor mats were placed just inside the main entry of each house. Instructions were left with the resident not to vacuum, shake, or move the mat. After approximately three to four weeks, the mat was retrieved and carefully placed and stored right side up in a clean, sealed envelope. The mat was vacuumed in a special “clean room” to collect the dust retained on the mat. The mass of dust collected is used to determine the dust and lead loading rate; milligrams per square meter per day, ($mg/m^2/day$).

2.4.2.3 Baltimore Repair and Maintenance

The BRM floor sampling methodology is intended to represent dust that has accumulated in carpet over time. Each room to be sampled was separated into a twelve grid system, and three numbers were chosen at random, with the sample collected from the middle of each selected grid. If furniture was in the way of the sample, then another grid was chosen randomly. One sample from each square foot area was collected sequentially in one sample container for a total of two floor composite samples for each house. The locations sampled were the living area (child’s principal play area) and youngest child’s bedroom to correspond with the HUD Risk Assessment dust wipe sampling locations. If carpet was not present in these locations, an alternate carpeted area was selected. If the home contained no carpeting, a BRM sample was not collected.

2.4.3 Soil Sampling

All 75 houses were sampled for soil (or had previous soil results from the CERCLA program) using BHSS methods, in addition to the HUD risk assessment soil sampling. BHSS soil data exist for almost every home in the Box; those data were used and no new BHSS soil samples were collected. Homes in the Box had been remediated prior to the study and, as a result, a clean soil concentration of 100 mg/kg was applied to participating homes in the Box. A Superfund soil sampling program is currently underway in the Basin. If a participating home in the Basin did not have data, then the property was sampled under the 2004 Superfund program. All houses sampled in other northern Idaho communities unaffected by mining had their soils sampled using the BHSS soil sampling method. In the BHSS, soil data is collected to depth (0-18 inches or 0-24 inches, depending on the sample location). However, only the 0-1 inch depth from different sample locations (e.g., yard, play area, driveway, flower bed, etc.) was sampled at the 25 Background community homes. These communities are unaffected by mining, and so lead contamination is not expected to be observed at depth, and the 0-1 inch depth is most representative of the exposure pathway.

2.5 Laboratory Analytical Methods

Samples collected as part of this study were submitted to a USEPA-National Lead Laboratory Accreditation Program (USEPA-NLLAP) Accredited Laboratory (Northern Analytical Laboratory) for lead analysis. The full Laboratory Standard Operating Procedure (SOP) as well as all laboratory certificates were provided in Appendix C of the QAP (PHD and TerraGraphics 2004). Standard analytical procedures were used for soil and dust samples (USEPA Method 6010B or ICP-AES) and as described in Appendices 14.1-14.3 of the *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing* (HUD 1995 and updates). The dust and soil samples collected were dried completely at a temperature of 105 °C. After drying, the sample was homogenized and sieved to -80 mesh.

SECTION 3.0 RESULTS

3.1 Paint Assessments and Sampling

Some adjustments to the typical HUD risk assessment process were necessary to accommodate the research design for this project. None of these adjustments fundamentally changed the manner in which the risk assessment was performed, but some of the early steps in the assessment were abbreviated or combined with other activities. The divergences from the routine HUD procedure were in: i) determination of the most appropriate evaluation method for the dwelling, and ii) collection of additional soil samples. The adjustment for completing a full lead-based paint inspection /risk assessment was part of the design of this study, and the collection of additional soil samples was described in the QAP (PHD and TerraGraphics 2004).

Typically, the pre-screening process during the visual inspection determines the level of investigation appropriate for each home. The risk assessor uses the following general guidelines to make this determination.

A Hazard Screen is recommended if the following three criteria apply:

- no children lived in the home (Form 5.0),
- the house rated in good condition (Form 5.1), and
- virtually all paint was intact (Form 5.2).

A recommendation for a lead-based paint inspection is appropriate if the following apply:

- children live in the home,
- the home rated in good condition, and
- virtually all paint was intact.

If these criteria were not met, a recommendation for a full risk assessment would be made. As these criteria are general guidelines, the risk assessor and owner have some discretion in deciding which inspection or assessment process is appropriate. As a result, the risk assessor may vary the recommendation based upon overall site conditions. For the purposes of this study, HUD Risk Assessors performed a full lead-based paint inspection /risk assessment on each property, regardless of the pre-screen /visual assessment results.

The results of this screening process are summarized in Tables 3.1a and b. For a house by house summary of the screening results see Appendix A, Table A-1. The visual assessment /pre-screening process identified 14 of the 75 total homes as not warranting full risk assessments. Two of these were Basin homes, eight homes were in the Box and four were Background homes. Seven houses likely would have only had a hazard screen performed and two may not have warranted inspection or assessment. The other five houses probably would have received only a lead-based paint inspection. Of the latter, there were single items on each property that were coated with damaged paints (i.e., two houses had windows with damaged paint, and one had a fence with damaged paint).

Table 3.1a Summary Visual Assessment Determinations by Area*

Community	Number of Homes	Based on the Visual Assessment, a risk assessor would have recommended: No further action	Lead-based Paint (LBP) Inspection	Hazard Screen	Risk Assessment
Basin	24	0	2	0	22
Box	26	2	2	4	18
Background	25	0	1	3	21
All Homes	75	2	5	7	61

* Excludes supplemental soil samples

Table 3.1b Summary Risk Assessment Determinations by Area*

Community	Number of Homes	Assigned risk level: All LBP in good condition, no elevated lead-dust or soils identified 1	Damaged LBP observed. No elevated lead-dust or soils identified 2	Elevated lead in dust identified 3a	Elevated lead in soil identified 3b	Significant Hazard Identified
Basin	24	0	7	9	14	17
Box	26	3	10	8	11	13
Background	25	10	11	2	2	4
All Homes	75	13	28	19	27	34

* Excludes supplemental soil samples

Note: Elevated dust (3a) and soil (3b) were identified in 12 homes. Six of these homes were in the Box and six were in the Basin. There were no homes in Background communities with both dust and soil hazards identified.

Nevertheless, per the study protocol, combined risk assessments including lead-based paint inspections were accomplished for all 75 homes. Tables 3.2a-c summarize interior and exterior XRF results by area, surfaces sampled, and by home for those inspections. Table 3.2a shows that Background communities had more exterior surfaces categorized in good condition, while the Basin homes had a greater percentage of exterior surfaces categorized as poor condition. Less than 5% of interior surfaces were classified in poor condition in any community. Table 3.2b shows that all three areas had a substantial percentage of surfaces reading positive for lead paint, with the highest frequency in the Background and lowest in the Basin. Nearly 50% of exterior surfaces in Background homes exhibited XRF readings greater than the lead paint threshold compared to near 40% in both the Basin and Box homes. Figure 3.1 shows that percentage of surfaces exceeding the lead paint threshold is greatest in the Background homes, with the frequency double that in the Basin and Box for interior surfaces. Average exterior lead concentration in the Background homes is about twice that in the Superfund area. For interior lead paint concentration, the Background average is nearly three times that in the Basin and Box (Table 3.2b). Table 3.2c shows the percentage of homes in each community with an average of all XRF results equal to or greater than 1.0 mg/cm^2. Approximately 75% of all homes in each community had average exterior XRF concentrations equal to or greater than 1.0 mg/cm^2. Similarly, between 96% and 100% of homes had at least one exterior XRF reading greater than 1.0 mg/cm^2. The Basin had the greatest percentage of homes (92%) with at least one exterior XRF reading at or exceeding 1.0 mg/cm^2 that was collocated with paint in fair to poor condition compared to 85% of Box and 80% of Background homes. Nearly half of all Background homes had an average of all interior XRF results at or exceeding 1.0 mg/cm^2, while around 20% of Box and Basin homes had an average of all interior XRF results at or exceeding 1.0 mg/cm^2. The Box had the greatest percentage of homes (96%) with at least one interior XRF reading at or exceeding 1.0 mg/cm^2 and 58% of Box homes had an interior surface reading equal to or greater than 1.0 mg/cm^2 that was also collocated with paint in fair to poor condition. Around 70% to 80% of Basin and Background homes had at least one interior surface reading at or exceeding 1.0 mg/cm^2, and approximately 40% of the homes in these communities had at least one interior surface reading at or exceeding 1.0 mg/cm^2 collocated with paint in fair to poor condition.

Table 3.2a Summary of Exterior and Interior Paint Conditions by Community

Community	Number and Percent of Surfaces						
	Total Surfaces	In Good Condition		In Fair Condition		In Poor Condition	
Exterior							
Basin	961	223	23%	370	39%	368	38%
Box	983	356	36%	335	34%	292	30%
Background	902	452	50%	319	35%	131	15%
Interior							
Basin	1,530	1,355	89%	133	9%	42	3%
Box	1,495	1,307	87%	154	10%	34	2%
Background	2,094	1,832	87%	242	12%	20	1%

Table 3.2b Summary of Exterior and Interior XRF Results by Community

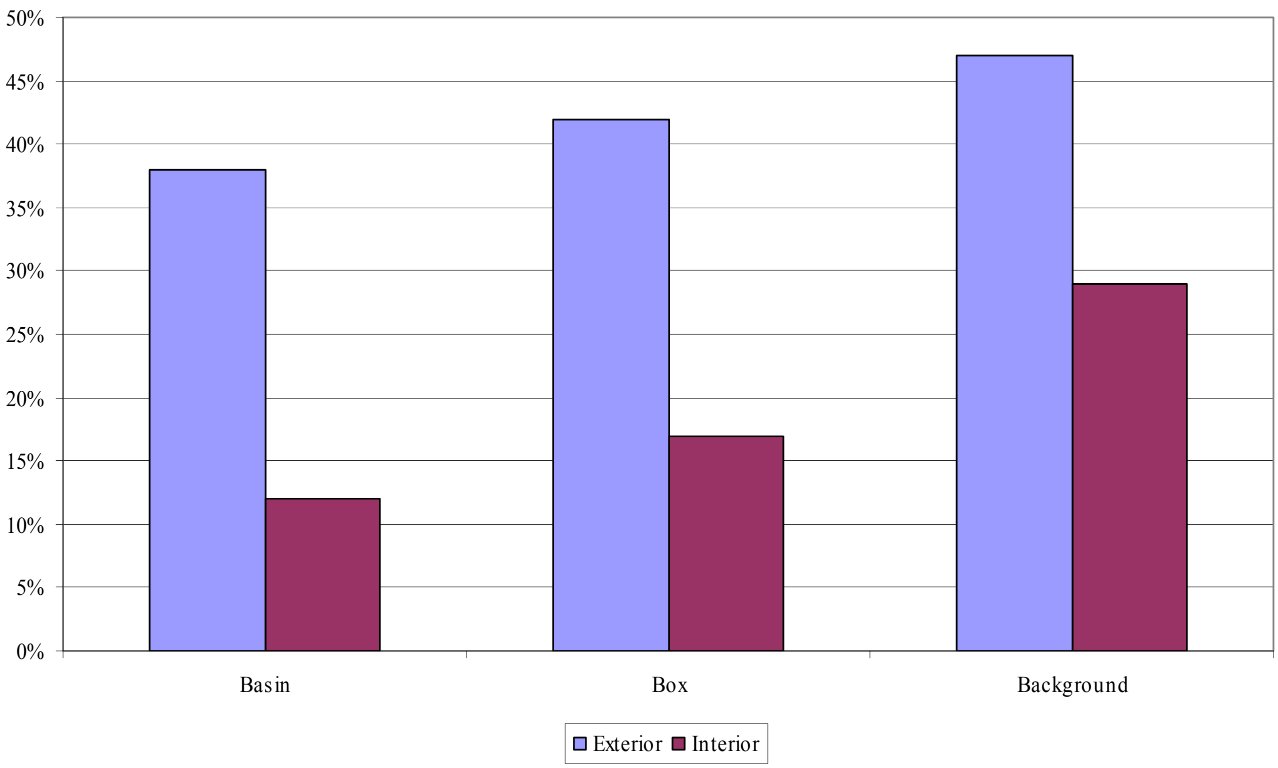
Community	Total Surfaces	Number and Percent of Surfaces with XRF Reading ≥ 1.0 mg/cm^2		Maximum (mg/cm^2)	XRF Results ≥ 0.8 mg/cm^2*	
					Average	Standard Deviation
Exterior						
Basin	961	360	37%	33	5.4	5.1
Box	983	385	39%	27	5.6	5.1
Background	902	415	46%	31	10.6	7.9
Interior						
Basin	1,530	172	11%	45	3.7	4.8
Box	1,495	244	16%	18	4.9	3.6
Background	2,094	606	29%	43	11.7	9.5

* Accuracy of the readings < 0.8 mg/cm^2 diminishes; therefore, readings ≥ 0.8 mg/cm^2 were used for the averages and standard deviations.

Table 3.2c Number of Homes in Each Community with XRF Concentrations Greater than 1.0 mg/cm^2

Community	Number and Percent of Homes						
	Total Homes	With the Average of All XRF Readings Greater than or Equal to 1.0 mg/cm^2		With at Least One XRF Reading Greater than or Equal to 1.0 mg/cm^2		With at least one XRF Reading Greater than or Equal to 1.0 mg/cm^2 Co-located with Paint in Fair or Poor Condition	
Exterior							
Basin	24	18	75%	23	96%	22	92%
Box	26	20	77%	26	100%	22	85%
Background	25	18	72%	25	100%	20	80%
Interior							
Basin	24	4	17%	19	79%	10	42%
Box	26	6	23%	25	96%	15	58%
Background	25	11	44%	18	72%	11	44%

Figure 3.1 Percent of Painted Surfaces with XRF Readings ≥ 1.0 mg/cm^2



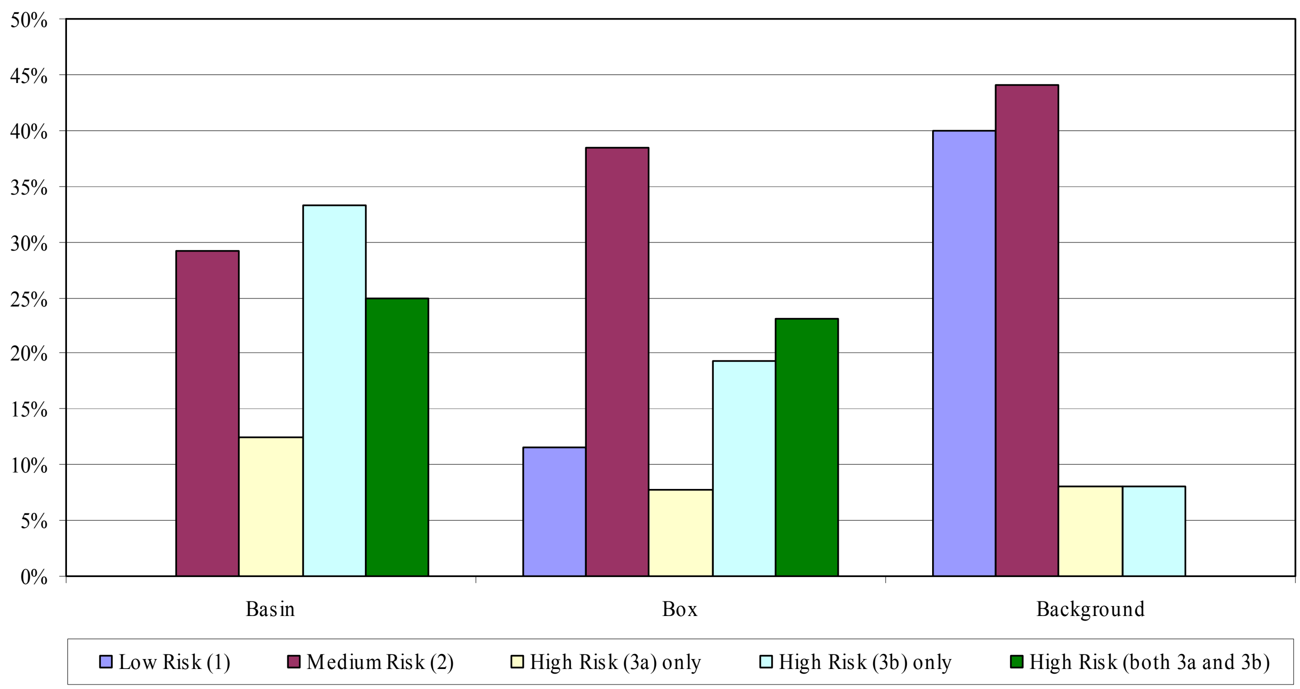
Aside from the determination to undertake full assessments at each property, the other divergence from the typical protocol involved soil sampling. Because the Box and Basin homes are in a Superfund site, HUD requested that all driplines and ROWs on each property be sampled. Ordinarily, only bare soil in driplines accessible to children would have been sampled and ROWs would not be sampled. Collecting these supplemental samples resulted in identifying several locations as a significant hazard (by the HUD criteria), that otherwise would not typically have been found.

Table 3.1b summarizes the overall results of the HUD Risk Assessment determination using the typical protocol and does not include consideration of the supplemental samples (See Appendix A, Table A-1). Ordinarily, the results of the HUD model for risk assessments are expressed in two rankings: significant hazard, or not a significant hazard. The procedure is specific to each site where lead is identified and accessible to children. A total of 34 of the 75 homes inspected (45%) showed significant hazards associated with lead in soil or dusts under the typical procedure. These 34 homes included 17 homes from the Basin, 13 homes in the Box, and four homes from the Background areas. However, soil hazards were identified for another 27 homes when the supplemental soil results were evaluated (See Section 4.3.3). Twenty-eight (28) homes showed damaged lead paint, but no soil or dust hazard.

In order to facilitate comparison of the HUD to Bunker Hill methods, a three-tiered approach to defining the HUD results was used, as described in Section 2.2 (i.e., low, medium, and high risk), and summarized in Tables 3.1b and Figure 3.2. A total of 13 homes were identified as Category 1 Low Risk. Three of these homes were in the Box and ten were from the Background communities. None were from the Basin. Twenty-eight homes were designated as Level 2, or having damaged lead paint, but negative soil and dust lead findings. Seven of these homes were from the Basin, 10 were from the Box and 11 from the Background communities. A total of 19 homes showed significant dust hazards and 27 showed significant soil hazards using the typical protocol. Nine Basin homes, eight Box homes and two Background homes showed dust hazards. Fourteen Basin homes, 11 Box homes and two Background home showed significant soil hazards by HUD criteria (See Section 3.2). Of these homes, 12 had both dust and soil hazards; six in the Basin and six in the Box. No background homes had both dust and soil hazards.

Figure 3.2 illustrates these results as a percentage of homes from each area. Forty percent (40%) of the Background homes are in the low risk category, as compared to less than 12% in the Box and none in the Basin. Intermediate or medium risk (i.e., damaged lead paint but no soil or dust hazard) ranged from 29% in the Basin to 38% in the Box to 44% in Background areas. Soil and dust hazards, however, were observed in less than 20% of Background homes as contrasted to 50% - 71% of Box and Basin homes, respectively.

Figure 3.2 Percent of Homes with Lead Hazards by Community Identified Using HUD Methodology*



3.2 Soil Surveys

The HUD protocol risk assessments discussed in the preceding Section identified significant hazards associated with soils at 27 homes. Considering the supplemental samples that were collected as part of this study, soils exceeding HUD criteria were observed at 54 homes. However, most of the exceedances of soil criteria at the additional homes were associated with dripline samples from vegetated or covered areas and rights-of-way samples that would not have been collected in a typical survey. The following discussions and comparisons do not make that distinction and consider the extra samples as additional hazard indicators.

3.2.1 HUD Protocol Soil Samples

Soil samples collected from all participating homes following the HUD protocol are summarized in Table 3.3. The geometric mean soil lead concentrations for all HUD soil samples for the Basin, Box and Background homes were 469 mg/kg, 303 mg/kg, and 88 mg/kg, respectively. The maximum concentrations in the Basin and Box were about 4,500 mg/kg, while the maximum lead concentration in Background communities was near 2,000 mg/kg. Figure 3.3 shows geometric mean soil lead concentrations for all HUD protocol samples by location and community. Sample locations include driveways, flower gardens, vegetable gardens, play areas, parking areas, rights-of-way, and pathways and sidewalks. Generally, soil lead concentrations were higher in the Basin, where the cleanup is underway, with means of around 300 mg/kg to

700 mg/kg. With the exception of driplines, driveways and ROW samples, Box mean concentrations were from about 100 mg/kg to 300 mg/kg, consistent with the cleanup protocol. Recontamination of ROWs has been noted as a continuing problem in the Box (TerraGraphics 2005b, USEPA 2005). Background concentrations average less than 100 mg/kg with exception of dripline samples (although no ROW samples were collected).

Table 3.3 and Figure 3.4 show that 65% of all soil samples collected in the Basin exceeded the USEPA/HUD standard for bare soils where children play (400 mg/kg), 39% of all soil samples exceeded this criterion in the Box, and 15% of all soil samples exceeded this criterion in Background communities. However, it should be noted that the Box cleanup threshold is 1,000 mg/kg soil lead and numerous areas remain with soil lead concentrations between 400 mg/kg and 1,000 mg/kg after cleanup. Twenty-three percent (23%) of Basin soil samples exceed the USEPA/HUD standard for bare soil areas (1,200 mg/kg), 10% of Box soil samples exceeded this criterion, and 1% of soils samples from Background communities exceeded the 1,200 mg/kg standard.

Closer examination of these data shows that the majority of criteria exceedances were associated with dripline samples. Table 3.4 compares dripline results to all other soils collected with the HUD protocol. Geometric mean concentrations for dripline soil samples collected from houses in the Basin, Box and Background communities were, respectively, 676 mg/kg, 510 mg/kg, and 254 mg/kg, in comparison to 398 mg/kg, 218 mg/kg, and 53 mg/kg for all other soils. Overall, geometric means for dripline soils were higher than other samples in all communities, with mean lead concentrations approximately 2 times greater than other soil samples in the Basin and Box and nearly 5 times greater than soil samples in Background communities.

Table 3.4 and Figure 3.5 shows that 84% of Basin dripline soil samples versus 56% of all other soil samples exceeded the standard for children's play areas. In the Box, 60% of dripline soil samples versus 25% of all other soil samples exceeded the standard for children's play areas. In Background communities, 38% of dripline soil samples versus 3% of all other soils around the house exceeded this criterion. The percentage of dripline soil samples that exceed the standard for bare area soils in the Basin, Box and Background communities was 28%, 20%, and 3%, respectively. Fewer soil samples collected from all other areas around the home exceed the standard for bare area soils in the Basin, Box and Background communities (20%, 4% and 0%, respectively).

Table 3.3 HUD Soil Summary Statistics by Community Group

Community	Number of Samples	Number and Percent of Samples Exceeding Standard for Play Areas*	Number and Percent of Samples Exceeding Standard for Bare Areas**	Lead Concentration (mg/kg)					
				Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Basin	80	52 (65%)	18 (23%)	4,750	20	839	917	469	3.42
Box	90	35 (39%)	9 (10%)	4,420	24	519	652	303	2.87
Background	89	13 (15%)	1 (1%)	2,180	5.0	191	292	88	3.73

* USEPA/HUD standard for play areas = 400 mg/kg
**USEPA/HUD standard for bare areas = 1,200 mg/kg
Half the detection limit was used if result was below detection limit.

