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Omaha Lead Site
Final Remedial Investigation Report

Volume I

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ENERGY WATER INFORMATION GOVERNMENT

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Acronyms and Abbreviations

ABA	Absolute Bioavailability
ACS	American Community Survey
ASTM	American Society for Testing and Materials
AUC	Area Under Curve
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	Below Ground Surface
BHHRA	Baseline Human Health Risk Assessment
BVID	Black & Veatch Identification Number
BVSPC	Black & Veatch Special Projects Corp.
CDC	Centers for Disease Control
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CERCLIS	Comprehensive Environmental Response Compensation and Liability Information System
CFR	Code of Federal Regulations
COC	Chain of Custody
COPC	Contaminant of Potential Concern
CTE	Central Tendency Exposure
DCHD	Douglas County Health Department
DI	Daily Intake
dl	deciliter
EBL	Elevated Blood Lead
EPA	Environmental Protection Agency
EMPA	Electron Microprobe
FS	Feasibility Study
FSP	Field Sampling Plan
ft^2	square feet
g	gram
GIS	Geographic Information System
GPS	Global Positioning System
HEPA	High Efficiency Particulate Air
HI	Hazard Index
HQ	Hazard Quotient
HRS	Hazard Ranking System

ICP-AES	Inductively coupled plasma-atomic emission spectrometry
IEUBK	Integrated Exposure Uptake Biokinetic Model for Lead in Children
kg	kilogram
L	liter
LBP	Lead Based Paint
LEGS	Laboratory for Environmental and Geological Studies, University of Colorado
LHCP	Lead Hazard Control Program
MCL	Maximum Contaminant Level
MS	Matrix Spike
MSD	Matrix Spike Duplicate
mg	milligram
NDEQ	Nebraska Department of Environmental Quality
NERL	National Exposure Research Laboratory
NHHS	Nebraska Health and Human Services System
NPL	National Priorities List
OLS	Omaha Lead Site
PA/SI	Preliminary Assessment/Site Inspection
ppm	parts per million
PRP	Potentially Responsible Party
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RAPMA	State of Nebraska Remedial Action Plan Monitoring Act
RBA	Relative Bioavailability
RBALP	Relative Bioavailability and Leaching Procedure
RfD	Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RPD	Relative Percent Difference
SAID	Sample Area Identification
SCS	U. S. Soil Conservation Service
SF	Slope Factor
TAL	Target Analyte List

TSCA	Toxic Substances and Control Act
µg	microgram
UNO	University of Nebraska, Omaha
USGS	U.S. Geological Survey
UTL	Upper Tolerance Limit
XRF	X-ray fluorescence

Executive Summary

The U.S. Environmental Protection Agency (EPA) initiated a remedial investigation (RI) of the Omaha Lead Site (OLS) in Omaha, Nebraska (CERCLIS Identification NESFN0703481) in 2001. The RI is the methodology that the Superfund program has established for investigating the risks posed by uncontrolled hazardous waste sites. The RI at the Omaha Lead Site was conducted for EPA by Black & Veatch Special Projects Corp. (BVSPC) under EPA Work Assignment No. 07-RICO-07ZY, Contract No. 68-W5-004, and Task Orders 0031, 0091 and 0101, Contract No. EP-S7-05-06.

In 2004, BVSPC prepared an interim Remedial Investigation/Feasibility Study (RI/FS) Report to address the soil contamination at the site to support EPA's Interim Record of Decision (ROD). The Interim ROD contained the interim action levels that EPA is presently using to perform remedial actions at residential properties. This Final RI Report has been prepared to provide additional information to support the final ROD.