Figure 3.3 Geometric Mean Soil Lead Concentration by Sample Location and Community - HUD Methodology

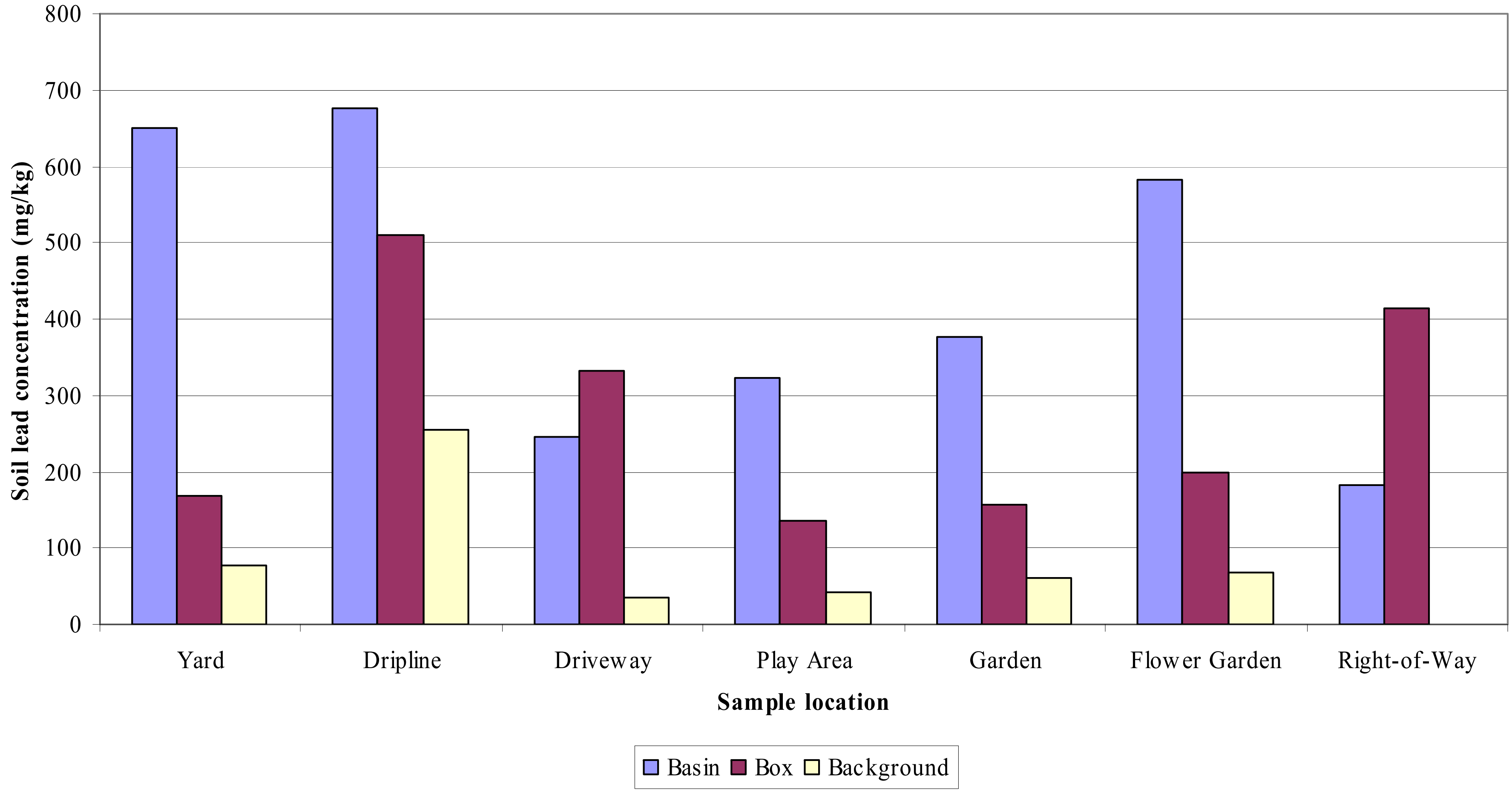
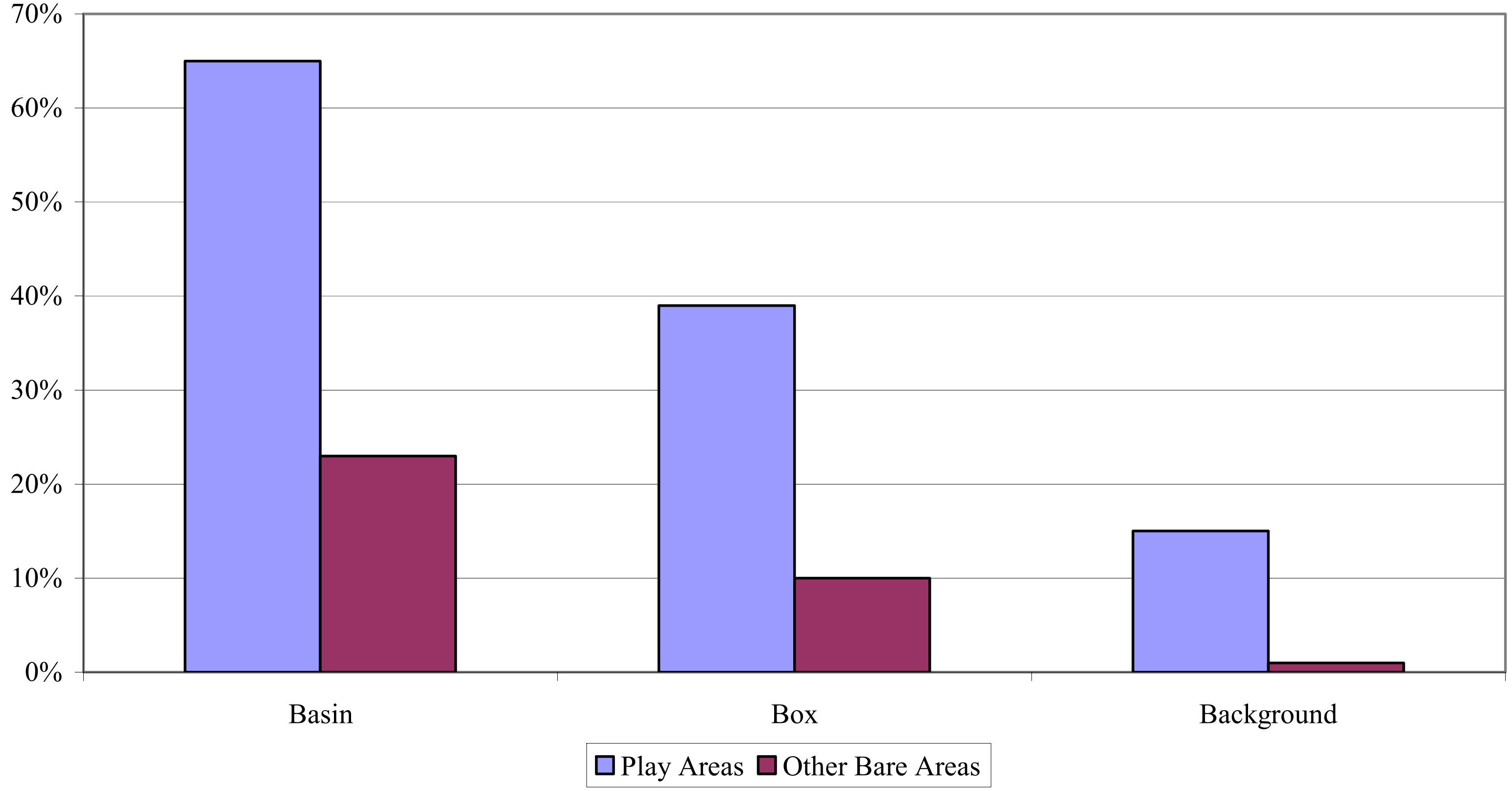


Table 3.4 HUD Dripline Soil Samples Versus All Other HUD Soil Samples

Community	Number of Samples		Number and Percent of Samples Exceeding Standard for Play Areas*		Number and Percent of Samples Exceeding Standard for Bare Areas**		Lead Concentration (mg/kg) Average		Lead Concentration (mg/kg) Geometric Mean		Lead Concentration (mg/kg) Geometric Standard Deviation	
	Dripline	Other	Dripline	Other	Dripline	Other	Dripline	Other	Dripline	Other	Dripline	Other
Basin	25	55	21 (84%)	31 (56%)	7 (28%)	11 (20%)	992	770	676	398	2.94	3.55
Box	35	55	21 (60%)	14 (25%)	7 (20%)	2 (4%)	739	379	510	218	2.50	2.74
Background	29	60	11 (38%)	2 (3%)	1 (3%)	0 (0%)	411	84	254	53	3.29	2.85

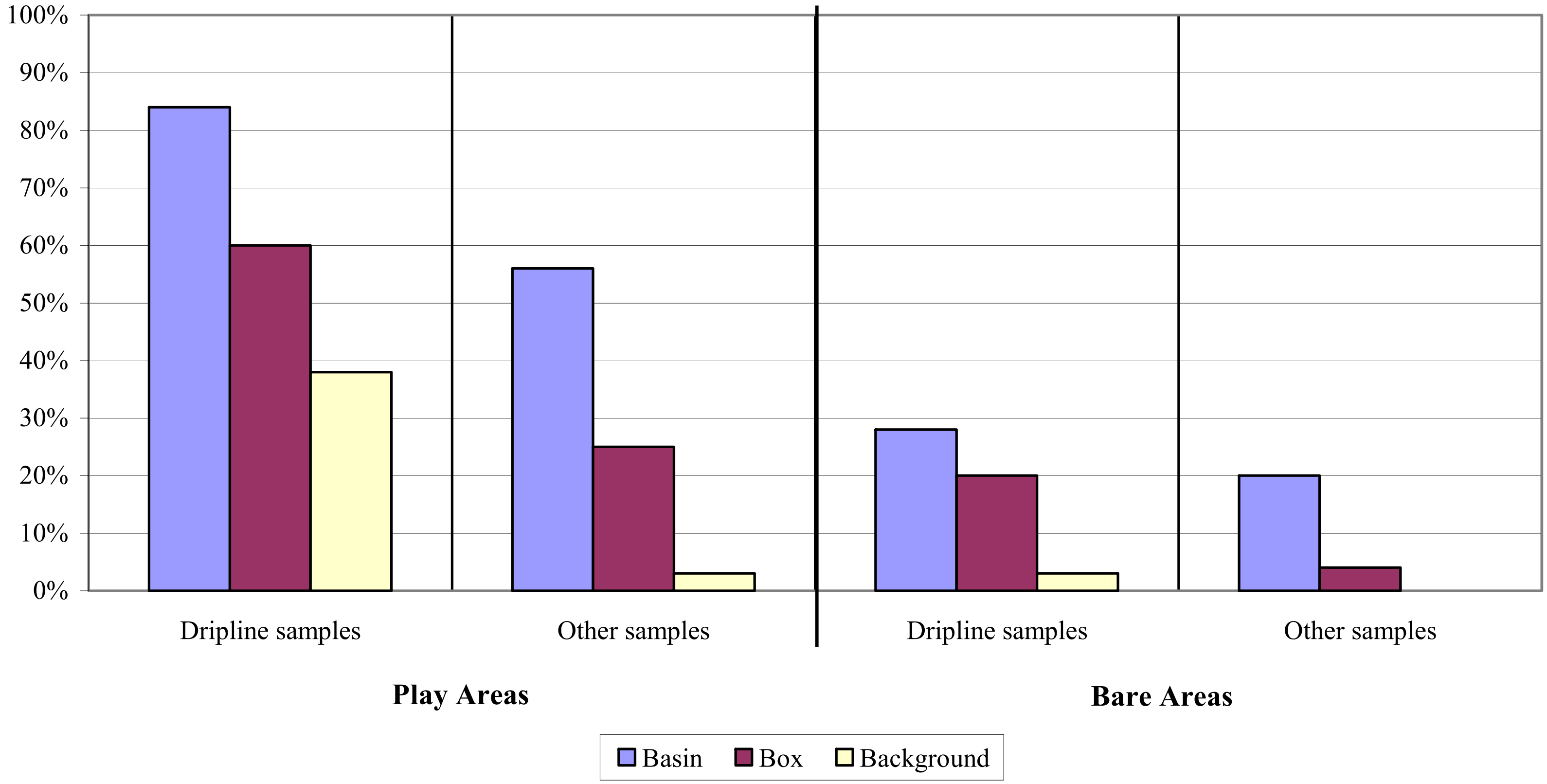
* USEPA/HUD standard for play areas = 400 mg/kg
**USEPA/HUD standard for bare areas = 1,200 mg/kg

Figure 3.4 Percent of Soil Samples Exceeding USEPA/HUD Standards* for Play Areas and Bare Areas by Community



* USEPA/HUD standard for play areas = 400 mg/kg
USEPA/HUD standard for bare areas = 1,200 mg/kg

Figure 3.5 Comparison of Dripline and Other Soil Samples Exceeding USEPA/HUD Standards for Play Areas and Bare Areas by Community*



* USEPA/HUD standard for play areas = 400 mg/kg
USEPA/HUD standard for bare areas = 1,200 mg/kg

3.2.2 BHSS Protocol Soil Samples

In order to reduce project costs, rather than resample BHSS homes, soil samples (previously collected under the BHSS protocol) were used. BHSS sampling was conducted only at background homes for this study. Due to the nature of Box sampling, there are fewer sample locations per home in the Box communities than in Basin and Background communities. All participating homes in the Box had been remediated prior to the study, and as a result, it is assumed that soil concentrations are equal to those of clean replacement soils, or less than 100 mg/kg lead. However, when remediation occurred in the Box, some contamination was left in place around foundations and large trees. All samples collected from Box homes are assumed to be yard soil samples.

Table 3.5 summarizes results for soil samples collected under the BHSS protocol for the three communities. In order to compare soil samples collected under the BHSS protocol with those collected under the HUD protocol, results for samples collected from the top one inch of soil only are summarized in Tables 3.5. The HUD protocol samples collected from Box homes showed a geometric mean concentration of 510 mg/kg for driplines and 218 mg/kg for all other samples (Table 3.4). All yard soils in the Box currently show a geometric mean of less than 150 mg/kg (TerraGraphics 2005c).

Table 3.5 BHSS Soil Summary Statistics by Community Group

Community	Number of Samples	Maximum Concentration (mg/kg)	Minimum Concentration (mg/kg)	Average (mg/kg)	Standard Deviation	Geometric Mean (mg/kg)	Geometric Standard Deviation
Basin	124	8,900	15.3	1,260	1,694	682	3.02
Box	26	100	100	100	0	100	1.00
Background	136	1,470	5.0	110	176	61	2.89

Half the detection limit was used if results were below detection limits.

Figure 3.6 shows mean soil lead concentrations for all samples collected by both methodologies. The geometric mean concentration for soil samples collected by the BHSS protocol in the Basin is 682 mg/kg compared to 100 mg/kg in the Box and 61 mg/kg in Background communities (Table 3.5). (Table 3.5 indicates a lack of variance for Box soil samples. As mentioned previously, this is because a nominal soil concentration of 100 mg/kg was assumed for all the Box homes, which have been remediated). The maximum soil result (8,900 mg/kg) was collected from a Basin home.

Figure 3.6 Comparison of Geometric Mean Soil Lead Concentrations HUD Methodology vs. BHSS Methodology

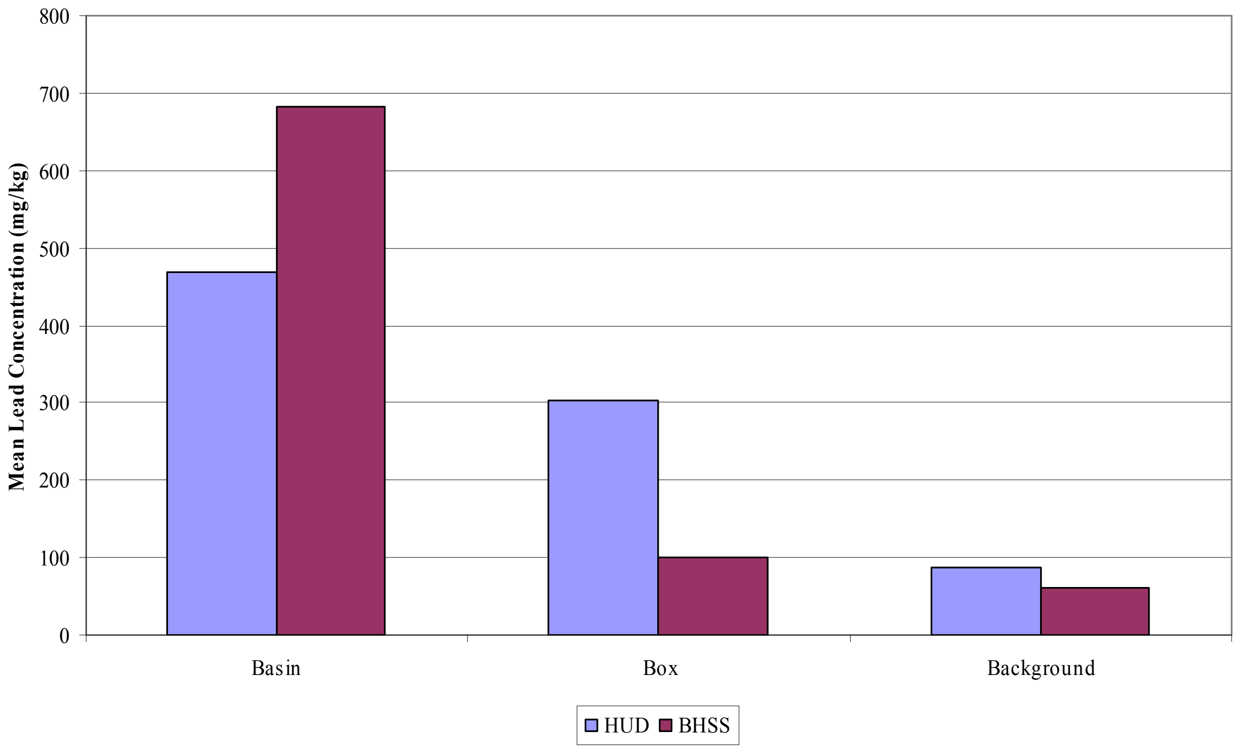


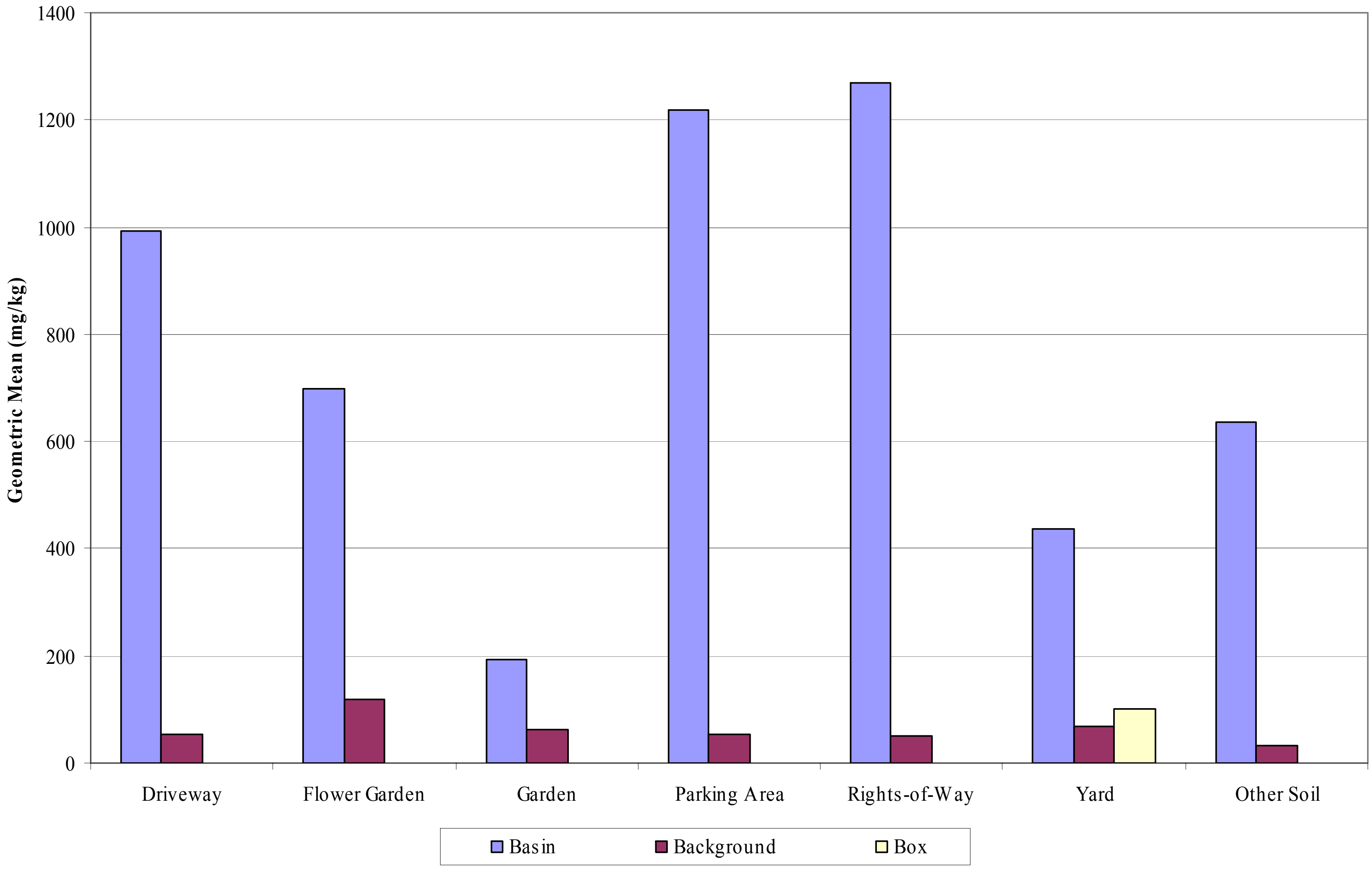
Table 3.6 and Figure 3.7 summarize soil samples by community and by sample location. As all BHSS Box soil results are for yard soils, comparison between soils from other discrete locations (i.e., driveway, garden, and parking) can only be made between Basin and Background communities. Geometric mean yard soil concentrations were highest in the Basin (438 mg/kg) and lowest in Background communities (69 mg/kg). Overall, mean soil concentrations from other discrete locations are greatest in the Basin when compared to Background concentrations. The mean concentrations for Basin parking areas and driveways are 1,218 mg/kg and 994 mg/kg, respectively, compared to approximately 55 mg/kg for parking areas and driveways in Background communities.

Table 3.6 BHSS Soil Summary Statistics by Community Group and Sample Location

Sample Location	Community	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)	Average (mg/kg)	Standard Deviation	Geometric Mean (mg/kg)	Geometric Standard Deviation
Dripline*	Basin	2	--	--	--	--	--	--
Driveway	Basin	16	8,640	147	1,967	2,241	994	3.72
Driveway	Background	11	337	5.0	90.7	93.5	54.9	3.23
Flower Garden	Basin	7	1,760	274	844	552	698	1.97
Flower Garden	Background	19	1,040	5.0	235	273	120	3.78
Garden	Basin	5	431	58.8	257	173	194	2.54
Garden	Background	18	278	11.0	86.8	65.4	63.0	2.48
Other Soil	Basin	19	4,860	63.2	1,031	1,193	637	2.79
Other Soil	Background	7	166	5.0	62.1	64.7	32.9	3.72
Play Area*	Basin	1	--	--	--	--	--	--
Play Area*	Background	1	--	--	--	--	--	--
Parking Area	Basin	8	8,900	106	3,139	3,467	1,218	5.54
Parking Area	Background	8	235	13.0	81.8	73.1	54.8	2.81
Right-of-Way	Basin	24	7,920	15.3	1,946	1,830	1,270	3.23
Right-of-Way	Background	43	1,470	11.0	96.7	224	49.5	2.54
Yard	Basin	47	2,877	127	575	552	438	1.99
Yard	Box	26	100	100	100	0	100	1.00
Yard	Background	29	304	14.0	91.3	69.8	69.2	2.22

*Results not shown to protect the confidentiality of participants.