Site History

The ASARCO lead facility, which was in operation from 1871 until 1997, was located at 500 Douglas Street in downtown Omaha on an approximately 23-acre site on the west bank of the Missouri River. The land where this ASARCO facility operated was owned by Union Pacific Railroad Company from the 1860s until it was sold to ASARCO in 1946. The ASARCO facility processed lead bullion containing recoverable amounts of gold, silver, antimony, and bismuth using the traditional pyro-metallurgical process. This process consisted of adding metallic and nonmetallic compounds to molten lead, separation of the lead from the other metals, and removing impurities. While the ASARCO plant was in operation, lead and other metals were emitted to the atmosphere through smokestacks and these contaminants were transported downwind to be deposited on the ground surface by the combined action of turbulent diffusion and gravitational settling. The ASARCO facility was closed in 1997 and the property is now owned by the City of Omaha and being reutilized for commercial and public purposes.

Aaron Ferer and Sons Co. constructed a secondary lead smelter and a lead recycling facility in the early 1950s at 555 Farnam Street in Omaha. Aaron Ferer operated this facility until 1963 when the facility was sold to a predecessor of Gould Electronics, Inc. (Gould). Gould operated the facility until it was closed in 1982. While this facility was in operation, lead was emitted into the atmosphere through a stack and transported downwind to be deposited on the ground surface by the combined action of turbulent diffusion and gravitational settling. Gould sold the property to Douglas County in the early 1980s. Douglas County performed a clean up at the property and it is now a county park. Several other businesses in the Omaha area utilized lead in their manufacturing processes.

In 1998, the Omaha City Council solicited assistance from the EPA in addressing the problems with lead contamination in the area. In 1999, the EPA initiated an investigation into the lead contamination under the authority of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), 42 U.S.C. § 9600 et seq., also known as the Superfund law.

The EPA began sampling residential properties used for licensed child-care services in March 1999. Between March 1999 and February 2009, surface soil samples were collected from 37,076 residential properties. In 2004, BVSPC prepared an RI/FS Report that evaluated the soil contamination at the site. Following preparation of the RI/FS, EPA issued an interim ROD on December 15, 2004. The selected remedy in the interim ROD required the excavation and removal of lead-contaminated soils, backfilling the excavated areas to original grade with clean topsoil, and restoring a grass lawn. Generally the properties that were designated for an interim response included:

- Any residential-type property where at least one non-foundation soil sample exceeded 800 parts per million (ppm) lead;
- Residences with any non-foundation sample exceeding 400 ppm lead where a child identified with an elevated blood lead level resides; and
- Child-care facilities and other high child-impact areas with any non-foundation sample exceeding 400 ppm lead.

When a remedial response action was initiated at a property meeting any of the above criteria, soil excavation and replacement was performed in all portions of the property where soils concentrations of 400 ppm or higher were detected, including drip zones. The EPA has completed soil remediation at 4,611 residential properties to date.

Site Description

The original boundaries of the OLS focus area were established at the time the Site was listed on the EPA National Priorities List (NPL). During the 2004 RI, the Omaha Lead Site Focus Area was expanded to include an area south of L Street to the Sarpy County Line (Harrison Street), an area north of Ames Avenue to Redick Avenue, and an area to the west of 45th Street. The focus area was expanded in 2008 to include an area north to Read Street and west to 56th Street.

Previous Investigations

In 1997, the Centers for Disease Control (CDC) issued a recommendation for local governments to analyze data pertinent to lead poisoning and to issue targeted screening guidelines that reflect the lead risk at the local level. In November 1998, the Douglas County Health Department (DCHD) published the results of an early childhood blood screening study which indicated that lead concentrations in the blood samples tested exceeded the national average. From July 1, 1997, to June 30, 1998, the DCHD Childhood Lead Poisoning Prevention Program screened 2,843 children for blood lead levels. The screening results indicated that 596 children had blood lead levels of 10 micrograms per deciliter (µg/dl) or higher.

In August 2001, BVSPC submitted a Preliminary Assessment/Site Inspection (PA/SI) Report to EPA that included all data collected for EPA by Jacobs Engineering prior to July 2000 and data collected for EPA by BVSPC from July 2000 through April 2001. A preliminary Hazard Ranking System (HRS) score was also prepared to determine the need for future activities at the site. During the SI for the Omaha Lead Site, subsurface soil samples were collected at approximately 550 properties where surface soil samples were collected at the same location. The subsurface samples were collected from the 0-8 inch, 8-16 inch, and 16-24 inch ranges. The number of samples in which lead was detected decreased at each downward depth interval. The average, maximum, and median lead concentrations also decreased as depth increased, indicating little to no migration downward from surface soils. The results indicated that, in general, if the surface soil lead concentrations are low there is no reason to believe that the concentrations would increase with depth. These results lead EPA to discontinue depth sampling at the end of the SI.