Figure 3.7 BHSS Soil Concentrations by Community Group and Sample Location



3.3 Dust Surveys

3.3.1 HUD Protocol Dust Samples

Table 3.7 summarizes the results of HUD dust wipe samples collected in each community. Only 19 of 308 samples (6%) collected in the Study exceeded the USEPA/HUD criteria, nine in the Basin, eight in the Box, and two in the Background communities. (One sample (70,300 µg/ft^2) was collected from under the floor of a reloading table and was removed prior to summarizing results in Table 3.7). Thirteen of the exceedances were for window sills and six for floors. After averaging the dust wipes samples, 4% of the homes in each the Basin and Box exceeded the floor USEPA/HUD standard of 40 µg/ft^2, while zero homes in the Background communities exceeded the floor standard. Seventeen percent (17%) and 12% of the Basin and Box homes' average window sill lead loadings exceeded the USEPA/HUD standard of 250 µg/ft^2, while only one home's average in the Background communities exceeded the window sill standard.

Table 3.7 Dust Wipe Summary Statistics by Community Group and Surface Sampled

Surface	Community	Number of Samples	Number and Percent of Samples Exceeding EPA/HUD Standards*	Number of Homes with Average Lead Loading Exceeding EPA/HUD Standards*	Lead Loading (ug/ft^2) Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Floor	Basin	65	3 (5%)	1 (4%)	99	5.0	9.3	15	6.4	1.94
	Box**	78	3 (4%)	1 (4%)	328	5.0	12.6	37	7.0	2.08
	Background	72	0 (0%)	0 (0%)	21	5.0	5.4	2	5.2	1.24
Window Sill	Basin	30	6 (20%)	4 (17%)	1,988	9.2	181	397	53	4.13
	Box	35	5 (14%)	3 (12%)	3,586	10.5	203	616	48	4.05
	Background	26	2 (8%)	1 (4%)	1,081	5.0	81.7	214	27	3.40
Other***	Background	1	--		--	--	--	--	--	--

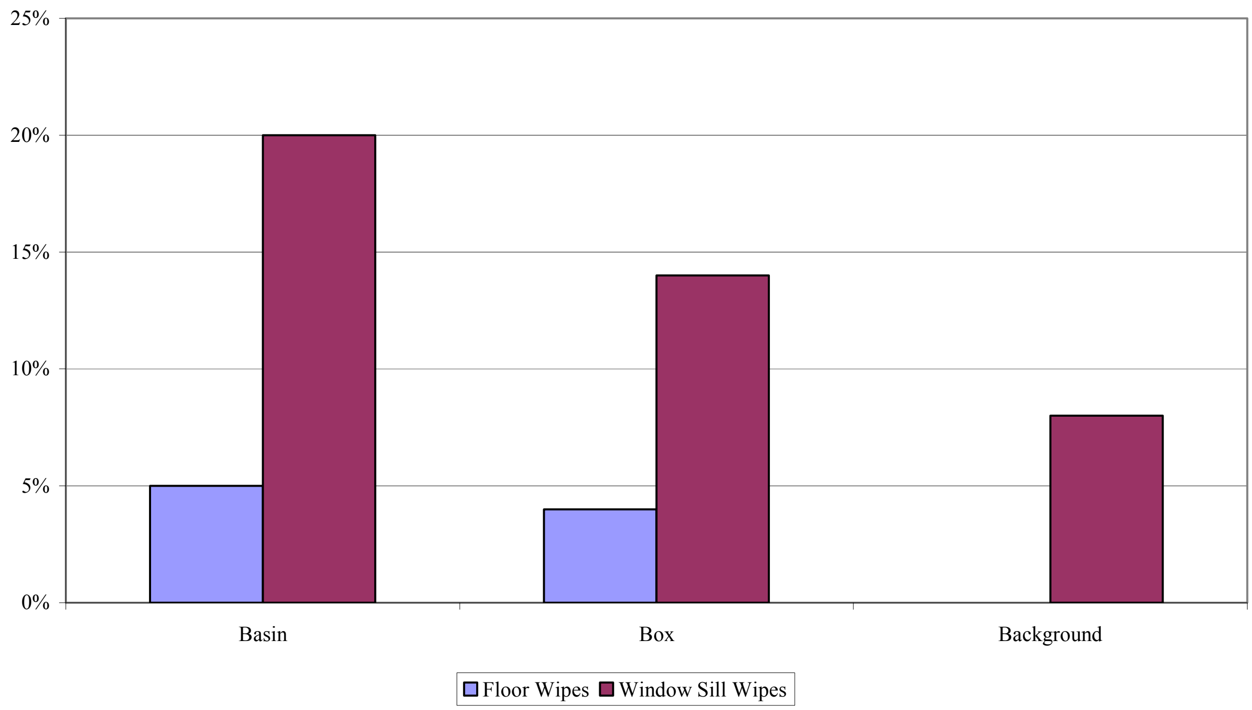
* USEPA/HUD standards = 40 ug/ft² for floors, 250 ug/ft² for window sills.

**One sample was collected from the floor under a reloading table (70,300 ug/ft^2) and was removed prior to summary.

***Results not shown to protect confidentiality of participant. The surface sampled was a cabinet.

Figure 3.8 shows the percentage of wipe samples greater than the USEPA/HUD Standards. Twenty-percent (20%) of Basin window sill wipes and 14% of Box sill wipes exceeded the 250 µg/ft^2 for window sills, while 8% of sill wipes exceed this level in Background homes. Five percent (5%) of floor wipe samples collected in the Basin and 4% in the Box were greater than the USEPA/HUD Standard of 40 µg/ft^2. No floor wipes exceeded this criterion in the Background communities.

Figure 3.8 Percent of Lead Dust Wipes Exceeding USEPA/HUD Standard by Community*



* USEPA/HUD standard = 40 ug/ft² for floors, 250 ug/ft² for window sills.

Overall geometric mean loading values in Table 3.7 show that mean loading for window sill wipe are between 5 and 9 times higher than mean loading for floor wipes. The Basin had the highest geometric mean loading value for window sills (53 micrograms per square foot; $\mu g/ft^2$) compared to the Box (48 $\mu g/ft^2$) and Background communities (27 $\mu g/ft^2$).

The mean loading values for floor wipes in the Basin, Box, and Background communities are (6.4 $\mu g/ft^2$, 7.0 $\mu g/ft^2$, and 5.2 $\mu g/ft^2$, respectively). However, a large percentage of wipes in all communities did not have detectable levels of lead (non-detects) and were assigned a value of 5 µg/wipe (half the detection limit) for use in calculations. Ninety-seven percent (97%) of floor wipe samples and 77% of window sill wipe samples in Background communities were non-detects. In the Basin and Box, 86% and 75% of floor wipe samples and 70% and 57% of window sill wipe samples, respectively, did not have detectable lead levels. The highest floor wipe sample (70,300 mg/kg) was collected from under an ammunition reloading table from a home in the Box. The second highest floor wipe sample (328 mg/kg) was collected from an entry way of a house in the Box. The highest sill wipe sample (3,586 mg/kg) was collected from a kitchen window in the Box.

Figures 3.9a and b show dust wipe sample results by sample location, surface, and community. Overall, mean loading values for floors do not differ greatly by room sampled. However, geometric mean loadings for floors in Background communities are generally lower than those in the Basin and Box. Mean window sill loading values are 1.5 to 2 times higher in the Box and

Basin compared to Background communities. Similar to mean loadings for floors, there are no noticeable trends in window sill loadings when comparing results by room sampled.

Figure 3.9a Floor Dust Wipe Loading By Community and Location

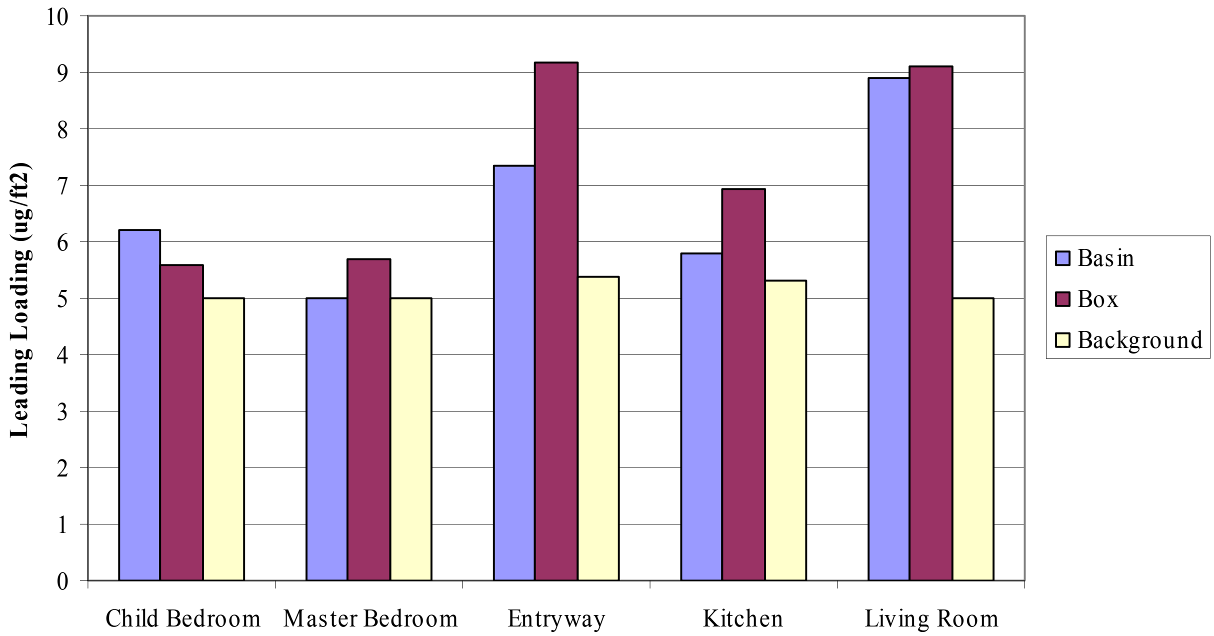
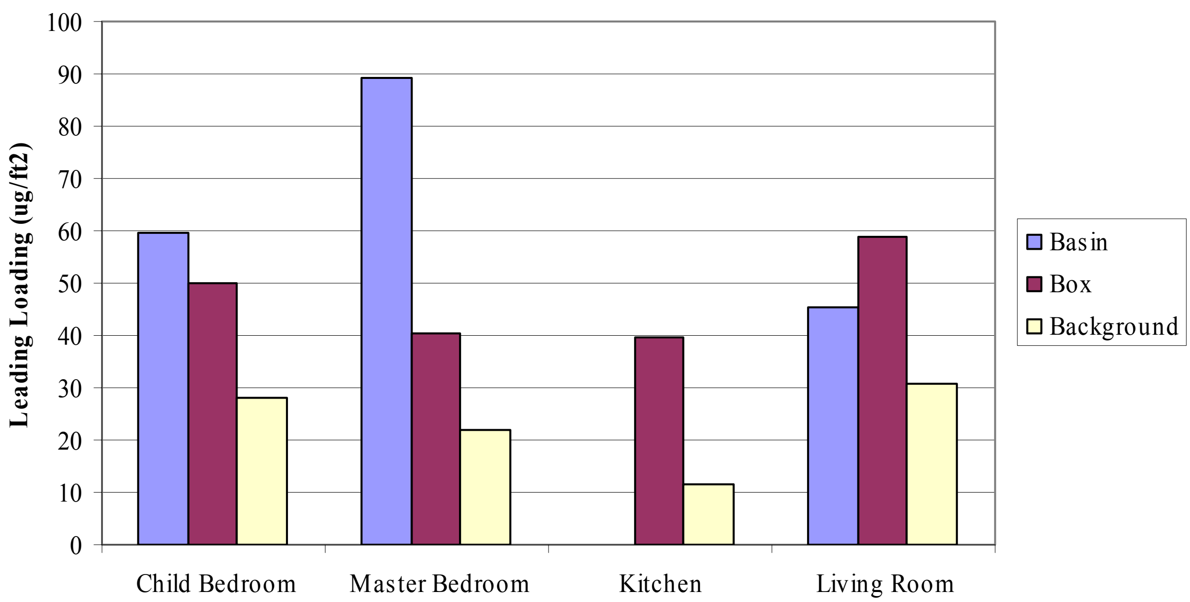


Figure 3.9b Window Sill Dust Wipe Loading By Community and Location



3.3.2 BHSS Protocol Dust Samples

3.3.2.1 Vacuum Cleaner Bag and Dust Mat Summary

Tables 3.8a-c summarize vacuum bag and dust mat lead concentrations and high samples (greater than or equal to the 1,000 mg/kg action level used at the BHSS) and loading rates for all communities. Geometric mean vacuum bag lead concentrations for the Basin and Box are 551 mg/kg and 471 mg/kg, respectively, with the highest sample (27,300 mg/kg) collected from a home in the Box. Twenty-four percent (24%) of all vacuum bag samples collected in the Basin are greater than or equal to 1,000 mg/kg and 14% are greater than or equal to 1,000 mg/kg in the Box. The geometric mean vacuum bag concentration for Background communities is 129 mg/kg, and no vacuum bag samples exceed 1,000 mg/kg.

Table 3.8a Summary Statistics for Vacuum Samples

Community	Number of Samples	Number and Percent of High Samples*	Lead Concentration (mg/kg)					
			Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Basin	17	4 (24%)	2,210	211	695	532	551	1.98
Box	22	3 (14%)	27,300	25.0	1,746	5,731	471	3.42
Background	20	0 (0%)	933	47.0	201	223	129	2.50

* exceeding 1,000 mg/kg lead
Half the detection limit was used if results were below detection limits.

Table 3.8b Summary Statistics for Mat Samples (Lead Concentration)

Community	Number of Samples	Number and Percent of High Samples*	Lead Concentration (mg/kg)					
			Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Basin	23	3 (13%)	2,000	70.5	575	552	396	2.42
Box	25**	1 (4%)	9,330	121	746	1,799	391	2.30
Background	25	0 (0%)	501	12.0	129	138	79	2.80

* exceeding 1,000 mg/kg lead
** one mat had insufficient sample volume for laboratory analysis.
Half the detection limit was used if results were below detection limits.

Table 3.8c Summary Statistics for Mat Samples (Dust and Lead Loading Rates)

Community	Number of Samples	Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Dust Loading Rate (mg/m²/day)							
Basin	23	4,070	77	963	863	672	2.55
Box	26	10,075	31	1,469	2,179	694	3.75
Background	25	16,621	172	2,108	3,349	1,109	2.95
Lead Loading Rate (mg/m²/day)							
Basin	23	3.53	0.01	0.66	0.87	0.27	4.94
Box	25*	9.88	0.02	0.97	2.08	0.31	4.65
Background	25	1.346	0.005	0.20	0.29	0.09	3.88

* one mat had insufficient sample volume for laboratory analysis.
Half the detection limit was used if results were below detection limits.

Geometric mean dust mat samples are lower than mean vacuum bag samples in all communities, with mean concentrations in the Basin and Box around 390 mg/kg and a mean concentration in Background communities of 79 mg/kg. This follows a trend noted in previous analyses that dust mat and vacuum bag concentrations converge as soil remediation nears completion (TerraGraphics 2004, 2005b). In addition, a study on Background house dust levels outside the Box in communities unaffected by mining revealed that mat and vacuum bag lead concentrations showed no significant difference between the two techniques (Spalinger et al. in-press). Thirteen percent (13%) of Basin dust mat samples and 4% of Box dust mat samples are greater than or equal to 1,000 mg/kg. No dust mat samples from Background communities exceed 1,000 mg/kg.

Table 3.8c shows that geometric mean dust loading rates were greatest in Background communities (1,109 $mg/m^2/day$); nearly two times the geometric mean dust loading rates in the Basin and Box (672 $mg/m^2/day$ and 694 $mg/m^2/day$). Conversely, geometric mean lead loading rates in the Basin and Box are around 3 times greater than the mean lead loading rate in Background communities. Geometric mean dust mat lead loading rates in the Basin, Box, and Background communities are 0.27 $mg/m^2/day$, 0.31 $mg/m^2/day$, and 0.09 $mg/m^2/day$, respectively.

3.3.2.2 BRM Summary

Table 3.9 summarizes BRM lead concentrations and dust and lead loadings by community. Geometric mean lead concentrations in the Basin and Box (397 mg/kg and 426 mg/kg, respectively) are about four times greater than mean lead concentration in Background communities (101 mg/kg), with the highest sample in the Basin (2,150 mg/kg). BRM concentrations are compared to the action level for high house dust (≥1,000 mg/kg) used at the BHSS. Five BRM samples (11%) collected from the homes in the Basin and 3 BRM samples (6%) from Box homes exceed this criterion. No BRM samples from homes in Background communities exceed 1,000 mg/kg. Geometric mean dust loading values for all three community groups are comparable, ranging from 18,023 micrograms per square meter (mg/m^2) in the Basin to 20,434 mg/m^2 in the Box. Geometric mean lead loading values are 7.2 mg/m^2 and 8.7 mg/m^2 in the Basin and Box (respectively) and 2.0 mg/m^2 in Background communities.

Table 3.9 BRM Summary Statistics by Community

Community	Number of Samples	Number and Percent of High Samples*	Lead Concentration (mg/kg)					
			Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Basin	47	5 (11%)	2,150	94.0	528	427	397	2.16
Box	51	3 (5%)	1,850	126	500	324	426	1.74
Background	49	0 (0%)	446	25.0	123	84	101	1.88

* exceeding 1,000 mg/kg lead

Community	Number of Samples	Dust Loading (mg/m^2)					
		Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Basin	47	104,844	1,378	28,679	27,035	18,023	2.86
Box	51	177,108	1,184	29,952	32,083	20,434	2.40
Background	49	206,961	2,135	31,388	35,528	19,696	2.74

Community	Number of Samples	Lead Loading (mg/m^2)					
		Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Basin	47	83	0.15	15.7	18.2	7.2	4.5
Box	51	63	0.38	14.8	16.1	8.7	3.0
Background	49	26	0.11	3.9	5.2	2.0	3.3

Half the detection limit was used if results were below detection limits.

Table 3.10 compares BRM lead concentrations and dust and lead loadings by sample location (i.e., samples collected from bedrooms versus living rooms). Geometric mean concentrations for BRM samples collected from bedrooms and living rooms are comparable (236 mg/kg and 275 mg/kg, respectively). However, geometric mean dust and lead loading values differ markedly between bedroom and living room samples, with lower dust and lead loadings occurring in bedrooms in comparison to living rooms. Geometric mean dust loadings for bedroom and living room samples from all communities are 15,655 mg/m^2 and 24,491 mg/m^2, respectively. Mean lead loadings for bedroom and living room samples are 3.7 mg/m^2 and 6.7 mg/m^2, respectively.

Table 3.10 BRM Summary Statistics by Sample Location

Location	Number of Samples	Lead Concentration (mg/kg)					
		Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Bedroom	69	2,150	25.0	351	357	236	2.49
Living Room	74	1,850	32.0	412	370	275	2.60
Other	4	717	157	417	233	363	1.89

Location	Number of Samples	Dust Loading (mg/m^2)					
		Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Bedroom	69	121,026	1,184	23,703	23,895	15,655	2.63
Living Room	74	206,961	3,131	36,943	36,868	24,491	2.58
Other	4	15,572	5,920	11,051	4,335	10,346	1.54

Location	Number of Samples	Lead Loading (mg/m^2)					
		Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Bedroom	69	63	0.11	8.2	11.8	3.7	3.96
Living Room	74	83	0.21	14.8	17.6	6.7	4.16
Other	4	10	0.93	5.2	3.9	3.8	2.83

Mean BRM lead concentrations and dust and lead loadings were also examined by community group and sample location (Table 3.11). Geometric mean concentrations for BRM samples collected from bedrooms and living rooms in Background communities are comparable (103 mg/kg and 100 mg/kg, respectively). However, in the Basin and Box, geometric mean lead concentrations are slightly elevated in living rooms when compared to bedrooms, with mean concentrations in Basin living rooms near 450 mg/kg compared to mean concentration in bedrooms around 360 mg/kg. In the Box, the mean living room concentration is 470 mg/kg compared to a mean concentration in bedrooms of around 370 mg/kg.

Table 3.11 BRM Summary Statistics by Community and Sample Location

Location	Community	Number of Samples	Lead Concentration (mg/kg) Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Bedroom	Basin	21	2,150	94.0	520	509	361	2.37
	Box	24	1,330	126	425	243	375	1.66
	Background	24	446	25.0	128	95	103	1.96
Living Room	Basin	23	1,630	139	563	370	452	2.01
	Box	26	1,850	204	560	380	470	1.79
	Background	25	289	32.0	119	75	100	1.82
Other	Basin	3	445	157	316	146	289	1.72
	Box*	1	--	--	--	--	--	--

Location	Community	Number of Samples	Dust Loading (mg/m^2) Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Bedroom	Basin	21	98,744	1,378	19,236	22,383	11,366	2.94
	Box	24	121,026	1,184	25,996	29,052	17,356	2.53
	Background	24	79,261	2,135	25,318	19,546	18,685	2.39
Living Room	Basin	23	104,844	4,413	39,708	28,493	29,862	2.31
	Box	26	177,108	6,602	34,236	35,173	24,138	2.28
	Background	25	206,961	3,131	37,214	45,674	20,718	3.14
Other	Basin	3	15,572	5,920	10,226	4,909	9,461	1.62
	Box*	1	--	--	--	--	--	--

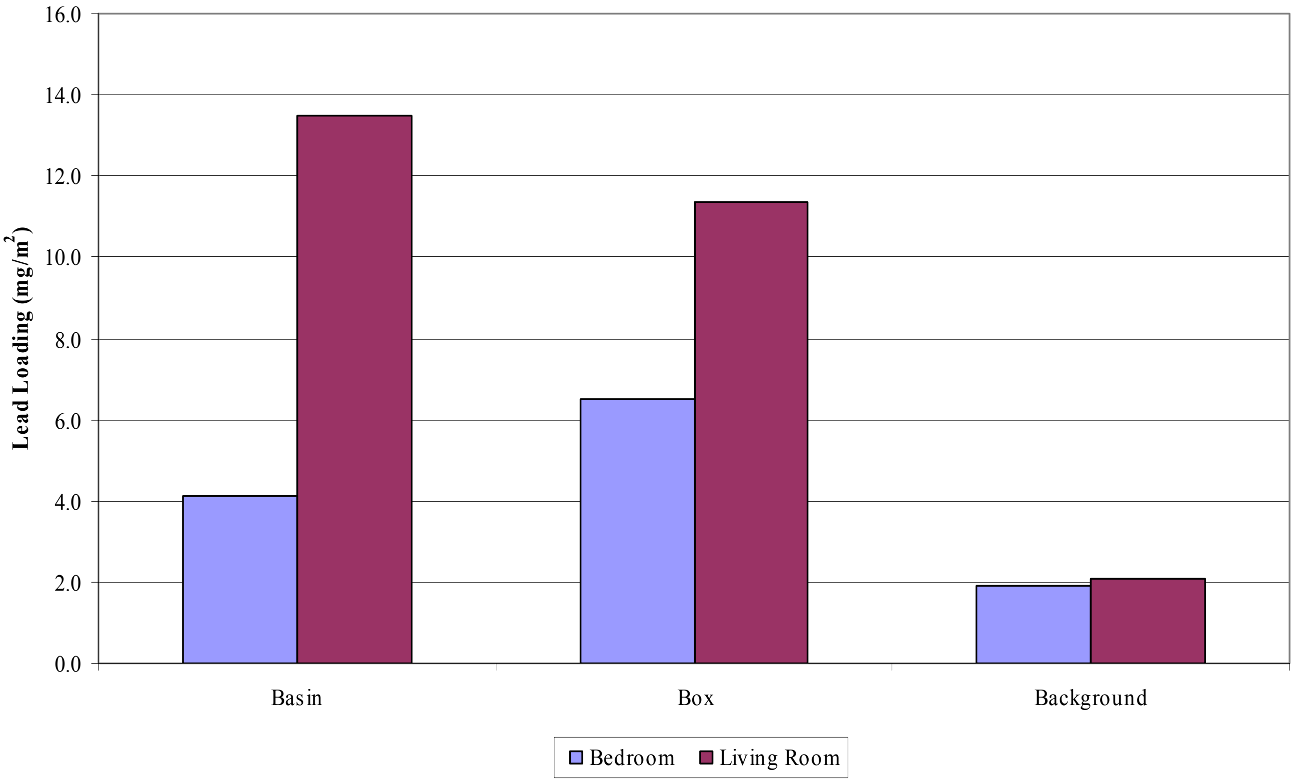
Location	Community	Number of Samples	Lead Loading (mg/m^2) Maximum	Minimum	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Bedroom	Basin	21	27	0.15	8.8	8.3	4.1	4.77
	Box	24	63	0.38	12.6	17.2	6.5	3.21
	Background	24	12	0.11	3.3	3.4	1.9	3.16
Living Room	Basin	23	83	0.61	23.6	22.4	13.5	3.45
	Box	26	61	1.36	17.1	15.2	11.3	2.66
	Background	25	26	0.21	4.4	6.6	2.1	3.50
Other	Basin	3	7	0.93	3.7	3.0	2.7	2.75
	Box*	1	--	--	--	--	--	--

* Results not shown to protect the confidentiality of participant.