On April 5, 2000, the EPA initiated an apportionment investigation in an effort to determine the sources of lead contamination found in the soil of residential properties at the site. The EPA collected 32 soil samples from the former ASARCO refinery property and the former Gould property and compared the lead in these samples to that found in the soils of 28 residential properties. A report of this activity was finalized in September 2002. In 2007, EPA performed an additional study that expanded the areal distribution of lead speciation for community soils. Samples were collected from an additional 49 properties at the Omaha Lead Site, primarily from the northern and southern portion of the Focus Area. The samples were collected from residential properties, parks, and vacant lots.

The 2002 and 2007 data were combined to provide data from soils with bulk lead concentrations (66 to 5,788 mg/kg) averaging approximately 800 mg/kg lead. The 2007 report concluded that pyrometallurgical forms of lead were the largest identifiable lead source in residential yards; more than 90 percent of the yard samples speciated had pyrometallurgically apportioned lead; at least 32 percent of the bulk lead found in community soils is from a pyrometallurgical source; there is a strong lead isotopic correlation between community soils and the ASARCO plant with apparent limited input from the Gould facility or leaded gasoline; and that lead paint can not be isotopically ruled out as a source of lead, but isotopes suggest its significance is also limited.

Scope of Remedial Investigation

There were two main objectives for the RI. First, data was collected to develop a risk assessment for metal contaminants and to calculate a site specific clean-up level for the metal contaminants. Media evaluated for the risk assessment included surface soil, interior dust, and potable water. The second objective was to collect data to define the extent of contamination. The scope of the activities conducted for the 2004 Interim RI Report included:

- Sampled surface soil (1 inch depth) from residential properties in the area of investigation.
- Sampled subsurface soil (maximum depth 24 inches) from approximately 550 residential yards in the area of investigation.
- Sampled 159 randomly selected residential properties for interior dust in 2003.
- Conducted a demographic survey.
- Conducted bioavailability analyses on residential soil samples.
- Lead apportionment analysis.
- Performed analyses on the origin of other metals.

The scope of the activities conducted for this Final RI Report included:

- Sampled surface soil (1 inch depth) from residential properties in the area of investigation.
- Lead apportionment analysis.
- Collected soil samples from public parks in Omaha.
- Conducted a drip zone width contamination study.
- Collected dust samples and potable water samples from 98 residential homes in 2007.
- Performed Lead Based Paint (LBP) assessments on properties determined to be eligible for soil remediation.
- Performed a LBP recontamination study in 2008 to determine the potential for elevated soil lead levels to develop in the drip zone area of homes due to deteriorating LBP where surface soils and drip zones had been remediated.
- Performed a bench scale treatability study in 2007 to evaluate the influence of phosphate treatment on the bioaccessability of lead contamination in OLS soils

Nature and Extent of Contamination

Surface Soil

Between March 1999 and February 2009, surface soil samples were collected from 34,564 residential, elevated blood level (EBL), and child care properties within the Omaha Lead Site and analyzed for lead. An additional 2,511 properties were sampled outside the focus area. The properties were relatively evenly distributed throughout the expanded Focus Area at the site and represent lead concentrations in surface soil in all areas of the site. At the time this RI Report was prepared, soil samples had not been collected from the northern and western portion of the area defined as the Final Focus Area.

Of the 37,076 properties sampled in the investigation, 8,552 properties had at least one non-foundation sample with a total lead concentration between 400 ppm and 800 ppm and 4,144 properties had at least one non-foundation sample with a maximum lead concentration greater than or equal to 800 ppm, which is the lead concentration that triggers a response for a typical residence under the Interim ROD.

Approximately 23 percent of the properties sampled contained lead concentrations between 400 ppm and 800 ppm. Approximately 11 percent of the properties sampled contained lead concentrations greater than or equal to 800 ppm.

Indoor Dust

Dust samples were collected from 159 properties within the site boundary during October and November 2003. At each property where interior samples were collected, three vacuum dust samples were collected from the floor and one wipe sample was collected from a window sill. The EPA regulations concerning lead concentrations in wipe samples are found in the Code of Federal Regulations (CFR) at 40 CFR 745.227(h)(3)(i). The regulation specifies that a dust-lead hazard is present in a residential dwelling when the weighted arithmetic mean lead loadings for all single surface or composite samples of floors and interior window sills are equal to or greater than 40 µg/ft^2 for floors and 250 µg/ft^2 for interior window sills, respectively. Lead concentrations in 31 of the wipe samples collected from the window sills exceeded 250 µg/ft^2. Wipe samples were not collected from the floors during this sampling effort.

Dust samples were collected from 98 properties during November and December 2007. At each property where interior samples were collected, one composite dust sample was collected from the floors of three rooms using a vacuum. One composite wipe sample was collected from the window sill, window trough, and floor of the home. Each composite wipe sample consisted of individual wipes collected from the living area and two bedrooms in the home. The lead concentrations in the vacuum samples ranged from 9.4 ppm to 3,810 ppm. Lead concentrations in 25 of the wipe samples collected from the window sills were equal to or exceeded 250 µg/ft^2 and the lead concentrations in 5 of the wipe samples collected from the floors were equal to or exceeded 40 µg/ft^2.

Potable Water

Potable water samples were collected in November and December 2007 from each residence where indoor dust samples were collected. The samples were analyzed for lead and the analytical results were compared to the EPA maximum contaminant level (MCL) for lead (15 µg/L). The potable water from one property contained lead concentrations for the first flush sample (prior to using any water sources in the morning) and post flush sample (after letting the water run for 5 minutes) of 48.8 µg/L and 634 µg/L, respectively. The potable water at the home was re-sampled in April 2008 and the lead concentrations were 10.2 µg/L and 4.7 µg/L, respectively.

Lead Based Paint Assessments

BVSPC has performed LBP assessments at 2,894 properties since the beginning of 2006. LBP assessments are ongoing and the number of assessments is being continuously updated. The data from the LBP assessments indicated that there were 1,335 properties where deteriorating LBP, if it were to fall onto the ground surface within 6 feet of the foundation and be uniformly mixed with the top 1 inch of soil, would result in an increase in the lead concentration in the soil to more than 400 ppm.

Drip Zone Width Study

BVSPC conducted a drip zone width study to characterize the drip zone in the Omaha Lead Site Focus Area for a representative group of homes and determine if a single drip zone width applicable to all residences could be identified. The data from the study indicated that soil lead concentrations drop below 400 ppm at approximately 6 feet from the exterior foundation wall, based on average lead concentrations at 6-inch intervals from the exterior foundation wall to 10 feet from the structures.

Lead Based Paint Recontamination Study

Soil samples were collected from 25 properties prior to paint stabilization and 21 where paint stabilization had been performed. Average soil lead concentrations along the transects generally remained below 400 ppm, and those instances where average lead concentrations exceeded 400 ppm were limited to drip zone areas within 6 feet of the foundation. Samples collected from all properties at distances greater than 6 feet from the foundation averaged less than 400 ppm.

The data indicate that the majority of the elevated lead concentrations were confined to the area within 6 feet of the foundation of the home. The data also indicate soil lead concentrations were lower and less frequent at properties sampled following HEPA vacuuming of exposed soils at the conclusion of paint stabilization at the home. The data indicate that HEPA vacuuming performed following paint stabilization reduces the occurrence of elevated lead levels in the drip zone soils.