Similar to the dust and lead loading patterns demonstrated by BRM results from all communities (described above), lower dust and lead loading values occurred in bedrooms when compared to living rooms in the Basin and Box (Figure 3.10). In the Basin and Box, mean dust loading values for bedrooms are 11,366 mg/m^2 and 17,356 mg/m^2 compared to 29,862 mg/m^2 and 24,138 mg/m^2

in living rooms, respectively. Similarly, geometric mean lead loading in Basin living rooms is 3 times higher than bedrooms (13.5 mg/m^2 vs. 4.1 mg/m^2) and nearly 2 times higher in Box living rooms versus bedrooms (11.3 mg/m^2 vs. 6.5 mg/m^2). However, dust and lead loading values in bedrooms and living rooms are comparable in Background homes (mean dust loading=18,685 mg/m^2 and 20,718 mg/m^2, respectively, and mean lead loading=1.9 mg/m^2 and 2.1 mg/m^2, respectively).

Figure 3.10 Geometric Mean Lead Loading (mg/m^2) in Child's Bedrooms & Living Rooms by Community Using BRM Method



3.3.2.3 Dust Lead Concentration and Loading Summary

Figure 3.11 shows geometric mean dust lead concentrations for the three BHSS dust sampling methodologies for each community group. Mean concentrations are similar in the Box and Basin ranging from about 400 mg/kg to 550 mg/kg with vacuum bag samples slightly higher than BRM and mat samples. All three methods find lead concentrations of about 100 mg/kg in the Background communities. Figure 3.12 shows the percentage of these samples exceeding the 1,000 mg/kg criteria by community. Two to three times as many exceedances are noted in the Basin as in the Box, with no high samples observed in the Background areas. In the Basin and Box, the percent of vacuum samples exceeding the criteria is nearly double that of mat or BRM samples.

Figure 3.11 Comparison of Geometric Mean Lead Concentrations (mg/kg) for Vacuum, Mat, and BRM Samples by Community

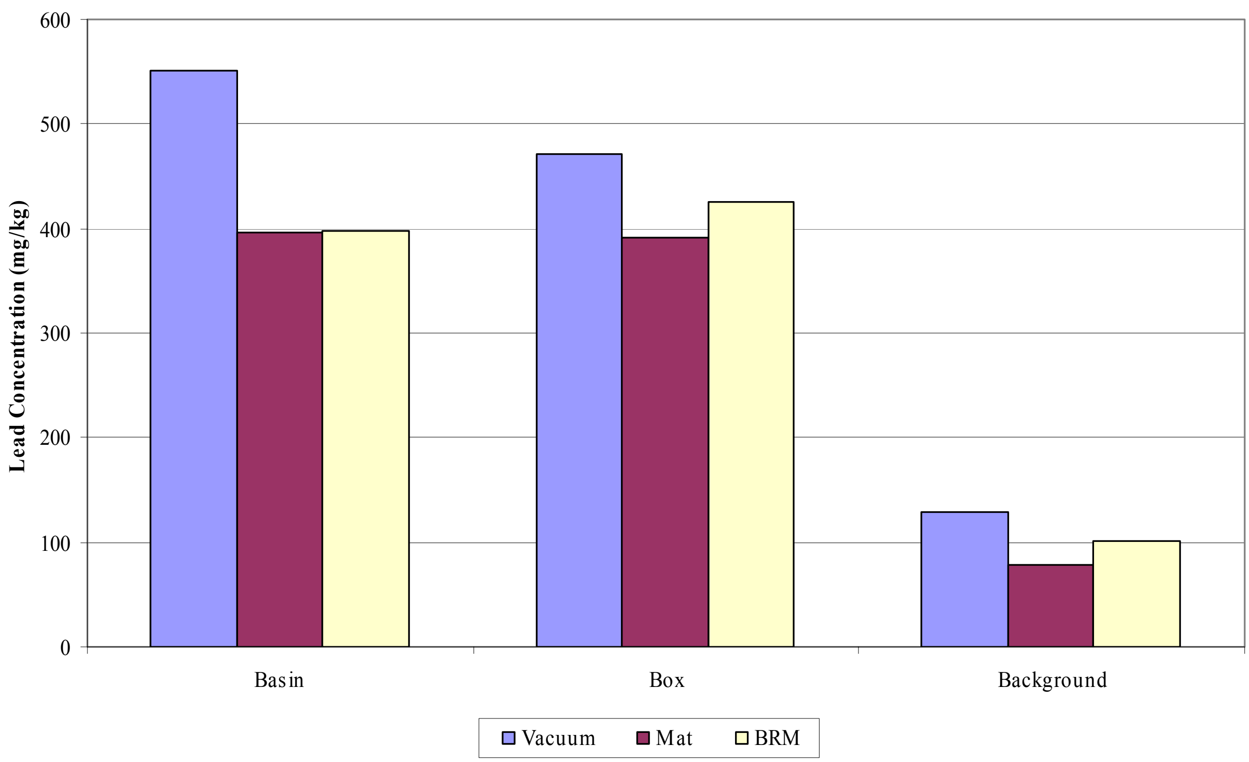
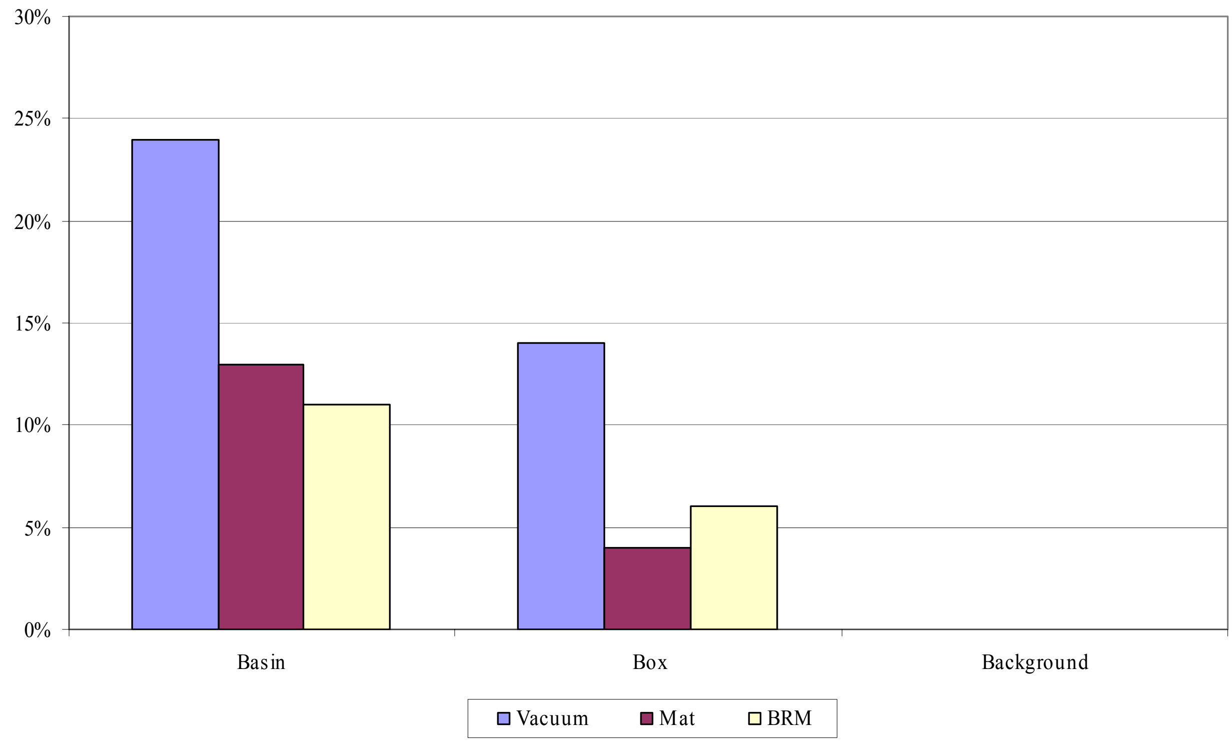


Figure 3.12 Percent of Vacuum, Mat, and BRM Samples Exceeding BHSS Criteria (1,000 mg/kg) by Community



Figures 3.13a and b show lead loadings and rates for the BRM and mat methods. For mats, the loading rates measured in the Basin and Box are about three times that noted for the Background areas. Similarly, the BRM lead loadings in the carpets are about 3½ to 4 times greater in the Box and Basin than in Background areas. The mat lead loading rate incorporates the amount of time the mats are in a home, as opposed to the BRM lead loading which has no time factored into the collection of the sample. The dust mat collects dust inside a home for about one month, while the BRM vacuums dust from a carpet instantaneously at the time of sampling.

Figure 3.13a Geometric Mean Lead Loading Rate (mg/m^2/day)
for Mat Samples

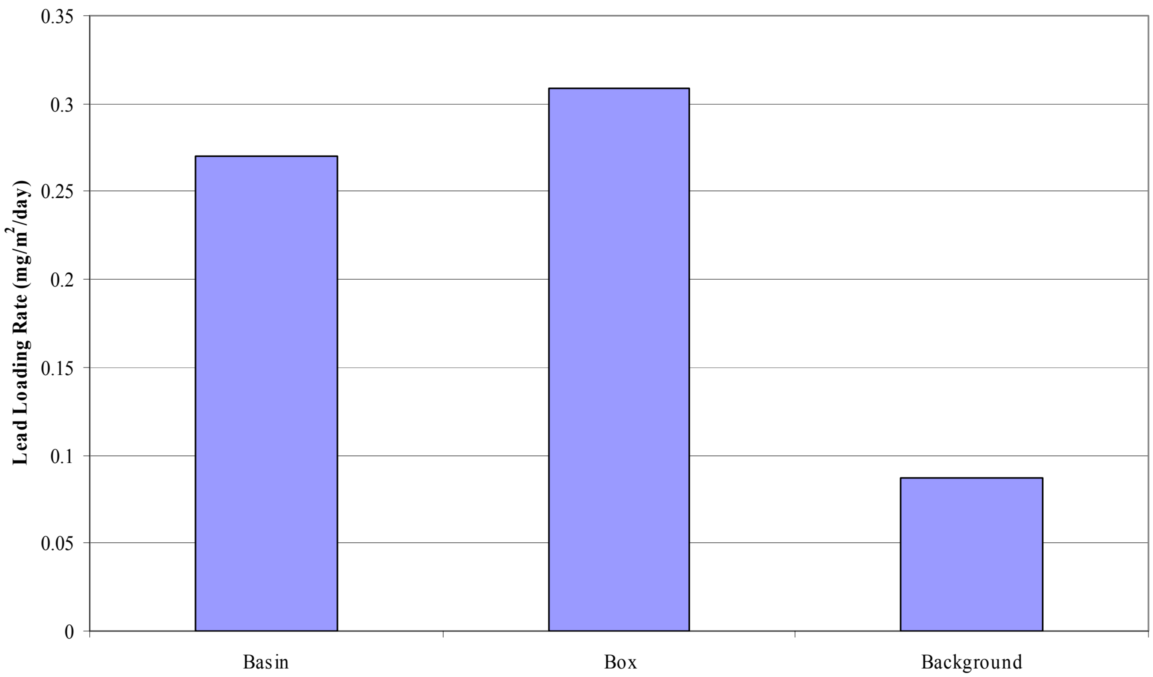
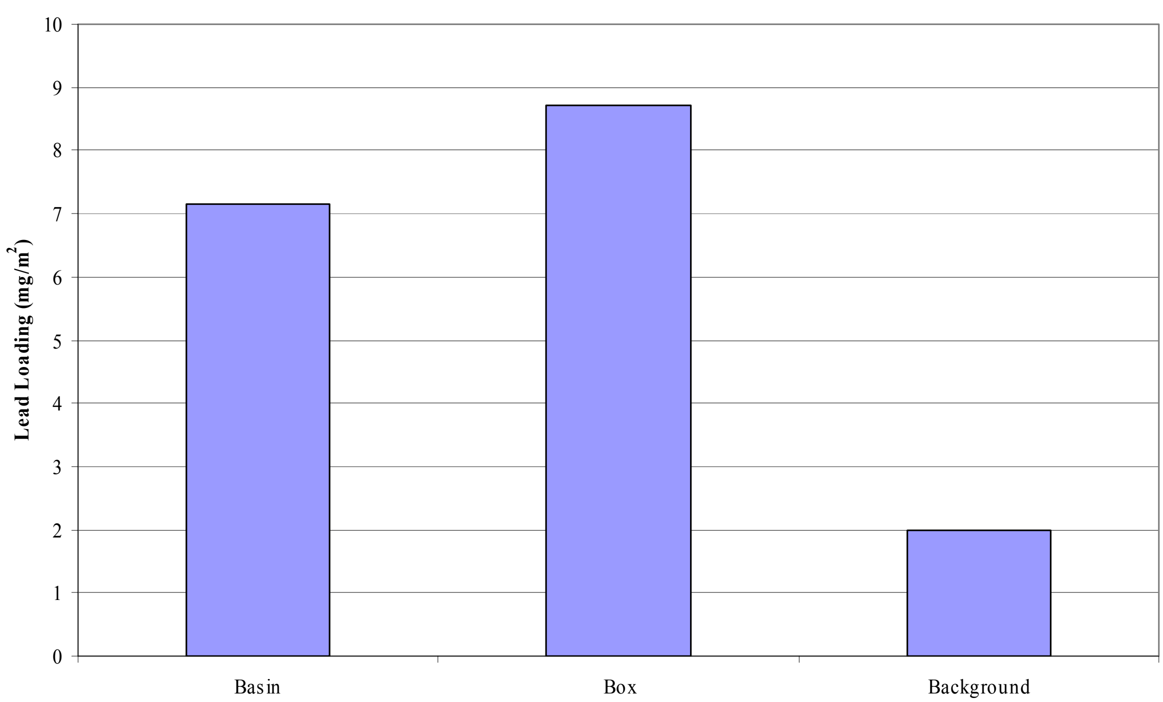


Figure 3.13b Geometric Mean Lead Loading (mg/m^2)
for BRM Samples



3.4 Screening Interview Questionnaire Summary

Questionnaire data relating to house age, family size, hobbies and occupations were collected prior to selecting homes for participation in the study. A total of 102 homes were solicited using the Screening Interview Questionnaire described in the QAP (PHD and TerraGraphics 2004). The answers to the questionnaire were reviewed for similarities prior to selecting a home for participation. The primary criteria used for selecting homes were older houses built prior to1960 (preferably pre-1940), houses with children, and the condition of paint (based on a preliminary assessment completed for the Screening Interview). After homes were selected, and enrollment occurred with a signed informed participant consent form, sampling was scheduled. Residents were also told after enrollment that they would receive a fifty-dollar incentive pay after all sampling activities were complete, in order to encourage their continued participation.

Sampling began in the Superfund Site homes in September and continued into October; finishing in the Background communities. Difficulties encountered with participation occurred when residents with signed consent forms decided to not participate at the time samplers arrived at their home or the participant could not be contacted again once enrolled. These types of problems are not atypical, and have been dealt with many times during Superfund sampling activities in the past. Some of the homes screened were considered as back-up homes, and were enrolled if a drop-out occurred. Near the completion of sampling a few homes dropped out, no more recruited homes were available, and the entire towns of Potlatch and Bovill had been solicited. As a result, recruitment began in the town of Troy. Four houses from Troy were selected to participate and completed the total of 75 units for this study.

A select number of factors from the Screening Interview Questionnaire are summarized in Table 3.12 for the 75 participants. The factors summarized have been shown to be significant factors affecting house dust lead concentrations and loading rates in past research conducted at the BHSS (TerraGraphics 2000). A majority of the factors were similar across the three communities with regard to house age, whether the participant owns or rents, the length of time living at the home, remodeling, the use of throw rugs and entryway mats, accessible basements/attics/crawl spaces, and centralized heating air ducts. Children resided at all the homes participating in the Box and Background communities, and only a few homes did not have children living at the home in the Basin (Table 3.12). The assessment of the condition of the paint recorded during the Screening Interview was completed similar to the HUD method with regard to categorizing the paint in poor or good condition. As noted during the Screening Interview, the majority of homes in all three communities were identified with poor exterior paint condition (i.e., visible chipping, chalking, or peeling). A majority of the homes from the BHSS were identified as having poor interior paint condition, with the majority of the interiors in Background homes identified as having good interior paint condition. This assessment was preliminary and was not completed by HUD risk assessors, but by trained staff performing the Screening Interview. In some cases, only a few rooms inside the homes were accessible for visible assessment at the time of the Screening Interview. Section 3.1 and Tables 3.1a-b summarize the certified Risk Assessor's inspection of the paint at these homes.

Table 3.12 Screening Interview Questionnaire Summary

Question	Possible Answers	Basin	Box	Background
Year Built	Before 1960	92%	64%	83%
	1960-1978	0%	0%	0%
	After 1978	0%	0%	4%
	Don't Know	8%	36%	13%
Own/Rent	Rent	33%	42%	30%
	Own	67%	58%	70%
Length Lived in Home	< 1 month	4%	4%	4%
	1-2 months	0%	0%	0%
	2-3 months	4%	0%	4%
	3-6 months	4%	23%	9%
	6-12 months	17%	12%	9%
	1-5 years	21%	27%	39%
	>5 years	50%	35%	35%
	Don't Know	0%	0%	0%
Interior Painted or Window Sills Sanded, Removed, Remodeled	Yes	75%	40%	72%
	No	25%	60%	28%
	Don't Know	0%	0%	0%
Date of Interior or Window Sill Work	Within last year	50%	50%	33%
	1-2 years ago	17%	13%	0%
	> 2 years ago	33%	38%	60%
	Don't Know	0%	0%	7%
Home Remodel or New Carpet/Furniture	Yes	33%	36%	61%
	No	67%	64%	39%
	Don't Know	0%	0%	0%
Date of Remodel or New Carpet/Furniture	Within last year	38%	56%	67%
	1-2 years ago	38%	0%	8%
	> 2 years ago	25%	44%	17%
	Don't Know	0%	0%	8%
Number of throw rugs/entrance mats	None	13%	12%	14%
	One at one entrance	29%	35%	32%
	At some entrances	8%	0%	9%
	At all entrances	50%	54%	45%
Number of throw rugs/area rugs inside the home	None	8%	12%	4%
	1-2	46%	42%	39%
	3-5	38%	27%	26%
	>5	8%	19%	30%
Number of adults who regularly live in home	1	21%	19%	4%
	2	71%	65%	83%
	3	8%	12%	9%
	4	0%	0%	4%
	5	0%	4%	0%
Number of children who regularly live in home	0	6%	0%	0%
	1	28%	63%	29%
	2	22%	13%	43%
	3	28%	13%	21%
	4	11%	0%	7%
	5	6%	13%	0%
Centralized Heating/Air Conditioning	Yes	58%	54%	35%
	No	42%	46%	65%
Accessible Basement	Yes	54%	58%	52%
	No	46%	42%	48%
Accessible Attic	Yes	71%	65%	61%
	No	29%	35%	35%
	Don't Know	0%	0%	4%
Accessible Crawl Space	Yes	38%	31%	45%
	No	58%	69%	55%
	Don't Know	4%	0%	0%
Condition of Inside Paint	Good	17%	8%	76%
	Chipping, chalking, peeling, or bite marks	83%	92%	24%
Condition of Outside Paint	Good	0%	8%	23%
	Chipping, chalking, peeling, or bite marks	100%	92%	77%

SECTION 4.0 COMPARISON ANALYSES

The results summarized in Section 3.0 (Tables 3.2 through 3.11) were used in comparison analyses to assess differences among the three communities and between sampling methodologies. Analysis of Variance (ANOVA) and multiple comparison procedures (SAS 2004) were applied to soil and dust lead concentration and loading variables to assess differences among the three communities. Paired T-tests and Hotellings T^2 statistics were used to assess if significantly different lead concentrations and loadings were observed between the sampling techniques. The Hotellings T^2 is an extension of a paired T-test, used when more than two factors are being compared on the same experimental unit (i.e., BRM, vacuum, and mat lead concentrations from the same home). Paired statistics were applied because the experimental unit in this study was the home (or property) and all sampling techniques were applied in each home.

This section also presents correlation and linear regression modeling used to quantify relationships among soil, paint, and house dust. A conservative approach was applied to the statistical analyses in this study because of the possibility of Type I errors when running a large number of analyses. In order to reduce false-positive conclusions, the p-value used to assess significance was reduced from the typical $p \leq 0.05$ to $p \leq 0.01$. In addition, the dust and soil lead data are more normally distributed when log-transformed, so transformed variables were used in the comparison and regression analyses, unless otherwise indicated.

It is important to note that previous studies have shown that house age has a significant effect on lead concentration and loading results. However, all homes solicited and selected for this study were built prior to the 1960s, with most built prior to the 1940s. As a result, house age was considered a controlled or constant variable in these analyses.

4.1 Soil Sampling Results and Methods

The HUD and the BHSS methods differ in purpose as well as technique. HUD sampling is targeted at the top inch of bare soil in areas where children may be exposed. The BHSS sampling is accomplished to provide both composite and discrete location samples to characterize the residential property for both remedial and potential exposure purposes. Both methodologies can result in multiple samples per location or multiple sample locations per property. In the following analyses, property average soil concentrations are calculated and used in the ANOVAs and paired T-tests.

4.1.1 HUD Soil Results by Community

Tables 3.3-3.4 and Figure 3.3 summarized all HUD soil samples collected from different sample locations across the three communities (or study areas). After averaging multiple samples per sample location, the driplines and yards contained the largest number of results per community, whereas ten or less results per community were observed for the driveways, gardens, and play areas. Comparison analysis was not performed on the other areas, parking areas, and rights-of-way results because there were too few samples (<5 per community).

Yard soil samples are not significantly different between the Box and Background homes, but both are significantly different from the Basin yards ($p<0.0001$). Dripline samples show geometric mean soil concentrations of 676 mg/kg in the Basin, 510 mg/kg in the Box, and 254 mg/kg in the Background samples (See Figure 3.3). Multiple comparison tests show the Basin and Box dripline results are not significantly different, and the Box and Background results are not significantly different, whereas the Background and Basin dripline results are different from each other ($p=0.0057$). The driveway results show the Box and Basin are not different from each other, but are significantly different from Background ($p=0.0003$). The play area results showed that the Background homes were different from the Basin homes (however, the Box was not different from either) ($p=0.0044$), while the lead concentrations in the gardens were not different among the communities ($p=0.012$).

Because the dripline areas may be more influenced by lead-based paint than other locations, the HUD soil results were summarized by driplines and all other sample locations (See Table 3.4). The average lead concentration per home, for all soils other than driplines, shows significant differences among all the communities ($p<0.0001$). Multiple comparison tests between communities show Basin and Box lead concentrations for soils other than dripline are not different from each other but are different from the Background towns. A paired T-test was also performed for each community to determine if the HUD soil sampling method resulted in differences between dripline lead concentrations and other soil lead concentrations (Table 3.4). Both the Box and Background concentrations showed significant differences between driplines and other soils ($p=0.0012$ and $p<0.0001$, respectively). The Basin dripline concentrations were not different from the other soil results ($p=0.1$). These results indicate that when mining contamination is present (and not remediated), lead paint contamination of soils may not be detectable.

4.1.2 BHSS Soil Results by Community

Tables 3.5 and 3.6 summarize soil lead concentrations for BHSS surface (0-1 inch) samples collected in the Basin and Background areas. The Box yards have been remediated and are assumed to be clean with assigned soil lead concentrations of 100 mg/kg. Because the soil lead concentrations are assigned a clean concentration of 100 mg/kg, there is no variance among the BHSS Box results, and so were not included in the comparison analysis. Play areas, parking areas, and gardens did not have a sufficient number of observations for comparison. The remaining sample locations (yards, ROW, driveways, other soil areas, and flower gardens) all showed significantly different results between the Basin and Background communities ($p<0.004$). Mean driveway, ROW, and parking area lead concentrations in the Background communities averaged slightly over 50 mg/kg, while the Basin communities showed high levels of lead with means near 1,000 mg/kg, or higher (Table 3.6). Basin yard soils show a geometric mean of 453 mg/kg compared to an estimated Box yard soil mean of about 100-150 mg/kg (TerraGraphics 2005a) and a Background community mean of 69 mg/kg.

4.1.3 Comparison of HUD and BHSS Soil Sampling Methodologies

The BHSS soil sampling strategy is to characterize all soils on the property, whereas the HUD methodology focuses on those areas where children may play and bare soil exists. As a result, HUD results may not be representative of the entire property. Comparisons of results from the HUD and top inch samples from the BHSS methodology were compared for homes in the Basin and Background areas. The Box soil data were not included, as these concentrations are considered to be 100 mg/kg lead and no variance exists among the Box homes. Using both Basin and Background homes, no significant difference was observed between average soil lead concentrations by the HUD or BHSS methodologies ($p=0.34$). This suggests that either the HUD or BHSS samples provide similar results, and either or, or a combination thereof, may be used in the quantitative analyses.

4.1.4 Soil Sampling Methods Summary and Discussion

These comparative analyses show that there are no significant differences between the HUD and BHSS methodologies with respect to mean lead concentrations. Both methods provide similar results for the top inch of soils in common locations. The HUD soil protocol emphasizes bare soil locations in the yard and may be more representative of the immediate exposure to children, where the BHSS method better facilitates remedial actions. There are clear differences between Basin and Background soil concentrations for nearly every sampling location. Basin yard soils average about 7 times greater than Background areas and ROWs, driveways and parking areas in the Basin are nearly 20 times Background concentrations. Differences between BHSS Box results and other areas were not evaluated, as re-sampling of Box homes following remediation was not undertaken for the BHSS methodology.

Driplines sampled under the HUD protocol show significantly different concentrations than other samples for the Box and Background, but not in the Basin. This result suggests that paint-sourced lead in soils may not be detectable in the presence of mining contamination in the Superfund Site, until remediation is complete. Following remediation there are no significant differences in Box and Background soil lead levels, including the elevated dripline concentrations. These covered dripline soils are not considered a significant hazard in a typical HUD risk assessment.

4.2 Paint and Dust Lead Sampling Results and Methodologies

4.2.1 XRF Paint Lead Loading by Community

Table 3.2a summarizes the exterior and interior condition of the paint across the three communities. Interior paint conditions were similar among the three communities with 87%-89% of the paint assessed in good condition. Exterior conditions were better in the Background communities with 50% in good condition compared to 23%-36% in good condition in the BHSS. An ANOVA was performed on the interior and exterior XRF average reading per home and Duncan's multiple comparison test showed the Background homes to have significantly higher lead content in paint than the Box and Basin ($p<0.005$) (see Table 3.2b). The variable indicating lead paint hazards is a combination of the XRF reading and the condition of the paint. In Table 3.2c, the last column indicates that the three communities had a large number of exterior paint hazards; with paint hazards identified in 92% of Basin homes, 85% of Box homes, and 80%of Background homes (80%). The interior paint hazards were similar among the three communities averaging around 50% of the homes.

4.2.2 Vacuum Bag Lead Concentration by Community

Geometric mean vacuum bag lead concentrations were 551 mg/kg, 471 mg/kg and 129 mg/kg for the Basin, Box and Background communities, respectively (Table 3.8a). Multiple comparisons between communities show that the Box and Basin mean vacuum bag dust lead concentrations are significantly different and about four times greater than mean Background concentration ($p<0.0001$). No significant difference between the Box and Basin vacuum bag lead concentrations were observed in the multiple comparison tests. These results are consistent with recent observations in the Box and Basin. Geometric mean vacuum bag concentrations for about 152 homes in the Box communities ranged from 239 mg/kg to 494 mg/kg in 2004 (TerraGraphics 2005b). In the Basin towns, 2004 mean community vacuum bag lead concentrations from 293 homes ranged from 198 mg/kg to 561 mg/kg (TerraGraphics 2006).

4.2.3 Mat Dust Lead Concentration and Loading by Community

Geometric mean mat dust concentrations follow the same pattern as vacuum bag concentrations. The Basin and Box geometric mean mat lead concentration is about 5 times greater, and significantly different, than the Background area mat dust lead at 396 mg/kg, 391 mg/kg and 79 mg/kg, respectively (Table 3.8b). There are no significant differences among dust loading rates ($p=0.21$). Lead loading rates differ at the $p=0.006$ level, with the Box and Basin lead loading about three times those in Background communities; 0.31mg/m^2/day, 0.27 mg/m^2/day and 0.09 mg/m^2/day, respectively (Table 3.8c).

These results are also similar to Box and Basin-wide studies conducted in 2004. Mat dust concentrations from 396 homes in the Basin ranged from 117 mg/kg to 420 mg/kg geometric mean by town (TerraGraphics 2006). Box results from 337 homes ranged 136 mg/kg to 393 mg/kg by town (TerraGraphics 2005b). Dust loading rates ranged from 360 mg/m^2/day to 841 mg/m^2/day in the Box, and from 376 mg/m^2/day to 918 mg/m^2/day in the Basin. Lead loading rates were 0.05 mg/m^2/day to 0.33 mg/m^2/day in the Box and 0.09 mg/m^2/day to 0.39 mg/m^2/day in the Basin. Farfel et al. 2001 used the mat technique in an urban setting contrasting new homes and homes built before 1950. They similarly noted no significant difference in dust loading rate but significant differences in dust lead concentration (107 mg/kg vs. 1,149 mg/kg) and lead loading rate (9 µg/ft^2/day vs. 130 µg/ft^2/day) or 0.097 mg/m^2/day and 1.4 mg/m^2/day, respectively.

4.2.4 BRM Lead Concentration and Loading by Community

BRM lead concentrations follow similar patterns as vacuum bag and mat lead concentrations, and BRM dust loading also follows similar patterns as mat dust loading rate.

4.2.4.1 Bedroom Sampling by Community

Significant differences were found in lead concentration of the dust extracted from the bedroom carpets by the BRM method. Geometric mean concentrations for the Basin, Box and Background communities were 361 mg/kg, 375 mg/kg, and 103 mg/kg, respectively (Table 3.11). The Box and Basin concentrations are nearly four times higher, and significantly different, than the

Background ($p<0.0001$). The Box and Basin concentrations are not significantly different. There was no significant difference in dust loading in these carpets among study areas ($p=0.19$), but lead loading showed significant differences ($p=0.007$). Geometric mean lead loading in the Box and Background communities were significantly different at 6.5 mg/m^2 and 1.9 mg/m^2, respectively. However, lead loadings in the Basin and Background communities were not significantly different, and the Basin and Box were not significantly different. There was considerable variation in the Basin results for the bedrooms (Table 3.11).

4.2.4.2 Living Room Sampling by Community

Similar differences were found in lead concentration and loadings of the dust extracted from living room carpets by the BRM method. Geometric mean concentrations for the Basin, Box and Background communities were 452 mg/kg, 470 mg/kg and 100 mg/kg, respectively (Table 3.11). The Box and Basin lead concentrations were significantly different than, and nearly five times greater than Background ($p<0.0001$). The Box and Basin concentrations were not significantly different. There was no significant difference in dust loading in these carpets among communities ($p=0.41$), but lead loading followed the same pattern as lead concentration. Geometric mean lead loading was not significantly different in the Box and Basin showing 11.3 mg/m^2 and 13.5 mg/m^2, respectively. However, the Background communities showed a significantly different mean of 2.1 mg/m^2.

4.2.5 HUD Dust Wipe Loading By Community

In contrast to the BHSS dust sampling methods, no significant differences in dust wipe loadings (floor, $p=0.04$ and window sill, $p=0.2$) among the three communities were observed. This result is likely due to the large number of below-detection readings and small number of exceedances of USEPA/HUD criteria (Table 3.7). Mean floor loading were 6.4 µg/ft^2 for the Basin, 7.0 µg/ft^2 for the Box, and 5.2 µg/ft^2 for the Background (Table 3.7). Mean window sill lead loadings were 53 µg/ft^2 for the Basin, 48 µg/ft^2 for the Box, and 27 µg/ft^2 for the Background (Table 3.7). After segregating the data further by surface, community, and room sampled (Figures 3.9a and b), floor loading means for each of the rooms did not vary among the three communities, except for the living room, where mean lead loadings in BHSS homes almost doubled compared to Background homes. Mean bedroom window sill lead loadings in the Basin homes were almost 2-4 times those in the Background homes. Not as many window sill wipes were below detection limits as floor wipes.

4.2.6 Comparison of HUD to BHSS House Dust Sampling Methodologies

The different sampling methodologies used in the HUD and BHSS protocols produce a number of dust lead measurement variables. The BHSS entryway floor mat method provides lead concentration and dust and lead loading rates. The BRM provides lead concentration and dust and lead loadings. Vacuum bag samples provide only lead concentration, and dust wipe samples provide only lead loading. The BRM, vacuum, and floor mat lead concentrations were compared using Hotellings T^2 and no significant difference among these three methods were observed ($p=0.073$ using the living room BRM concentration; $p=0.3$ using the bedroom BRM concentration). Lead loading was compared among the dust wipe, BRM, and floor mats in units of µg/ft^2 and a significant difference was observed ($p<0.0001$). The multiple comparison test shows that the dust wipe lead loadings are significantly different from the mat and BRM lead loadings ($p<0.0001$). However, mat and BRM lead loadings are not different from each other ($p=0.3$). This finding may be due to the large number of dust wipe results that were below detection limits.

No differences were observed among the BRM, mat, and vacuum lead concentrations. This result was expected as trends between dust mat and vacuum concentrations have been converging in the BHSS for the past several years (TerraGraphics 2005b, TerraGraphics 2000). In the Box, prior to the complete remediation of exterior soils, mat lead concentrations were significantly higher than vacuum bag lead concentrations. As remediation was completed and exterior soil lead concentrations were reduced, vacuum and mat lead concentrations were no longer significantly different. In addition, a study conducted in 1999 in background communities observed no significant difference between these variables (Spalinger et al. in-press, TerraGraphics 2000). These results suggest that the mat methodology is reflective of the community exterior soils. As exterior soil contamination is reduced, lead tracked into the home is reduced and both sampling methods begin to show similar lead concentrations. The BRM has only been used in special studies at the BHSS and does not have continuous data to examine similar trends.

4.2.7 Dust Sampling Methods Discussion and Summary

Comparison of dust risk assessment methods is less straight-forward than soils. Various vacuuming techniques and wipe methods have been studied. These methods vary in the measurement obtained, collection technique, and location sampled in the home. Historically, lead concentration in house dust was the most common measurement collected. Generally, sampling methodologies to determine concentration collect dust in a solid matrix form by vacuum techniques and report results in mass of lead per mass of dust. Later efforts focused on measurement of lead loading (e.g., mg/m^2) or loading rates (e.g., mg/m^2/day). Collecting loading versus concentration measurements greatly affects sampling methodology. To determine concentrations, only a sufficient quantity of dust must be collected. However, to determine loading, dust must be collected from a specific area and/or time period. Wipe techniques generally collect less mass of sample and are subject to greater variation and frequent below detection limit findings (bdls). Wipe techniques are generally more effective on hard surfaces when measuring dust directly accessible by children. Vacuum techniques are generally more effective on carpets, where the reservoir of lead dust is measured, but may or may not be accessible.

The HUD dust criteria rely on dust lead loading values conducted by a dust wipe methodology and focus on window sills and floors. The BHSS methodology relies on dust lead concentration supplemented by loading estimates based on larger volume samples collected by vacuum techniques, concentrated on carpet reservoirs of lead dust (See Section 2.2.3). Several attempts have been made to reconcile these different techniques at the BHSS, both in laboratory and field testing. These results were summarized in the 1999 Five Year Review (TerraGraphics 2000).

At that time, it was concluded that there is no clear consensus on the most appropriate methodology for sampling house dust. No standard or universally accepted house dust sampling technique had been developed to assess dust inside the home. There was general consensus, however, that the interior of the house serves as a reservoir for lead, especially soft surfaces (i.e., carpets and furniture), and that these media are the most difficult to sample (CH2M Hill 1991, Adgate et al. 1995).

Since that time, the BHSS and dust wipe methods were extensively evaluated in three reports with respect to effectiveness in quantifying exposure in the Box and Basin (TerraGraphics 2002, 2004a and 2005b). Those studies concluded that the BRM and wipe techniques are likely the most appropriate for measuring interior loading and current exposure in a house. The dust mat technique is likely the best indicator of continuing outdoor source contribution to dust lead in the house, and the vacuum bag remains the simplest sampling method to identify the need for intervention. House dust concentration best correlates with blood lead levels. The question regarding which sampling method is most appropriate for identifying houses that may require interior remediation requirements at the BHSS remains unresolved.

The BRM technique is cumbersome and would be expensive to implement on a community-wide scale. Dust mats are easier to implement but have a substantial labor requirement to distribute and recover the mat and to collect the dust sample by vacuuming. The dust wipe technique is easier to implement than the BRM, but the results vary with the frequency and timing of cleaning and could be easily influenced by chalking and/or chipping paint. The vacuum bag is the simplest, but least controlled sampling method, and dependent on homeowner habits. It is not clear what level measured by any of these techniques represents a risk-based action criteria, although the there are USEPA/HUD standards for dust wipes and the BHSS ROD cites a 1,000 mg/kg concentration threshold based on historic studies using the vacuum bag technique.

Other researchers have noted both similar and conflicting results. Lanphear et al. 1995 compared three dust collection methods in a side-by-side approach and noted that lead loading (µg/ft^2), as opposed to lead concentration (mg/kg), showed higher correlation with children's blood lead levels. Of the three methods compared (HUD wipes, BRM, and vacuum method), the BRM and wipe methods were better correlated with blood lead. Yiin et al. 2002 noted that measurements of lead in carpet and from hard surfaces relate differently to blood lead. They noted six studies of hard surfaces (i.e., floors and window sills) where loading was found to be better correlated with blood lead (Adgate et al. 1995, Bornschein et al. 1986, Charney et al. 1983, Clark etal. 1991, Davies et al. 1991, Lioy et al. 1998). Two studies were cited where dust lead concentrations collected by vacuum sampling of carpets were better correlated (Laxen et al. 1987, Yiin etal 2000). Yiin 2000 also notes that carpet cleaning was not effective in reducing lead concentration.

4.3 Quantitative Analysis of Dust, Paint, and Soils Relationships

4.3.1 Correlation Matrices

Correlation matrices were developed to assess relationships between variables across the study. These correlations were summarized and used to develop stepwise and general linear regression models to evaluate and quantify soil, paint and dust relationships. Discussion of the correlations is generalized to reflect overall findings as numerous forms of the variables were assessed (e.g., median, mean, maximum, log transformed, etc.). Additionally, some variables that combined results were developed to enhance the overall analyses. These included aggregating soil results by the different methods and using the average, median or maximum concentration. Specific variable forms were refined during selection of the final regression forms in order to quantitatively describe variable relationships.

Window sill wipe samples showed weak (r=0.35-0.64), but significant (p=0.01-0.0001), correlations with the BHSS soil source and combination soil variables, and exterior paint condition. Window sill wipes were also positively correlated with floor wipes and log-transformed entryway mat lead loadings. Conversely, floor wipe lead loadings were positively correlated to HUD soils and combined soils. Floor wipes were positively correlated to both mat loading and BRM loading. Neither wipe technique showed any significant correlation with interior or exterior paint variables. Quantitative analysis of the wipe samples is limited by the large number samples with results below the detection level.

The log-transformed vacuum bag lead concentrations are positively correlated with the HUD, BHSS and combined soil concentration variables (r=0.32-0.45, p=0.01-0.0004) and the BRM and mat dust lead concentrations. There were no significant relationships identified with paint variables, either transformed or non-transformed. Mat lead concentrations show stronger correlations with the soil variables (r=0.49-0.63, p<0.0001) than with vacuum bag variable. The mat lead loading rate was significantly correlated to the same soil variables and both the exterior and interior paint condition. Mat lead loading also showed positive correlation with floor wipes and the BRM lead loadings.

BRM concentrations and lead loadings showed the strongest correlations among dust and soil source variables, (r=0.40-0.60, p=0.0001). These correlations were only marginally better with the log-transformed variables. In contrast to the mat lead loading, the BRM results showed no significant correlation with paint variables.

Other significant correlations to note are those between interior and exterior paint condition (r=0.55, p=0.0001), interior and exterior paint concentration (r=0.5, p=0.0001), and HUD and BHSS soils (r=0.75, p=0.0001).

4.3.2 Regression Analyses

4.3.2.1 Stepwise Regressions

Stepwise linear regression were performed to assess which combinations of soil and paint variables significantly affect the dependent dust variables at p<0.01. Selected paint and soil variables were then employed in linear regression models and evaluated by the R^2-statistic and variable significance. The soil variable selected for use in these regressions was the average of the HUD soil lead concentrations excluding dripline results. Dripline results were excluded to maximize independence among the soil and paint variables. This variable was always significant in the models and was used as the surrogate for all soil lead concentrations.

Although there was no significant difference in lead concentration among samples collected from vacuum bags, entryway mats and the BRM; stepwise models were run for each method with different results. Stepwise regressions for vacuum bag lead concentrations found only the soil variable to be significant, but no additional variables entered the model at p=0.15 level. Similar results were obtained for the BRM lead concentration. The HUD soil concentration (without driplines) was also the strongest variable for mat lead concentration. However, for mat concentrations, the exterior lead paint concentration and exterior paint condition were both marginally significant (p=0.03-0.05) in the presence of the yard soil variable. As a result, a composite paint hazard variable (concentration*condition) that assumes the average exterior paint concentration when condition is poor and a value of zero with good condition was created for linear regression analysis.

For mat lead loading, three independent variables entered the model. The HUD soil variable and exterior paint condition and interior average lead concentration were all significant at the p=0.01 level. For window sill wipes, the HUD soil and exterior paint condition were both significant, but interior paint concentration was not significant at p=0.12. For floor wipes, only the soil variable was significant, with interior paint concentration entering at p=0.1 in the presence of soil. The BRM lead loading model also selected the HUD soil variable first, with both the interior and exterior paint condition variables marginally significant at p=0.07.

4.3.2.2 Selected Regression Models

Examination of the different models showed dust lead concentration and loadings are all related to the average HUD soil concentration (excluding the dripline results). This variable explained 18% of the variability in vacuum bag dust lead and 37% in the living room BRM dust lead concentration. No other variables were significant with these dust concentration variables. The mat dust lead concentration model is shown in Table 4.1a. This model indicates that the HUD soil variable and the average exterior paint XRF reading explain about 36% of the variability in the mat lead concentrations. Comparison of the standardized coefficient estimates for these variables suggests that about 75% of the lead in mats is due to soils and about 25% from paint. This is similar to results observed in the HHRA and the review by the National Academy of Sciences (TerraGraphics 2001, NAS 2005).

Table 4.1a General Linear Model and Regression Coefficients for Dust Mat Lead Concentrations

Dependent Variable: Log Mat Lead Concentration
R-Square=0.364 (P<0.0001)
N = 72

Variable	Estimate	Pr>t	Standardized Estimate
Intercept	2.3777	<0.0001	0
Log average HUD soil results excluding driplines	0.57246	<0.0001	0.61795
Average exterior XRF lead concentration	0.07518	0.0587	0.18956

Table 4.1b also shows the select model for lead loading rate on entryway mats. Twenty-eight (28%) of the variability of the mat lead loading rate is explained by soil lead concentration (excluding dripline results), the exterior minimum paint condition, and the interior average XRF reading. The standardized estimates suggest that about 40% of the explained lead load is attributable to soils and 30% to each of the indoor and outdoor paint variables.

Table 4.1b General Linear Model and Regression Coefficients for Dust Mat Lead Loading Rate

Dependent Variable: Log Mat Lead Loading Rate
R-Square=0.281 (P<0.0001)
N = 71

Variable	Estimate	Pr>t	Standardized Estimate
Intercept	-5.28422	<0.0001	0
Log average HUD soil results excluding driplines	0.4581	0.0012	0.35805
Average interior XRF lead concentration	0.19406	0.01	0.2791
Minimum exterior paint condition	0.75779	0.0037	0.31323

The strongest regression was for BRM lead loading, shown in Table 4.1c. Forty-one percent (41%) of the variability in the BRM living room lead loadings (mg/m^2) was explained by both the average HUD soil lead concentration (excluding the dripline results) and the average of the interior paint hazard variable (concentration*condition). Standardized estimates for these variables suggest that about 80% of the lead originates with soil and 20% from interior paint.

Table 4.1c General Linear Model and Regression Coefficients for Living Room BRM Lead Loading

Dependent Variable: Log Living Room BRM Lead Loading
R-Square=0.407 (P<0.0001)
N = 71

Variable	Estimate	Pr>t	Standardized Estimate
Intercept	-1.85281	0.0022	0
Log average HUD soil results excluding driplines	0.69278	<0.0001	0.59975
Average interior paint hazard (concentration x paint condition)	3.91989	0.0683	0.17353

The regression models were weak for floor wipes and window sill wipes. Thirteen percent (13%) of the variability in the average floor wipe was explained by soil and the minimum interior paint condition, whereas, 19% of the variability in the average window sill wipes was explained by soil, the minimum exterior paint condition, and the average interior paint concentration.

4.3.3 Quantitative Analyses Summary and Discussion

The quantitative analyses suggest that dust lead concentrations and consequent lead loadings are strongly related to outdoor soil concentrations. The effective soil variable used in these analyses is the average (or composite) of all HUD method samples excluding the dripline results. This variable represents the average bare soil concentration surrounding the home and may be more representative of current soil contribution and children' potential exposure than the BHSS samples being collected to facilitate remediation activities. Dust lead concentration from vacuum bags and the BRM methodology (which collect dust largely from carpeted floors) are significantly related only to the soil variable and not to paint condition or paint lead concentration. The soil variable explains about 18% and 37% of the variation in dust lead concentration, respectively, for vacuum bags and BRM dusts.

The lead concentration in dusts collected from entryway mats, however, is positively related to both soils and exterior paint condition and concentration. These variables explain about 37% of the variability in entryway mat lead concentration. This suggests an active pathway into the home from dusts contaminated by both mining industry waste in the soil and paint. Based on the living room BRM lead loading regression model (Table 4.1c), the relative sums-of-square, F-statistic and standardized regression coefficients suggest that soil is the largest contributor (about 80%) with interior paint having a lesser (20%), but significant effect.

With regard to lead loading, the mat lead loading rate is a better indicator of how much lead may be moving into the home along this pathway. Selected regression analyses show that 28% of the variability in lead loading rate is explained by soil, exterior paint and interior paint. The paint variables continue to show less significance than soil, but the standardized coefficients suggest paint may have a contribution similar to soils in this model.

The strongest regression model, however, was found for the BRM loadings in the living room carpets. This model shows that soil and interior paint variables explain 41% of the variability in dust lead loading, with a relative soil contribution of 80% and interior paint hazard contribution of 20%. Exterior paint was not significant in carpet dust loading. This leads to an overall conclusion that soil probably contributes from 60%-80% of the lead to house dust.

These results are remarkably similar to the findings of the 1996 Coeur d'Alene Basin Exposure Study (IDHW 2000) and the extended analyses of paint and soil exposures conducted in the HHRA for the Basin (TerraGraphics 2001). That study reviewed contemporaneous dust, soil and paint results from about 330 homes in the Basin. In those analyses, the select model explained 44% of the variability in log mat lead concentration using four variables: i) log of the yard soil lead concentration, ii) the maximum interior lead XRF reading, iii) the minimum interior paint condition, and iv) exterior median lead XRF loading. The HHRA concluded that both soil and paint were potential sources of lead in house dust. The relative sums-of-square, F-statistic and standardized regression coefficients suggest that soil was the largest contributor with both interior and exterior paint having similar, but lesser, significance than soils. Homes with extraordinarily poor paint condition (2% to 19% of Basin homes) also showed increased mat dust lead concentrations. That analysis also suggested that community mean soil lead concentrations and paint lead loading co-vary as a function of housing and community age and that any major paint lead affect on dust lead concentration was manifested through soils. Older homes may have more lead paint, higher soil lead content, and may have accumulated more lead dust from historic industrial operations and be located closer to mineral industry activities.

Four variables were significant in describing 36% of the variability in the lead loading rate. The log of yard soil lead concentration was again the most significant variable followed by the interior minimum paint condition, the community mean soil concentration, and the interior paint maximum lead loading by XRF. In this case, the maximum interior lead XRF reading remained significant at p=0.02 in the presence of community soil. Exterior paint lead content was not significant.

The HHRA and these analyses were extensively reviewed by the National Academy of Sciences (NAS 2005) and the NAS concurred with these findings stating that: "EPA *(in the HHRA)* applied reasonable methods to apportion risk among exposure sources, including those unrelated to mining wastes. EPA concluded that although lead from old house paint probably contributed to the exposure of some children, lead-contaminated soil was the primary contributor to health risk from lead" (NAS 2005, pp. 5, emphasis added). NAS also conducted supplementary analysis of the entryway mat data used in the HHRA and concluded that appropriate additional analyses of the data "…. would have provided additional supporting evidence upon which to base a soil contribution of 60% for indoor dust" (NAS 2005, pp. 207).

4.4 Comparison of Risk Determinations – HUD vs. BHSS Protocols

4.4.1 Risk Criteria

Sample results were compared to risk criteria for both the HUD and BHSS protocols. The comparison was accomplished for paint, dust and soils. Both the HUD and BHSS protocols begin with a visual assessment of paint condition in the home, a determination of whether children are present, and collection of data regarding home, demographic and neighborhood risk co-factors. With regard to paint, the visual assessment procedures are nearly identical, as much of the BHSS protocol was developed from earlier HUD methodologies. As a result, both protocols identified the same homes as potentially hazardous with regard to lead paint exposures. However, the protocols differ in the follow-up steps. The HUD protocol follows the positive paint determination with either a hazard assessment, lead-based paint survey, or risk assessment. However, the full lead-based paint inspection and risk assessment protocol was followed for every home in this study, regardless of the results of the initial visual survey (See Section 2.2).

The BHSS protocol conducts the visual paint assessment as part of the initial site visit, which includes administering a questionnaire and evaluating the home and yard for soil and dust sampling. The follow-up on potential positive lead-based paint findings includes counseling and advice regarding abatement and intervention measures that can be taken to minimize exposures; and offers of blood, soil and dust testing, and consultation with the LHIP, if desired. In this study, all homes received the full suite of BHSS follow-up sampling and evaluation, regardless of the results of the initial survey (See Section 2.3).

The actual HUD hazard determination, however, is based on follow-up dust sampling within the home and soil sampling for the exterior sources. This is accomplished because soil and dust, contaminated by lead-based paint, are the primary routes of concern in HUD risk assessments. These samples results are evaluated during the risk assessment phase in the HUD protocol.

The BHSS protocol follows a similar format, but the initial focus is toward soils contaminated by decades of mineral industry activity as the primary source of lead. In a corollary to XRF surveys facilitating paint abatement, the BHSS protocol undertakes considerably more soil sampling than the HUD method. These detailed soil data provide the basis for identifying particular hazards and implementing appropriate remedies. However, both protocols direct sampling at the soil and dust media that are the direct sources of ingestion to children. As a result, it is possible to directly compare whether the HUD and BHSS methods identify similar hazards for the same home in the respective risk assessment protocols.

This is accomplished by establishing the risk categories identified in Section 3.1 and summarized in Tables 3.1a-b. As described in Section 2.2, those categories are 1 - Low Risk (no lead paint damage), 2 - Medium Risk (damaged paint, no soil or dust hazard), 3a –Dust Hazard Identified, 3b - Soil Hazard Identified.

4.4.2 Paint Assessment

The pre-screening initial visual assessment typically results in one of four recommendations summarized in Table 3.1a. Because of the study design, fourteen homes received a risk assessment that otherwise would have had no follow-up, a hazard assessment or lead-based paint survey. This occurred for eight Box, two Basin, and four Background homes.

Two homes would have been recommended for no further action. Subsequent combined risk assessments conducted for these homes found damaged lead paint in one home (Category 2), but no lead dust or soil. The damaged paint finding was on an exterior fence that the risk assessor believed could be addressed without additional follow-up.

Seven homes were recommended for a hazard screen only. One Box home and one Background home were subsequently classified as Category 1, with low risk. One Box and two Background homes were Category 2, with some damaged lead-based paint. One Box home showed a soil hazard (Category 3b) and one Box home had both soil and dust hazards (Categories 3a and 3b) identified. These results reflect soil and dust hazards in the Superfund areas that are not accounted for in the initial HUD visual screen.

Five homes were recommended for a lead-based paint inspection only. Subsequent risk assessments found one Basin home with elevated dust lead (Category 3a), one Box and one Basin home with elevated soil lead (Category 3b), one Category 1 home, and one Category 2 home.

Risk assessments were recommended for 61 homes under the HUD visual screen; 22 in the Basin, 18 in the Box, and 21 in the Background communities. However, due to the study design, all 75 homes received combined lead-based paint inspections and risk assessments. Of the 75 homes, 13 were found to have all paint in good condition and no significant soil or dust hazard (Category 1) (see Table 3.1b). Ten of these 13 homes were in the Background areas and three were in the Box. Twenty-eight homes had some damaged lead paint, but no soil or dust hazard (Category 2). Seven of these homes were from the Basin communities, 10 were from the Box and 11 were from the Background. Nineteen homes were identified with dust hazards (Category 3a), nine from the Basin, eight from the Box, and two from the Background areas.

Twenty-seven homes were identified with soil hazards (Category 3b) according to HUD typical guidance. In actuality, 54 homes had soil lead levels exceeding the USEPA/HUD guidelines, but the additional homes had samples collected from driplines and ROWs that would not have otherwise qualified (See Sections 3.1 and 3.2 for additional discussion). Of the 27 homes identified with a significant soil hazard (excluding the supplemental soil samples), 14 were from the Basin, 11 from the Box and two from the Background communities.

The HUD protocol goes on to make a detailed determination of lead-based paint through an XRF-based survey of numerous sample locations throughout the interior and exterior of the home. These data provide the basis for isolating the source of any hazard in the home and provides insight to selecting and implementing an appropriate abatement method. Tables 3.2b-c summarize the XRF data collected for the 75 homes.

4.4.3 HUD vs. BHSS Soil Assessments

4.4.3.1 Overall

The comparison of risk determinations for HUD versus BHSS sampling protocols is complicated by the supplemental sampling that was conducted for the HUD portion of the study. Several ROWs and covered or vegetated dripline areas were sampled in this study that, likely, would not have been collected in the typical HUD procedures. Several of these samples exceeded the USEPA/HUD criteria levels for lead and were considered significant hazards according to the protocol. The soil risk determination, however, would have been different for several properties, if the supplemental samples had not been collected. In addition, soil lead concentrations that are classified as a hazard under the USEPA/HUD criteria are acceptable under the site-specific Superfund criteria in the Box and Basin.

In order to compare risk determination results between the HUD and BHSS protocols, risk determinations are made both with and without the supplemental soil results. Table 4.2 shows the soil results including supplemental samples and Table 4.3 excludes those samples from the determination (also see Appendix A, Tables A-2 and A-3). HUD identifies potential risk associated with soils exceeding 400 mg/kg lead in areas where children play or bare areas exceeding 1,200 mg/kg. Grab samples are obtained directly from these areas to make the assessment. The BHSS criteria for the Box assessment relied on a composite sample collected from the front and back yards of the home. If that sample exceeded 1,000 mg/kg the entire yard was considered an excessive risk and was remediated. Certain discrete areas, such as driveways, gardens and children's play areas were also sampled and remediated if the lead level exceeded 1,000 mg/kg, even if the yard was below the 1,000 mg/kg trigger level. These criteria were largely extended to the Basin, although a second category of "greening" was added to facilitate vegetating bare areas with soil lead levels between 700 mg/kg and 1,000 mg/kg.

Table 4.2 Summary HUD/BHSS Risk Evaluation for Soil Hazards Including Supplemental HUD Soil Samples

Community	Number of Homes	Soil Risk Evaluation: EPA/HUD Criteria: Child Play Area Soil Lead ≥ 400 mg/kg	Soil Risk Evaluation: EPA/HUD Criteria: Bare Area Soil Lead ≥ 1,200 mg/ kg	Soil Risk Evaluation: BHSS Criteria: Soil Lead ≥ 1,000 mg/kg	Soil Lead Risk: HUD	Soil Lead Risk: BHSS	HUD/BHSS Agreement: No Risk	HUD/BHSS Agreement: Risk	HUD/BHSS Agreement: Total
Basin	24	21	13	21	21	21	2	20	22
Box	26	22	8	0	22	0	4	0	4
Background	25	11	1	2	11	2	14	2	16
Total	75	54	22	23	54	23	20	22	42

Table 4.3 Summary HUD/BHSS Risk Evaluation for Soil Hazards Excluding Supplemental HUD Soil Samples

Community	Number of Homes	Soil Risk Evaluation: EPA/HUD Criteria: Child Play Area Soil Lead ≥ 400 mg/kg	Soil Risk Evaluation: EPA/HUD Criteria: Bare Area Soil Lead ≥ 1,200 mg/ kg	Soil Risk Evaluation: BHSS Criteria: Soil Lead ≥ 1,000 mg/kg	Soil Lead Risk: HUD	Soil Lead Risk: BHSS	HUD/BHSS Agreement: No Risk	HUD/BHSS Agreement: Risk	HUD/BHSS Agreement: Total
Basin	24	13	13	21	14	21	2	13	15
Box	26	11	7	0	11	0	15	0	15
Background	25	1	1	2	2	2	22	1	23
Total	75	25	21	23	27	23	39	14	53

Including Supplemental Samples: Table 4.2 shows that the HUD method, including the supplemental samples, identified 54 of the 75 (72%) total homes as exhibiting a potential soil risk. All 54 homes showed levels exceeding the 400 mg/kg criteria for children's play areas and 22 home yards had bare area soils exceeding 1,200 mg/kg. The HUD method identified 21 homes in the Basin, 22 homes in the Box and 11 homes in the Background areas as presenting excessive soil risk. In contrast, the BHSS identified 23 of the 75 homes (31%) as exhibiting excessive soil risk. None of the homes noted by the HUD method in the Box were identified by BHSS methods, as Box remediation is complete and all homes were assigned a soil value of 100 mg/kg. BHSS methods identified 21 homes in the Basin and two homes in the Background areas with high soil lead levels.

Excluding Supplemental Samples: Table 4.3 summarizes the results excluding the supplemental HUD samples. Under this scenario the HUD methodology identified 27, as opposed to 54, homes with significant soil risk. Fourteen of those homes were in the Basin, 11 were in the Box, and two in the Background areas. By the site-specific criteria, none of the Box homes identified by the HUD method are classified as hazards by BHSS methods. However, all but two of the homes in the Basin and Background areas noted by HUD were identified by the BHSS methods. The BHSS method identified one additional home in the Background areas and eight additional homes in the Basin with significant soil hazards.

4.4.3.2 Box Homes

Including Supplemental Samples: In the Box, remediation is complete, and by definition, all soil lead risk that would be identified by the BHSS protocol has been addressed. As a result, the

BHSS protocol does not identify any yard soils hazards. The HUD protocol, however, identified excess risk at 22 of 26 homes sampled in the Box (Table 4.2). All 22 of these home soils exceeded the 400 mg/kg criteria and 8 homes were noted with soil lead levels exceeding 1,200 mg/kg (Table 4.2). In total, 100 samples collected by the HUD method in the Box exceeded the USEPA/HUD standards. Seventy-two of these samples exceeded the 400 mg/kg criteria, which is acceptable under the BHSS protocol (i.e., < 1,000 mg/kg). Most of these samples were from driplines (38) and bare areas (10). The remainder of the samples above the 400 mg/kg criteria was from parking areas, driveways and ROWs (15 samples) and gardens (6 samples).

Of greater concern are 28 samples that exceeded the 1,200 mg/kg bare area criteria. Driplines accounted for 15 of these samples; 7 were from bare areas; 4 from driveways, ROWs and parking areas; one from a garden; and one from under a deck. Remediation records from those homes where samples exceeded the 1,200 mg/kg criteria were reviewed to determine if these locations were remediated and whether there has been significant re-contamination. In almost all cases, these samples are from covered driplines or under decks that may have not been remediated due to proximity to the structure. The remainder are from parking, driveways or ROWs that have likely been recontaminated. The dripline and under deck areas are difficult to remediate and were recognized during development of the remedial design process as an acceptable risk in the context of the overall cleanup. Recontamination of ROWs and parking areas has been noted as a deficiency in both five year reviews of the Site (TerraGraphics 2000, 2005b and USEPA 2005) and these areas are being monitored.

***Excluding Supplemental Samples*:** Eleven of the homes in the Box were classified as exhibiting significant soil hazards due to dripline or ROW samples that would not have been collected in a typical HUD risk assessment. As a result, 11 Box homes, as opposed to 22 homes would have been identified with soil hazards under the typical HUD guidelines (Table 4.3). Under this scenario, excluding the supplemental samples, the HUD and BHSS protocols agreed on 15, as opposed to four, Box homes. Several of the 11 Box homes where the risk determinations did not agree were due to the difference in the 400 mg/kg HUD versus the 1,000 mg/kg BHSS threshold criteria.

4.4.3.3 Basin Homes

Including Supplemental Samples: In the Basin, the HUD method (including the supplemental samples) identified 21 of 24 homes with high soil lead levels. Thirteen (13) of those home soils exceeded both the 400 mg/kg and 1,200 mg/kg criteria (Table 4.2). The BHSS protocol identified 12 of those 13 homes. One home that exceeded both HUD criteria was not detected in the BHSS protocol. Eight homes exceeded HUD's 400 mg/kg criterion for children's play areas only. The BHSS protocol identified those 8 homes as having excessive risk. Three homes were below the HUD risk criteria. One of those homes was identified as a risk by BHSS protocol. In summary for the Basin, 22 of 24 homes (92%) were identified as high-risk by either the HUD or BHSS protocol. The two methods agreed on 20 homes that represented excessive risk and on 2 homes that did not (also 92%). Each protocol identified one (1) home as presenting excess risk that the other did not (i.e., differing on 8% of the homes for soil risk).

Excluding Supplemental Samples: Seven of the homes in the Basin were classified as exhibiting significant soil hazards due to dripline or ROW samples that would not have been collected in a typical HUD risk assessment. As a result, 14 Basin homes, as opposed to 21 homes would have been identified with soil hazards under the typical HUD guidelines (Table 4.3). Under this scenario, excluding the supplemental samples, the HUD and BHSS protocols agreed on 15, as opposed to 22, homes.

4.4.3.4 Background Homes

Including Supplemental Samples: For the Background areas, the HUD protocol identified 11 of 25 homes (44%) with high soil lead levels (Table 4.2). Only one of these homes had a sample exceeding the 1,200 mg/kg criteria. This sample was collected from a dripline on an exterior shed. All other high samples were from locations accessible by children with soil lead levels between 400 mg/kg and 1,200 mg/kg. A total of 12 samples were included in this category and 10 were from dripline locations, one from a garden, and one from under a swing set. The BHSS method identified two homes (8%) with high soil lead levels, both also identified by HUD. As a result, the HUD and BHSS protocols agreed on 16 of 25 homes in the Background communities with regard to soil risk (Table 4.2).

Excluding Supplemental Samples: Nine of the homes in the Background communities were classified as exhibiting significant soil hazards due to dripline or ROW samples that would not have been collected in a typical HUD risk assessment. As a result, two Background homes would have been identified with a soil hazard under the typical HUD guidelines, versus the 11 homes identified due to supplemental sampling (Tables 4.2 and 4.3). Under this scenario, excluding the supplemental samples, the HUD and BHSS protocols agreed on 23, as opposed to 16, homes.

4.4.3.5 Soil Hazard Determination Summary

These results suggest that the HUD criteria are effective in identifying high soil lead levels that offer exposure to children (i.e., bare and play areas). In the Box and Basin, the USEPA/HUD standard represents a threshold that has been superseded by site-specific Superfund criteria. As a result, the disagreements due to the difference in standards in the Box are not a major concern. In the Basin, the supplemental sampling was successful in identifying soil hazards and there was nearly complete agreement with the BHSS protocol. However, the typical HUD protocol (excluding supplemental sampling) would not have observed soil hazards in several homes in the Basin where substantial risk remains. Conversely, in Background homes, the HUD and BHSS protocols agreed on 23 of 25 homes without the supplemental sampling. The additional sampling identified nine homes as exhibiting soil hazards that are likely of minimal concern under typical criteria.

Including Supplemental Samples: Overall, when considering all soil samples, including the supplemental dripline and ROWs, the HUD and BHSS protocols agreed on 42 of 75 homes (or 56%). Both protocols agreed that 20 of the 75 homes (27%) offered no excess risk with respect to soils and 22 homes are high by both protocols (29%). The largest disagreements occurred in the Box. In the Box, the HUD and BHSS protocols agreed on four of 26 homes (15%) where the HUD protocol found no exceedances of USEPA/HUD standards. However, the HUD protocol found 8 Box homes (31%) with levels exceeding the 1,200 mg/kg that are not identified by the BHSS protocol. The BHSS methods assume that all Box home yards that the HUD protocol found to be high are remediated and do not present excess risk.

In the Background areas, the HUD and BHSS protocols disagreed on nine homes (36%), where the HUD protocol found 11 homes presenting high risk compared to two identified as high risk by the BHSS methods. In the Basin, each protocol identified one home at-risk that the other did not.

***Excluding Supplemental Samples*:** When the supplemental samples were excluded, the BHSS and HUD protocols agreed on 53 of 75 homes; 15 in the Box, 15 in the Basin and 23 Background homes. Both methods agreed that 39 homes had no soil hazard. Fifteen of these were in the Box, two in the Basin and 23 in the Background communities. Both methods identified 14 homes with significant soil hazards, 13 in the Basin and one in the Background communities. Major disagreements were associated with 11 homes in the Box identified by the HUD protocol and were due to the 400 mg/kg versus 1,000 mg/kg soil lead threshold discrepancy.

4.4.4 Dust Assessments

4.4.4.1 Box Homes

Table 4.4 shows the risk determinations for dust hazards between the HUD and BHSS protocols (also see Appendix A, Tables A-2 and A-3). In the Box, the HUD protocol identified eight of 26 homes (31%) with high dust wipe samples (Table 4.4). Only one of those homes was high for both window sills and floor wipes. Four additional homes were high for window sills and three others had excessive floor lead loadings. Five of the 26 Box homes (19%) were high by BHSS methods, two by vacuum bag alone, one by BRM alone and the remainder by a combination of methods. The BHSS and HUD protocols agreed that 15 of 26 homes had no excessive dust lead levels and that 2 homes were high by both protocols. The HUD and BHSS protocols differed on 9 homes in the Box. The HUD method identified six homes as high that the BHSS protocol did not. Three of these findings were window sills, two were floors, and one was both floor and window sill. The BHSS methods found three high homes not noted by the HUD methods. All of those were noted in the BRM method and one each by the vacuum bag and mat methodologies.

Table 4.4 Summary HUD/BHSS Risk Evaluation for Dust Hazards

		Dust Evaluation									
		EPA/HUD Criteria		BHSS Criteria			Dust Lead Risk		HUD/BHSS Agreement		
Community	Number of Homes	Floor Dust Wipe Lead ≥ 40 µg/ft²	Window Sill Wipe Dust Lead ≥ 250 µg/ft²	Vacuum Bag Dust Lead ≥ 1,000 mg/kg	Dust Mat Lead ≥ 1,000 mg/kg	BRM Dust Lead ≥ 1,000 mg/kg	HUD	BHSS	No Risk	Risk	Total
Basin	24*	3	6	4	3	3	9	7	12	4	16
Box	26	4	5	3	1	3	8	5	15	2	17
Background	25	0	2	0	0	0	2	0	23	0	23
Total	75*	7	13	7	4	6	19	12	50	6	56

*BHSS dust samples were not collected from one Basin home.

4.4.4.2 Basin Homes

In the Basin the HUD dust wipe protocol identified nine of 24 homes (38%) with high dust lead levels (Table 4.4). Six of the nine homes identified by the HUD protocol had excessive window sill loadings and 3 homes had high floor lead loadings. No Basin homes were high for both floors and window sills. The BHSS and BRM combined methods identified seven of 23 homes (30%) with high dust lead levels by one or more methods. Two of the seven high homes were identified by the vacuum bag only, two by the mat sample only, and one by the BRM only. One home exceeded the BHSS criteria for all three methods and one by two methods. The BHSS and HUD protocols agreed that 12 of 23 Basin homes had no excessive dust lead levels and that four homes were high by both the HUD and BHSS protocols. The protocols disagreed on seven homes and one had missing data for the BHSS method. The HUD protocol identified four homes as high that the BHSS methods did not. Three of those four HUD identified homes were based on window sill samples, and one on a floor wipe. Three homes were identified by the BHSS methods that were not found high by the HUD protocol. Two of those were based on the vacuum cleaner sample and one on the mat sample.

4.4.4.3 Background Homes

In the Background areas, the HUD protocol identified two of 25 homes (8%) with high window sill lead loadings (Table 4.4). No other high levels were found in Background homes by either HUD or BHSS methods.

4.4.4.4 Dust Hazard Determination Summary

Overall, with respect to interior dust, the HUD and BHSS protocols agreed on 56 of 74 homes, or 76%. Most of the agreement was for 50 homes that presented no excess risk, 23 of which were in the Background communities, 12 in the Basin and 15 in the Box. The HUD and BHSS methods disagreed on 19 homes. The most disagreement was for 13 homes identified by the HUD protocol, but not by the BHSS methods (17% of all homes). Of these 13 homes, the most common difference was homes with high window sill loadings and no other positive finding (9 homes, or 12% of all homes). Six homes in the Box and Basin (8% of the total) were found to be high by the BHSS methods that were not detected in the HUD methodologies.

SECTION 5.0 SUMMARY /CONCLUSIONS

5.1 Risk Comparison of the HUD and BHSS Methodologies

Objective 1 - Quantitatively compare the number of houses that show an exposure risk from lead in house dust by the HUD Risk Assessment methods to the BHSS monitoring methods, and compare and discuss any observed differences or similarities among the four dust sampling techniques.

Because paint and soil are the primary sources for lead in dust, assessment results for these media are also summarized in this section.

Dust Hazards: The HUD and BHSS protocols rely on different dust sampling approaches. The HUD dust criteria rely on dust lead loading values (i.e., amount of lead per unit of surface area) conducted by a dust wipe methodology. This method measures the surface dust immediately available to children at specific locations on the floor and window sills. The BHSS methodology relies on dust lead concentration supplemented by loading estimates based on larger volume samples collected by vacuum techniques. The BHSS and dust wipe methods were extensively evaluated with respect to effectiveness in quantifying exposure in the Box and Basin (TerraGraphics 2005a).

This study, by comparing the same techniques across communities with similar house age and demographic status but different soil lead conditions, examined lead dust risk due to both paint and soil sources. Overall, the HUD and BHSS dust protocols agreed on 56 of 75 homes, or 75% (Table 5.1). Most of the agreement was for 50 homes that presented no excess risk, 23 in Background areas, 12 in the Basin and 15 in the Box. The HUD and BHSS methods disagreed on 19 homes. The most disagreement was for 13 homes identified by the HUD protocol, but not by the BHSS methods. Of these 13 homes, the most common difference was homes with high window sill loadings and no other positive finding (9 homes). This could be indicative of potential lead paint exposure associated with the windows that are not reflected in the carpet reservoirs or vacuum cleaner bags monitored in the BHSS. However, 11 of the 13 homes were located in the Box and Basin where soil lead sources could also contribute to window sill loadings. Six homes in the Box and Basin (12% of the homes from those areas) were found to be high by the BHSS methods that were not detected by the HUD methodologies. These homes had dust lead concentrations collected by BHSS vacuum techniques that exceeded 1,000 mg/kg, but did not exceed USEPA/HUD criteria for dust wipes (Table 5.1)

Table 5.1 Summary of Agreement by HUD and BHSS Protocols in Identifying Dust Hazards

Community	Number of Homes	Dust Lead Risk				HUD/BHSS Agreement		
		Identified by HUD	Identified by BHSS	Identified by HUD only	Identified by BHSS only	No Risk	Risk	Total
Basin	24*	9	7	5[a]	3[b]	12	4	16
Box	26	8	5	6[c]	3[d]	15	2	17
Background	25	2	0	2[e]	0	23	0	23
Total	75	19	12	13	6	50	6	56

*BHSS dust samples were not collected from one Basin home.

[a]Four homes were identified by high window sill loadings. One home had a high floor loading.

[b]One home was identified by mat dust loading and two homes had high vacuum bag concentrations.

[c]Three homes were identified by high window sill loadings, four homes had high floor loading, and one home had both high window sill and floor loadings.

[d]All three homes were identified by BRM loading, with one home identified by both BRM and mat dust loading and one home identified by BRM and vacuum methods.

[e]Both homes were idenfitifed by high window sill loadings.

As a result, both methods seem to be effective in identifying homes where excess risk due to active dust sources is not present. The protocols were especially consistent in the Background areas, where soil lead levels were low, agreeing on 92% of the homes. The BHSS methods, that collect aggregated dust from floor locations by vacuum, did not detect window sill hazards identified by HUD in several homes, including two (8%) in the Background areas. Conversely, the HUD method did not identify excess risk associated with carpet reservoirs and entry-way mats in three homes in each of the Box and Basin (about 12% of the homes in those areas), where soil lead predominates.

Paint: With regard to lead paint assessments, the HUD and BHSS visual assessment protocols are nearly identical and both identify the same potential lead paint hazards. The HUD lead paint protocol follows up with a lead paint inspection, XRF survey and risk assessment, as warranted. The BHSS protocol provides parental, occupant and landlord counseling and recommends that individuals obtain additional lead paint assistance outside of Superfund.

Soils: With respect to soils, there were substantial differences in the HUD versus BHSS results. These findings are complicated by the supplemental sampling that was accomplished in the HUD risk assessments. Because it was known that soil lead contamination is ubiquitous in the Superfund Site, responsible risk assessment procedures required sampling those potential sources. As a result, two divergences from typical HUD protocols were used in this study. Full HUD risk assessments were undertaken at all residences regardless of the results of the initial visual assessment. As a result, 14 homes received a full HUD risk assessment that otherwise would not have been sampled for soil and dust. Additionally, ROWs and vegetated or covered driplines, that would not typically be sampled, were included in the assessment. Finally, with regard to the Box that has already been remediated, the USEPA criteria used by the HUD protocols has been superseded by site-specific cleanup criteria under CERCLA. This resulted in the HUD protocol identifying soil hazards that are not considered excessive under the site-specific criteria at the BHSS.

As a result, these supplemental samples identified potential soil hazards that typically would have not been detected. When these supplemental HUD samples are included in the comparison, the HUD and BHSS protocols agreed on 42 of 75 homes (or 56%) (Table 5.2). There was agreement for 92% of Basin, 15% of Box, and 64% of Background homes. Both protocols agreed that 20 of the 75 homes (27%) were low risk and both protocols identified 22 homes (29%) with soil hazards. The largest disagreement occurred in the Box. The HUD protocol found 22 Box home yards (85% of Box homes, 29% of all homes) to exceed hazard criteria, whereas BHSS methods assume these homes are remediated and do not present excess risk (Table 5.2). In the Background areas, the HUD and BHSS protocols disagreed on nine homes (36% of Background homes, 12% of total homes), where the HUD protocol found 11 homes presenting high risk compared to two identified as high risk by the BHSS methods. The disagreement among Background homes was due to HUD identifying covered areas as play areas exceeding the 400 mg/kg standard. These likely would not have been sampled nor identified as a hazard in a typical HUD risk assessment. In the Basin, each protocol identified one home at-risk that the other did not (Table 5.2).

Table 5.2 Summary of Agreement by HUD and BHSS Protocols in Identifying Soil Hazards (Including Supplemental HUD Soil Sample)

Community	Number of Homes	Soil Lead Risk				HUD/BHSS Agreement		
		Identified by HUD	Identified by BHSS	Identified by HUD only	Identified by BHSS only	No Risk	Risk	Total
Basin	24	21	21	1[a]	1	2	20	22
Box	26	22	0	22[b]	0	4	0	4
Background	25	11	2	9[c]	0	14	2	16
Total	75	54	23	32	1	20	22	42

[a]One home identified by HUD protocols exceeded the USEPA/HUD standards for play and bare areas.

[b]Eight homes identified by HUD protocols exceeded the USEPA/HUD standard for bare areas. All homes exceeded the standard for play areas.

[c]One home identified by HUD protocols exceeded the USEPA/HUD standard for bare areas. All homes exceeded the standard for play areas.

When the supplemental samples were excluded from the comparison, the BHSS and HUD protocols agreed on 53 of 75, or 71% of all homes (Table 5.3). This included 15 Box (58%), 15 Basin (62%), and 23 Background (92%) homes. Both methods agreed that 39 homes had no soil hazard. Fifteen of these were in the Box, two in the Basin and 22 in the Background communities (Table 5.3). Both methods identified 14 homes with significant soil hazards, 13 in the Basin and one in the Background communities. Major disagreements were associated with 11 homes in the Box identified as soil hazards by the HUD protocol that are not considered an unacceptable risk under the BHSS site-specific criteria. These hazard identifications were due to either the 400 mg/kg USEPA/HUD standard versus the site-specific 1,000 mg/kg soil lead cleanup threshold discrepancy, or were dripline or ROW samples (Table 5.3). The HUD protocol identified six fewer homes as having soil hazards when the covered area samples were excluded from consideration.

Table 5.3 Summary of Agreement by HUD and BHSS Protocols in Identifying Soil Hazards (Excluding Supplemental HUD Soil Sample)

Community	Number of Homes	Soil Lead Risk				HUD/BHSS Agreement		
		Identified by HUD	Identified by BHSS	Identified by HUD only	Identified by BHSS only	No Risk	Risk	Total
Basin	24	14	21	1[a]	8	2	13	15
Box	26	11	0	11[b]	0	15	0	15
Background	25	2	2	1[c]	1	22	1	23
Total	75	27	23	13	9	39	14	53

[a]One home identified by HUD protocols exceeded the USEPA/HUD standards for play and bare areas.

[b]Seven homes identified by HUD protocols exceeded the USEPA/HUD standard for bare areas. All homes exceeded the standard for play areas.

[c]One home identified by HUD protocols exceeded the USEPA/HUD standards for play and bare areas.

Conclusions: Both the HUD and BHSS protocols conduct a similar visual inspection to identify potential lead paint hazards in homes. The HUD protocol provides additional testing, assessment, and abatement advice that is unavailable through Superfund.

Both dust protocols consistently identify homes with little or no risk. When supplemental samples are excluded, the BHSS protocol did not identify window sill hazards in about 16% of homes in the Box and Basin and 8% in Background communities. The HUD protocol failed to identify significant dust lead reservoirs in about 12% of homes in the Box and Basin, excluding supplemental samples.

These results confirm the conclusions of previous investigations that the BRM and wipe techniques are likely the most appropriate for measuring interior loading and current exposure in a house. The entryway mat technique is likely the best indicator of continuing outdoor source contribution to dust lead in the house, and the vacuum bag remains the simplest sampling method for determining the need for intervention. The question regarding which sampling method is most appropriate for identifying houses that may require interior cleaning remains unresolved.

The HUD and BHSS protocols agree on identifying soil hazards at about 70% of homes. Both are effective at identifying homes with little or no soil risk. Much of the disagreement with respect to soil hazards is associated with the site-specific risk management criteria, as opposed to methodology. The HUD criteria identify soils as hazards based on lead concentrations that are acceptable under site-specific criteria in the Superfund site.

The BHSS protocol relies on yard-wide composite samples, and does not specifically address dripline samples that were identified as potential soil hazards by the HUD method. Driplines have significantly higher concentrations than other sample locations. The typical HUD protocol would not have identified hazards at about 33% of homes in the Basin considered as having excess risk by the BHSS criteria. Most of these hazards were identified by the supplemental sampling conducted under the study protocol. The supplemental sampling did not identify the BHSS hazard at 43% of homes from all three areas.

5.2 Lead Paint, Soil and Dust Relationships

Objective 2 - Quantify the relationship between soil and paint to house dust.

The quantitative analyses suggest that dust lead concentrations and consequent lead loadings are strongly related to outdoor soil concentrations with some contribution from both exterior and interior paint to mat dust lead loading. These results are remarkably similar to the findings of the 1996 Coeur d'Alene Basin Exposure Study (IDHW 2000) and the extended analyses of paint and soil exposures conducted in the HHRA for the Basin (TerraGraphics 2001) and the recent analyses conducted on these data by the National Academy of Science (NAS 2005).

Dust lead concentration from vacuum bags and the BRM methodology are significantly related only to the soil variable and not to paint condition or paint lead concentration. The soil variable explains about 18% and 37% of the variation in dust lead, respectively, for vacuum bags and BRM dusts. The lead concentration in dusts collected from entryway mats is related to both soils and exterior paint condition and concentration. These variables explain about 37% of the variation in entryway mat lead concentration and the results suggest an active pathway into the home from dusts contaminated by both mining industry waste in the soil and paint.

The mat lead loading rate is the best indicator of how much lead may be moving into the home along this pathway. Selected regression analyses show that 28% of the variation in lead loading rate is explained by soil, exterior paint and interior paint. The paint variables continue to show less significance than soil. The strongest relationship was identified for the BRM loadings in the living room carpets. This model shows that soil and interior paint variables explain 41% of the variation in dust lead loading, with a relative soil contribution of 80% and interior paint contribution of 20%. Exterior paint was not significant in carpet dust loading. This leads to an overall conclusion that soil probably contributes from 60%-80% of the lead to house dust.

5.3 Environmental Media Lead Levels among Communities

Objective 3 - Determine differences in environmental media lead levels among the three types of communities sampled.

Lead Paint: All three areas had a substantial percentage of surfaces reading positive for lead paint, with the highest frequencies on exterior surfaces in the Background areas and lowest in the Basin. Nearly 50% of exterior surfaces in Background homes exhibited XRF readings greater than the lead paint threshold compared to near 40% in both the Box and Basin homes (Table 5.4). Analyses of variance procedures show that both exterior and interior lead paint surface loading in the Background areas are significantly greater than those in the Box and Basin ($p<0.0001$). Mean exterior lead concentrations in Background homes are about twice those in the Superfund area. For interior lead paint loading, the Background geometric mean is about 3 times that in the Basin and Box. Conversely, Background communities had substantially more exterior surfaces categorized in good condition, while the Basin and Box homes had a greater percentage of surfaces categorized as poor condition. The condition of interior surfaces was similar among the communities, with nearly 90% categorized in good condition (Table 5.4).

Table 5.4 Summary of Paint Conditions by Community

Community	Percent of Surfaces: In Good Condition	In Fair Condition	In Poor Condition	Reading ≥ 1.0 mg/cm^2	Average of XRF Results ≥ 0.8 mg/cm^{2*}
Exterior Surfaces					
Basin	23%	39%	38%	37%	5.1
Box	36%	34%	30%	39%	5.1
Background	50%	35%	15%	46%	7.9
Interior Surfaces					
Basin	89%	9%	3%	11%	4.8
Box	87%	10%	2%	16%	3.6
Background	87%	12%	1%	29%	9.5

* Accuracy of the readings < 0.8 mg/cm^2 diminishes; therefore, readings ≥ 0.8 mg/cm^2 were used for the averages.

Dust Lead: With respect to house dust lead concentration, all of the BHSS methods' results showed consistent levels and significant differences between the Superfund and Background communities. Geometric mean dust lead levels by all BHSS methods ranged from 350 mg/kg to 550 mg/kg in the Box and Basin, as opposed to 80 mg/kg to 130 mg/kg in the Background areas, or 4 to 5 times higher (Table 5.5). Dust loading rates as measured by the mat method were highest in the Background communities, while dust loadings, as measured by the BRM method, were similar among the three communities. Lead loadings and loading rates followed the same pattern as concentration and were about 3 to 4 times greater in the Superfund areas than in Background homes. There was no significant difference between Box and Basin dust concentrations and loadings (Table 5.5).

Table 5.5 Summary Statistics for BHSS House Dust Samples

Community	Geometric Mean (Geometric Standard Deviation): Mat Concentration (mg/kg)	Mat Dust Loading Rate (mg/m^2/day)	Mat Lead Loading Rate (mg/m^2/day)	Vacuum Concentration (mg/kg)
Basin	396 (2.42)	672 (2.55)	0.27 (4.94)	551 (1.98)
Box	391 (2.30)	694 (3.75)	0.31 (4.65)	471 (3.42)
Background	79 (2.80)	1,109 (2.95)	0.09 (3.88)	129 (2.50)

	BRM Lead Concentration (mg/kg)	BRM Dust Loading (mg/m^2)	BRM Lead Loading (mg/m^2)
Basin	397 (2.16)	18,023 (2.86)	7.2 (4.5)
Box	426 (1.74)	20,434 (2.40)	8.7 (3.0)
Background	101 (1.88)	19,696 (2.74)	2.0 (3.3)

Note: Half the detection limit was used if results were below detection limits.

Soils: Both the HUD and BHSS protocols show significantly different concentrations for soils among the three community groups. The results generally reflect the remediation status of the Superfund homes. Yard soils are not significantly different between the remediated Box and Background homes for several categories. Basin yard and HUD (excluding driplines) soil concentrations show means six to eight times higher than Background (Table 5.6). Driplines show elevated concentrations in all three areas, but are significantly greater in the Basin (Table 5.6).

Table 5.6 Soil Summary Statistics by Community Group for Yard and Dripline Results

Community	Geometric Mean (Geometric Standard Deviation)		
	BHSS Yard Soil Results (mg/kg)	HUD Soil Results Excluding Driplines (mg/kg)	HUD Dripline Soil Results Only (mg/kg)
Basin	438 (1.99)	398 (3.55)	676 (2.94)
Box	100 (1.00)	218 (2.74)	510 (2.50)
Background	69 (2.22)	53 (2.85)	254 (3.29)

Half the detection limit was used if result was below detection limit.

5.4 Background Lead Levels in Rural Idaho

Objective 4 - Provide baseline data regarding house dust lead levels and lead paint conditions in rural Idaho communities and their relation to BHSS homes.

This study repeated similar sampling that occurred in 1999, comparing Box and Background homes in demographically similar, non-mining areas of rural northern Idaho (TerraGraphics 1999, Spalinger et al. in-press). The 1999 study concluded that soils, vacuum bag, and entryway mat dust lead concentrations were significantly higher in the Box than comparable measurements in northern Idaho communities. Dust loading rates were not significantly different, but due to the increased concentration, lead loading rates were higher in the Box. This HUD 2004 investigation confirms those results, although the differences are not as great as in 1999 due to the continuing cleanup in the BHSS.

Soils: In the 1999 study, homes were grouped by house age. Category 1 homes were built before 1961, Category 2 homes from 1961 to 1978, and Category 3 homes after 1978. Soil lead levels were higher in older homes in both Background and BHSS towns. In the Background homes in 1999, mean soil lead concentrations were 85 mg/kg, 25 mg/kg and 21 mg/kg, by category, respectively (Table 5.7). In this 2004 study, the house age breakdown was not used as all homes were constructed prior to 1960. Background concentrations averaged less than 100 mg/kg with exception of dripline samples. The overall geometric mean for all HUD method samples in Background areas was 88 mg/kg. The mean for Background driplines was 254 mg/kg, while the non-dripline Background samples showed a geometric mean of 53 mg/kg lead (Table 5.6). Dripline samples were also higher relative to other samples in the Basin and Box, showing respective geometric means of 676 mg/kg and 510 mg/kg compared to 398 mg/kg and 218 mg/kg for all other soils (Table 5.6).

Table 5.7 Comparison of Soil Lead Concentrations in 1999 Study of Background and Box Homes

House Age Category	Number of Samples	Geometric Mean (mg/kg)	Geometric Standard Deviation (mg/kg)
Background			
Category 1	29	85	2.12
Category 2	8	25	2.47
Category 3	13	21	2.81
Box			
Category 1	183	233	3.93
Category 2	39	308	2.94
Category 3	10	173	1.91

Samples collected by the BHSS methodologies in the Background areas in 2004 showed similar results, with geometric means ranging from 33 mg/kg to 120 mg/kg for various portions of the yard. In 1999, Box geometric soil lead means for the three house age categories were 233 mg/kg, 308 mg/kg and 173 mg/kg, respectively, or about 3 to 12 times greater than levels in Background communities (Table 5.7). In 2004, the overall mean soil lead concentrations for the five Box communities are lower, reflecting the continued cleanup, and range from 129 mg/kg to 430 mg/kg (TerraGraphics 2005c).

Vacuum Bag Dust: The 1999 study noted that vacuum bag dust lead concentrations were significantly higher in older housing both in the Box and Background communities. Generally, BHSS levels were about 3 to 6 times higher than northern Idaho Background homes. Geometric means for Category 1 homes were 618 mg/kg for the Box and 193 mg/kg in Background communities (Table 5.8). In Category 2 homes, the respective concentrations were 393 mg/kg at the Box and 76 mg/kg Background (Table 5.8). For Category 3 homes, the levels were 180 mg/kg and 57 mg/kg, respectively (Table 5.8). In this 2004 HUD study, Basin, Box and Background vacuum bags showed geometric means of 551 mg/kg, 471 mg/kg and 129 mg/kg, respectively (Table 5.5). Overall vacuum bag dust lead levels for Box and Basin communities collected in other 2004 sampling efforts ranged from 198 mg/kg to 561 mg/kg in Basin communities and 239 mg/kg to 494 mg/kg in Box communities (TerraGraphics 2006 and 2005b).

Table 5.8 Comparison of Vacuum Lead Concentrations in 1999 Study of Background and Box Homes

House Age Category	Number of Samples	Geometric Mean (mg/kg)	Geometric Standard Deviation (mg/kg)
Background			
Category 1	28	193	2.24
Category 2	8	76	1.77
Category 3	13	57	2.72
Box			
Category 1	24	618	1.96
Category 2	15	393	2.52
Category 3	1	180	-

Floor Mat Dust: In 1999, Background mat dust lead concentrations were 143 mg/kg, 68 mg/kg and 48 mg/kg for Category 1, 2 and 3 homes, respectively (Table 5.9a). In 2004, the geometric mean concentration for mat dust was 79 mg/kg and did not differ significantly from samples collected by vacuum bag or BRM methods, (i.e., 129 mg/kg and 101 mg/kg, respectively) (Table 5.5). In this 2004 HUD study, Box homes showed a mean of 391 mg/kg for mat dust, while the Basin was not significantly different from the Box with a mean of 396 mg/kg (Table 5.5).

Table 5.9a Comparison of Mat Lead Concentrations in 1999 Study of Background and Box Homes

House Age Category	Number of Samples	Geometric Mean (mg/kg)	Geometric Standard Deviation (mg/kg)
Background			
Category 1	27	143	2.56
Category 2	7	68	1.74
Category 3	13	48	2.13
Box			
Category 1	188	1111	2.10
Category 2	42	845	2.71
Category 3	11	719	2.15

In 1999, floor mat dust lead concentrations showed a much greater divergence between Box and Background levels than is evident in 2004. The same age groups in the Box showed 1,111 mg/kg, 845 mg/kg and 719 mg/kg, respectively, or were 8 to 15 times greater than northern Idaho background in 1999 (Table 5.9a). In this HUD study, Box and Basin mat dust lead concentrations average about 391 mg/kg and 396 mg/kg, respectively, or five times Background. The lower levels in 2004 are reflective of the success of the Box cleanup in reducing house dust lead concentrations.

In this study, 2004 dust loading rates were higher, but not significantly different in Background homes. Geometric mean dust loading rates were 672 mg/m^2/day, 692 mg/m^2/day and 1,109 mg/m^2/day in Basin, Box and Background homes, respectively (Table 5.5). These loading rates were higher in all areas compared to those observed in 1999. In 1999, the dust loading rates for Box and Background homes were significantly different for Category 1 homes with respective geometric means of 665 mg/m^2/day and 279 mg/m^2/day (Table 5.9b). No significant difference was detected for house age Categories 2 and 3, with Background rates of 254 mg/m^2/day and 216 mg/m^2/day, respectively. Box dust loading rates were 382 mg/m^2/day for house age Categories 2 and 3.

Table 5.9b Comparison of Mat Dust Loading Rates in 1999 Study of Background and Box Homes

House Age Category	Number of Samples	Geometric Mean (mg/kg)	Geometric Standard Deviation (mg/kg)
Background			
Category 1	27	665	3.87
Category 2	7	254	1.59
Category 3	13	216	3.46
Box			
Category 1	188	279	2.80
Category 2	41	382	2.66
Category 3	11	382	3.12

Lead loading rates observed in this HUD study were about three times greater in the Basin and Box than those in Background communities; 0.31mg/m^2/day, 0.27 mg/m^2/day and 0.09 mg/m^2/day, respectively (Table 5.5). In 1999, the difference was 3.5 to 20 times depending on house age. Background floor mat lead loading rates, in 1999, were 0.095 mg/m^2/day, 0.017 mg/m^2/day and 0.014 mg/m^2/day for Category 1, 2 and 3 homes, respectively. The same house age groups in the Box in 1999 were 0.308 mg/m^2/day, 0.325 mg/m^2/day and 0.274 mg/m^2/day, respectively (Table 5.9c).

Table 5.9c Comparison of Mat Lead Loading Rates in 1999 Study of Background and Box Homes

House Age Category	Number of Samples	Geometric Mean (mg/kg)	Geometric Standard Deviation (mg/kg)
Background			
Category 1	27	0.095	5.23
Category 2	7	0.017	1.80
Category 3	13	0.014	2.54
Box			
Category 1	188	0.308	3.55
Category 2	41	0.325	3.81
Category 3	11	0.274	4.07

SECTION 6.0 REFERENCES

Adgate, J. L., C. Weisel, et al. (1995). "Lead in household dust: relationships between exposure metrics." Environ Res **70**(2): 134-47.

Bornschein, R. L., P. A. Succop, et al. (1986). "Exterior surface dust lead, interior house dust lead and childhood lead exposure in an urban environment." Trace Substances in Environmental Health **20**: 322-332.

CH2M Hill (1991). Final House Dust Remediation Report for the Bunker Hill CERCLA Site Populated Areas RI/FS. Bellevue, WA, Prepared for USEPA.

Charney, E., B. Kessler, et al. (1983). "Childhood lead poisoning. A controlled trial of the effect of dust- control measures on blood lead levels." N Engl J Med **309**(18): 1089-93.

Clark, S., R. Bornschein, et al. (1991). "Urban lead exposure of children in Cincinnati, Ohio." Chemical Speciation and Bioavailability **3**(3/4): 163-171.

Davies, D. J. A., I. Thornton, et al. (1991). "Lead intake and blood lead in two-year-old UK urban children." Sci Total Environ **90**: 13-29.

Ewers, L., S. Clark, et al. (1994). "Clean-up of lead in household carpet and floor dust." Am Ind Hyg Assoc J **55**(7): 650-7.

Farfel, M. R., A. O. Orlova, et al. (2001). "Comparison of two floor mat lead dust collection methods and their application in pre-1950 and new urban houses." Environ Sci Technol **35**(10): 2078-83.

Hilts, S. R., C. Hertzman, et al. (1995). "A controlled trial of the effect of HEPA vacuuming on childhood lead exposure." Canadian Journal of Public Health **86**: 345-350.

Idaho Department of Health and Welfare Division of Health (2000). Coeur d'Alene River Basin Environmental Health Assessment. Atlanta, GA, Agency for Toxic Substances and Disease Registry**:** 67.

Lanphear, B. P., T. D. Matte, et al. (1998). "The contribution of lead-contaminated house dust and residential soil to children's blood lead levels. A pooled analysis of 12 epidemiologic studies." Environ Res **79**(1): 51-68.

Lanphear, B. P., M. Weitzman, et al. (1996). "Lead-contaminated house dust and urban children's blood lead levels." Am J Public Health **86**(10): 1416-21.

Laxen, D. P., G. M. Raab, et al. (1987). "Children's blood lead and exposure to lead in household dust and water-- a basis for an environmental standard for lead in dust." Sci Total Environ **66**: 235-44.

Lioy, P. J., L. M. Yiin, et al. (1998). "The effectiveness of a home cleaning intervention strategy in reducing potential dust and lead exposures." J Expo Anal Environ Epidemiol **8**(1): 17-35.

National Research Council of the National Academies (NAS) (2005). Superfund and Mining Megasites-Lessons from the Coeur d'Alene River Basin.

Panhandle Health District and TerraGraphics (2004). Quality Assurance Plan (QAP) For Comparison of HUD Risk Assessment Methodology to Methods Used at the Bunker Hill Superfund Site in Idaho for the Identification of Risk from Lead in House Dust Revision No. 2.

Panhandle Health District (1986). Kellogg Revisited - 1983: Childhood Blood Lead and Environmental Status Report. Kellogg, ID, Panhandle Health District.

Rhoads, G. G., A. S. Ettinger, et al. (1999). "The effect of dust lead control on blood lead in toddlers: a randomized trial." Pediatrics **103**(3): 551-5.

Roberts, J. W. and P. Dickey (1995). "Exposure of children to pollutants in house dust and indoor air." Rev Environ Contam Toxicol **143**: 59-78.

SAS Institute Inc. (1999). SAS Version 8 for Windows, SAS Institute Inc., Cary, NC, USA.

Spalinger, S. M., M. C. von Braun, Petrosyan, V., and I.H. von Lindern. (In-press). "Northern Idaho House Dust and Soil Lead Levels Compared to the Bunker Hill Superfund Site." Environmental Monitoring and Assessment.

TerraGraphics (2006). Draft Coeur D'Alene Basin Blood Lead Absorption and Exposure Report. Moscow, ID, Prepared for Idaho Department of Environmental Quality.

TerraGraphics (2005a). Human Health Remedial Evaluation Report for the Bunker Hill Superfund Site Box - Revised for the 2005 Five Year Review. Moscow, ID.

TerraGraphics (2005b). Bunker Hill Superfund Site OU1 House Dust Status and Rights-of-Way Recontamination Report. Moscow, ID, Prepared for Idaho Department of Environmental Quality.

TerraGraphics (2005c). Technical Memorandum: Addendum to the Final Human Health Remedial Evaluation for the Bunker Hill Superfund Site Box - Updates for the 2005 Five Year Review. Moscow, ID, Prepared for Idaho Department of Environmental Quality.

TerraGraphics (2004). Final Bunker Hill Box Human Health Remedial Evaluation Report. Moscow, ID, USEPA Region 10 and Idaho Department of Health and Welfare Division of Environmental Quality.

TerraGraphics and U.S. Army Corps of Engineers (2002). Bunker Hill House Dust Pilot Final Remedial Effectiveness Report. Moscow, ID, United States Environmental Protection Agency Region X and Idaho Department of Environmental Quality.

TerraGraphics, URS Greiner Inc., et al. (2001). Final Human Health Risk Assessment for the Coeur d'Alene Basin. Moscow, ID, USEPA Region 10 and Idaho Department of Health and Welfare Division of Environmental Quality.

TerraGraphics (2000). Final 1999 Five Year Review Report Bunker Hill Site. Moscow, ID, Prepared for Idaho Department of Health and Welfare Division of Environmental Quality and U.S. Environmental Protection Agency Region 10.

TerraGraphics (1999). Draft Final 1999 Five Year Review Report Bunker Hill Site. Moscow, ID, Prepared for Idaho Department of Health and Welfare Division of Environmental Quality

TerraGraphics (1997). Summary of Lead Health Intervention and Source Removal Efforts 1985-1996. Kellogg, ID, Idaho Department of Health and Welfare Division of Environmental Quality.

Thornton, I., D. J. Davies, et al. (1990). "Lead exposure in young children from dust and soil in the United Kingdom." Environ Health Perspect **89**: 55-60.

U.S Census Bureau. (2000). "U.S. Census Bureau - Population Estimates." Retrieved May 26, from http://www.census.gov/popest/estimates.php.

U.S. Department of Housing and Urban Development (HUD) (1995 and updates). Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing.

U.S. Environmental Protection Agency Region 10 (USEPA) (2005). Second Five-Year Review for Bunker Hill Mining and Metallurgical Complex Superfund Site Operable Units 1,2, and 3 Idaho and Washington Public Review Draft. Seattle, WA.

U.S. Environmental Protection Agency Region 10 (USEPA) (2002). Record of Decision for Bunker Hill Mining and Metallurgical Complex Operable Unit 3. Seattle, WA, U.S. Environmental Protection Agency Region 10.

U.S. Environmental Protection Agency Region 10 (USEPA), Doolan, M., Jones, S., Brown, B., Bradly, B., Mah, B., Root, C., McEaddy, M., Casanova, R., Sparks, S., Mahmud, S., Hinnant, S., Jones, S. (2000). Review of the Bunker Hill Superfund Site 5 Year Review Report. Washington, D.C.

U.S. Environmental Protection Agency Region 10 (USEPA) (1992). Record of Decision for Bunker Hill Superfund Site Non-Populated Areas. Seattle, WA, U.S. Environmental Protection Agency Region 10.

U.S. Environmental Protection Agency Region 10 (USEPA) (1991). Record of Decision for Bunker Hill Superfund Site Populated Areas. Kellogg, Idaho, Region 10, USEPA.

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

von Lindern, I., S. Spalinger, Bero, B. N., Petrosyan, V., and von Braun, Margrit C. (2003b). "The influence of soil remediation on lead in house dust." The Science of The Total Environment **303**(1-2): 59-78.

Yankel, A. J., I. H. von Lindern, et al. (1977). "The Silver Valley lead study: the relationship between childhood blood lead levels and environmental exposure." J Air Pollut Control Assoc **27**(8): 763-7.

Yiin, L. M., G. G. Rhoads, et al. (2002). "Comparison of techniques to reduce residential lead dust on carpet and upholstery: the New Jersey assessment of cleaning techniques trial." Environ Health Perspect **110**(12): 1233-1237.

Yiin, L. M., G. G. Rhoads, et al. (2000). "Seasonal influences on childhood lead exposure." Environ Health Perspect **108**(2): 177-82.

Table A-1 Summary of HUD Risk Assessment Determinations*

Home No.	Community	Based on the Visual Assessment, a risk assessor would have recommended:				Assigned risk level				Immediate Hazard Identified	Risk Category (See Text)
		No further action	Lead-based Paint (LBP) Inspection	Hazard Screen	Risk Assessment	All LBP in good condition, no elevated lead-dust or soils identified 1	Damaged LBP observed. No elevated lead-dust or soils identified 2	Elevated lead in dust identified 3a	Elevated lead in soil identified 3b		
1	BASIN				x			x	x	x	3a, 3b
2	BASIN				x		x				2
3	BASIN				x				x	x	3b
4	BASIN				x				x	x	3b
5	BASIN				x				x	x	3b
6	BASIN				x			x	x	x	3a, 3b
7	BASIN				x		x				2
8	BASIN				x				x	x	3b
9	BASIN				x			x	x	x	3a, 3b
10	BASIN				x			x		x	3a
11	BASIN				x			x	x	x	3a, 3b
12	BASIN				x			x	x	x	3a, 3b
13	BASIN				x			x		x	3a
14	BASIN				x				x	x	3b
15	BASIN				x		x				2
16	BASIN				x		x				2
17	BASIN				x		x				2
18	BASIN				x		x				2
19	BASIN		x					x		x	3a
20	BASIN				x				x	x	3a
21	BASIN				x			x	x	x	3a, 3b
22	BASIN				x		x				2
23	BASIN		x						x	x	3b
24	BASIN				x				x	x	3b

Table A-1 Summary of HUD Risk Assessment Determinations*

		Based on the Visual Assessment, a risk assessor would have recommended:				Assigned risk level					
Home No.	Community	No further action	Lead-based Paint (LBP) Inspection	Hazard Screen	Risk Assessment	All LBP in good condition, no elevated lead-dust or soils identified 1	Damaged LBP observed. No elevated lead-dust or soils identified 2	Elevated lead in dust identified 3a	Elevated lead in soil identified 3b	Immediate Hazard Identified	Risk Category (See Text)
25	BOX			x		x					1
26	BOX		x						x	x	3b
27	BOX				x			x	x	x	3a, 3b
28	BOX	x				x					1
29	BOX			x			x				2
30	BOX				x		x				2
31	BOX	x					x				2
32	BOX			x					x	x	3b
33	BOX		x				x				2
34	BOX				x			x	x	x	3a,3b
35	BOX				x		x				2
36	BOX				x		x				2
37	BOX				x				x	x	3b
38	BOX				x			x		x	3a
39	BOX				x			x		x	3a
40	BOX				x		x				2
41	BOX				x		x				2
42	BOX			x				x	x	x	3a, 3b
43	BOX				x		x				2
44	BOX				x			x	x	x	3a, 3b
45	BOX				x	x					1
46	BOX				x				x	x	3b
47	BOX				x				x	x	3b
48	BOX				x			x	x	x	3a, 3b
49	BOX				x		x				2
50	BOX				x			x	x	x	3a, 3b

Table A-1 Summary of HUD Risk Assessment Determinations*

Home No.	Community	Based on the Visual Assessment, a risk assessor would have recommended:				Assigned risk level				Immediate Hazard Identified	Risk Category (See Text)
		No further action	Lead-based Paint (LBP) Inspection	Hazard Screen	Risk Assessment	All LBP in good condition, no elevated lead-dust or soils identified 1	Damaged LBP observed. No elevated lead-dust or soils identified 2	Elevated lead in dust identified 3a	Elevated lead in soil identified 3b		
51	BACKGROUND			x		x					1
52	BACKGROUND			x			x				2
53	BACKGROUND				x		x				2
54	BACKGROUND			x			x				2
55	BACKGROUND				x	x					1
56	BACKGROUND				x	x					1
57	BACKGROUND				x		x				2
58	BACKGROUND				x	x					1
59	BACKGROUND		x			x					1
60	BACKGROUND				x				x	x	3b
61	BACKGROUND				x		x				2
62	BACKGROUND				x		x				2
63	BACKGROUND				x		x				2
64	BACKGROUND				x	x					1
65	BACKGROUND				x			x		x	3a
66	BACKGROUND				x			x		x	3a
67	BACKGROUND				x	x					1
68	BACKGROUND				x		x				2
69	BACKGROUND				x		x				2
70	BACKGROUND				x	x					1
71	BACKGROUND				x	x					1
72	BACKGROUND				x	x					1
73	BACKGROUND				x		x				2
74	BACKGROUND				x				x	x	3b
75	BACKGROUND				x		x				2

LBP = Lead Based Paint

* Excludes supplemental soil samples

Table A-2 HUD/BHSS Soil Risk Evaluation Including Supplemental HUD Soil Samples*

		Soil Risk Evaluation					
		EPA/HUD Criteria		BHSS Criteria	Soil Lead Risk		
Home No.	Community	Child Play Area Soil Lead ≥ 400 mg/kg	Bare Area Soil Lead ≥ 1,200 mg/ kg	Soil Lead ≥ 1,000 mg/kg	HUD*	BHSS	Agree
1	BASIN	x	x	x	x	x	x
2	BASIN	x		x	x	x	x
3	BASIN	x	x	x	x	x	x
4	BASIN	x	x		x		
5	BASIN	x	x	x	x	x	x
6	BASIN	x	x	x	x	x	x
7	BASIN	x		x	x	x	x
8	BASIN	x	x	x	x	x	x
9	BASIN	x	x	x	x	x	x
10	BASIN	x		x	x	x	x
11	BASIN	x	x	x	x	x	x
12	BASIN	x	x	x	x	x	x
13	BASIN	x		x	x	x	x
14	BASIN	x	x	x	x	x	x
15	BASIN	x		x	x	x	x
16	BASIN						x
17	BASIN	x		x	x	x	x
18	BASIN	x		x	x	x	x
19	BASIN						x
20	BASIN	x	x	x	x	x	x
21	BASIN	x	x	x	x	x	x
22	BASIN			x		x	
23	BASIN	x	x	x	x	x	x
24	BASIN	x		x	x	x	x

Table A-2 HUD/BHSS Soil Risk Evaluation Including Supplemental HUD Soil Samples*

Home No.	Community	Soil Risk Evaluation: EPA/HUD Criteria: Child Play Area Soil Lead ≥ 400 mg/kg	Soil Risk Evaluation: EPA/HUD Criteria: Bare Area Soil Lead ≥ 1,200 mg/ kg	Soil Risk Evaluation: BHSS Criteria: Soil Lead ≥ 1,000 mg/kg	Soil Lead Risk: HUD*	Soil Lead Risk: BHSS	Soil Lead Risk: Agree
25	BOX	x			x		
26	BOX	x	x		x		
27	BOX	x	x		x		
28	BOX						x
29	BOX						x
30	BOX						x
31	BOX	x			x		
32	BOX	x	x		x		
33	BOX	x			x		
34	BOX	x			x		
35	BOX						x
36	BOX	x			x		
37	BOX	x	x		x		
38	BOX	x			x		
39	BOX	x			x		
40	BOX	x			x		
41	BOX	x			x		
42	BOX	x	x		x		
43	BOX	x	x		x		
44	BOX	x			x		
45	BOX	x			x		
46	BOX	x	x		x		
47	BOX	x	x		x		
48	BOX	x			x		
49	BOX	x			x		
50	BOX	x			x		

Table A-2 HUD/BHSS Soil Risk Evaluation Including Supplemental HUD Soil Samples*

Home No.	Community	Soil Risk Evaluation: EPA/HUD Criteria: Child Play Area Soil Lead ≥ 400 mg/kg	Soil Risk Evaluation: EPA/HUD Criteria: Bare Area Soil Lead ≥ 1,200 mg/ kg	Soil Risk Evaluation: BHSS Criteria: Soil Lead ≥ 1,000 mg/kg	Soil Lead Risk: HUD*	Soil Lead Risk: BHSS	Soil Lead Risk: Agree
51	BACKGROUND						x
52	BACKGROUND						x
53	BACKGROUND						x
54	BACKGROUND	x			x		
55	BACKGROUND						x
56	BACKGROUND	x		x	x	x	x
57	BACKGROUND	x			x		
58	BACKGROUND						x
59	BACKGROUND						x
60	BACKGROUND	x		x	x	x	x
61	BACKGROUND	x			x		
62	BACKGROUND	x			x		
63	BACKGROUND	x			x		
64	BACKGROUND						x
65	BACKGROUND						x
66	BACKGROUND						x
67	BACKGROUND						x
68	BACKGROUND						x
69	BACKGROUND						x
70	BACKGROUND						x
71	BACKGROUND	x			x		
72	BACKGROUND						x
73	BACKGROUND	x			x		
74	BACKGROUND	x	x		x		
75	BACKGROUND	x			x		

*Includes all supplemental soil samples in risk determination.

Table A-3 HUD/BHSS Soil Risk Evaluation Excluding Supplemental HUD Soil Samples*

		Soil Risk Evaluation			Soil Lead Risk		
		EPA/HUD Criteria		BHSS Criteria			
Home No.	Community	Child Play Area Soil Lead ≥ 400 mg/kg	Bare Area Soil Lead ≥ 1,200 mg/ kg	Soil Lead ≥ 1,000 mg/kg	HUD*	BHSS	Agree
1	BASIN	x	x	x	x	x	x
2	BASIN			x		x	
3	BASIN	x	x	x	x	x	x
4	BASIN	x	x		x		
5	BASIN	x	x	x	x	x	x
6	BASIN	x	x	x	x	x	x
7	BASIN			x		x	
8	BASIN	x	x	x	x	x	x
9	BASIN	x	x	x	x	x	x
10	BASIN			x		x	
11	BASIN	x	x	x	x	x	x
12	BASIN	x	x	x	x	x	x
13	BASIN			x		x	
14	BASIN	x	x	x	x	x	x
15	BASIN			x		x	
16	BASIN						x
17	BASIN			x		x	
18	BASIN			x		x	
19	BASIN						x
20	BASIN		x	x	x	x	x
21	BASIN	x	x	x	x	x	x
22	BASIN			x		x	
23	BASIN	x	x	x	x	x	x
24	BASIN	x		x	x	x	x

Table A-3 HUD/BHSS Soil Risk Evaluation Excluding Supplemental HUD Soil Samples*

		Soil Risk Evaluation			Soil Lead Risk		
		EPA/HUD Criteria		BHSS Criteria			
Home No.	Community	Child Play Area Soil Lead ≥ 400 mg/kg	Bare Area Soil Lead ≥ 1,200 mg/ kg	Soil Lead ≥ 1,000 mg/kg	HUD*	BHSS	Agree
25	BOX						x
26	BOX	x	x		x		
27	BOX	x	x		x		
28	BOX						x
29	BOX						x
30	BOX						x
31	BOX						x
32	BOX	x	x		x		
33	BOX						x
34	BOX	x			x		
35	BOX						x
36	BOX						x
37	BOX	x	x		x		
38	BOX						x
39	BOX						x
40	BOX						x
41	BOX						x
42	BOX	x	x		x		
43	BOX						x
44	BOX	x			x		
45	BOX						x
46	BOX	x	x		x		
47	BOX	x	x		x		
48	BOX	x			x		
49	BOX						x
50	BOX	x			x		

Table A-3 HUD/BHSS Soil Risk Evaluation Excluding Supplemental HUD Soil Samples*

Home No.	Community	Soil Risk Evaluation			Soil Lead Risk		
		EPA/HUD Criteria		BHSS Criteria			
		Child Play Area Soil Lead ≥ 400 mg/kg	Bare Area Soil Lead ≥ 1,200 mg/ kg	Soil Lead ≥ 1,000 mg/kg	HUD*	BHSS	Agree
51	BACKGROUND						x
52	BACKGROUND						x
53	BACKGROUND						x
54	BACKGROUND						x
55	BACKGROUND						x
56	BACKGROUND			x		x	
57	BACKGROUND						x
58	BACKGROUND						x
59	BACKGROUND						x
60	BACKGROUND	x		x	x	x	x
61	BACKGROUND						x
62	BACKGROUND						x
63	BACKGROUND						x
64	BACKGROUND						x
65	BACKGROUND						x
66	BACKGROUND						x
67	BACKGROUND						x
68	BACKGROUND						x
69	BACKGROUND						x
70	BACKGROUND						x
71	BACKGROUND						x
72	BACKGROUND						x
73	BACKGROUND						x
74	BACKGROUND		x		x		
75	BACKGROUND						x

*Excludes supplemental soil samples.

Table A-4 HUD/BHSS Dust Lead Risk Evaluation

Home No.	Community	Dust Evaluation					Dust Lead Risk		
		EPA/HUD Criteria		BHSS Criteria					
		Floor Dust Wipe Lead ≥ 40 µg/ft²	Window Sill Wipe Dust Lead ≥ 250 µg/ft²	Vacuum Bag Dust Lead ≥ 1,000 mg/kg	Dust Mat Lead ≥ 1,000 mg/kg	BRM Dust Lead ≥ 1,000 mg/kg	HUD	BHSS	Agree
1	BASIN		x				x		
2	BASIN								x
3	BASIN								x
4	BASIN								x
5	BASIN				x			x	
6	BASIN	x					x		
7	BASIN								x
8	BASIN			x				x	
9	BASIN		x				x		
10	BASIN	x			x		x	x	x
11	BASIN		x				x		
12	BASIN	x		x	x	x	x	x	x
13	BASIN		x			x	x	x	x
14	BASIN								x
15	BASIN			x				x	
16	BASIN								x
17	BASIN								x
18	BASIN								x
19	BASIN								x
20	BASIN								x
21	BASIN		x	x		x	x	x	x
22	BASIN								x
23	BASIN								x
24	BASIN		x				x		

Table A-4 HUD/BHSS Dust Lead Risk Evaluation

Home No.	Community	Dust Evaluation: EPA/HUD Criteria: Floor Dust Wipe Lead $\geq$ 40 µg/ft²	Dust Evaluation: EPA/HUD Criteria: Window Sill Wipe Dust Lead $\geq$ 250 µg/ft²	Dust Evaluation: BHSS Criteria: Vacuum Bag Dust Lead $\geq$ 1,000 mg/kg	Dust Evaluation: BHSS Criteria: Dust Mat Lead $\geq$ 1,000 mg/kg	Dust Evaluation: BHSS Criteria: BRM Dust Lead $\geq$ 1,000 mg/kg	Dust Lead Risk: HUD	Dust Lead Risk: BHSS	Dust Lead Risk: Agree
25	BOX								x
26	BOX								x
27	BOX		x				x		
28	BOX								x
29	BOX								x
30	BOX								x
31	BOX								x
32	BOX								x
33	BOX								x
34	BOX	x	x				x		
35	BOX				x	x		x	
36	BOX								x
37	BOX								x
38	BOX		x	x			x	x	x
39	BOX		x				x		
40	BOX					x		x	
41	BOX								x
42	BOX	x					x		
43	BOX			x		x		x	
44	BOX	x		x			x	x	x
45	BOX								x
46	BOX								x
47	BOX								x
48	BOX	x					x		
49	BOX								x
50	BOX		x				x		

Table A-4 HUD/BHSS Dust Lead Risk Evaluation

Home No.	Community	Dust Evaluation: EPA/HUD Criteria: Floor Dust Wipe Lead ≥ 40 µg/ft²	Dust Evaluation: EPA/HUD Criteria: Window Sill Wipe Dust Lead ≥ 250 µg/ft²	Dust Evaluation: BHSS Criteria: Vacuum Bag Dust Lead ≥ 1,000 mg/kg	Dust Evaluation: BHSS Criteria: Dust Mat Lead ≥ 1,000 mg/kg	Dust Evaluation: BHSS Criteria: BRM Dust Lead ≥ 1,000 mg/kg	Dust Lead Risk: HUD	Dust Lead Risk: BHSS	Dust Lead Risk: Agree
51	BACKGROUND								x
52	BACKGROUND								x
53	BACKGROUND								x
54	BACKGROUND								x
55	BACKGROUND								x
56	BACKGROUND								x
57	BACKGROUND								x
58	BACKGROUND								x
59	BACKGROUND								x
60	BACKGROUND								x
61	BACKGROUND								x
62	BACKGROUND								x
63	BACKGROUND								x
64	BACKGROUND								x
65	BACKGROUND		x				x		
66	BACKGROUND		x				x		
67	BACKGROUND								x
68	BACKGROUND								x
69	BACKGROUND								x
70	BACKGROUND								x
71	BACKGROUND								x
72	BACKGROUND								x
73	BACKGROUND								x
74	BACKGROUND								x
75	BACKGROUND								x