The length of time passed since the soil remediation had no apparent effect on the level of recontamination observed at properties sampled prior to stabilization in this study. The severity of the LBP problem identified during previous LBP assessments performed on structures showed a correlation with elevated soil lead levels measured at properties sampled prior to paint stabilization.

Public Parks

During April to June 2006, BVSPC collected soil samples from 39 small parks with an area less than 10 acres. The lead concentrations in one sample from 29th & Blondo Park (438 ppm) and three samples from Kellom Greenbelt Park (404 ppm, 477 ppm, and 554 ppm) exceeded 400 ppm. The locations were resampled and the lead concentrations were below 400 ppm (293 ppm, 172 ppm, 156 ppm, and 266 ppm, respectively).

During July 2007, BVSPC collected soil samples from 15 large parks with an area greater than 10 acres. Lead concentrations were detected above the 400 ppm screening level in three parks. Three soil samples from Levi Carter Park contained lead concentrations of 400 ppm, 401 ppm, and 542 ppm. One soil sample from Miller Park had a lead concentration of 416 ppm and one soil sample from Spring Lake Park contained a lead concentration of 539 ppm.

Baseline Human Health Risk Assessment

The BHHRA for the OLS was prepared by the Syracuse Research Corporation (Ref. 62). The purpose of the BHHRA is to characterize the risks to area residents, both now and in the future, from site-related contaminants present in environmental media, assuming that no steps are taken to remediate the environment or to reduce human contact with contaminated environmental media. The results of the final assessment are intended to help inform risk managers and the public about potential human risks attributable to site-related contaminants and to help determine where there is a need for action at the site.

The environmental medium of chief concern is surface soil that has been impacted by the wet or dry deposition of metal-containing airborne particulates released from the smelters. The human population of chief concern is residents in the area of the site, now or in the future, including both children and adults. Residents might be exposed to smelter-related contaminants in site soils by a number of different pathways, including ingestion, inhalation, and dermal contact with contaminated soil or dust, and ingestion of home-grown produce that may have taken up contaminants from the soil.

Chemicals of Potential Concern (COPCs) are chemicals which exist in the environment at concentration levels that might be of potential health concern to humans and which are or might be derived, at least in part, from site-related sources. The chief COPC at this site is lead. However, several other chemicals were identified that might also be of potential concern to humans, including the following: aluminum, antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, thallium, vanadium, and zinc.

Risks from Exposure to Lead

The population of chief concern for lead exposure is young children (age 0-84 months). This is because young children tend to have higher intakes of lead than adults, tend to absorb more lead than adults, and are inherently more sensitive to lead than adults. If environmental exposures to lead in a residential area are acceptable for young children, exposures are usually also acceptable for older children and adults, including pregnant women.

In addition to these exposures to smelter-related releases of lead, children may also be exposed to lead from other sources as well. This includes lead from leaded paint, as well as lead in drinking water and food from grocery stores. Because risk from lead depends on exposure from all of these sources, these exposure pathways are also included in the risk evaluation for lead.

The EPA identified 10 µg/dL as the concentration level at which effects begin to occur that warrant avoidance. For convenience, the probability that an observed blood lead value will exceed 10 µg/dL is referred to as P10. The EPA has established a health-based goal there should be no more than a 5% chance that a child will have a blood lead value above 10 µg/dL. That is, if P10 is ≤ 5%, risks from lead are considered acceptable.

The EPA has developed a mathematical model for evaluating lead risks to residential children. This model is referred to as the IEUBK model. This model requires as input data on the levels of lead in all potentially contaminated environmental media (soil, dust, water, air, diet) at a specific location, and on the amount of these media taken in (by ingestion or inhalation) by a child living at that location. Given these inputs, the model calculates an estimate of the distribution of blood lead values that might occur in a population of children exposed to the specified conditions, including the value of P10.

The results of the lead risk evaluation include the following key points:

- Of the 28,478 properties evaluated, a total of 19,445 homes (68%) are predicted to have P10 values at or below the health-based goal of 5%, and 9,033 properties (32%) have values that exceed the goal.
- Of these 9,033 properties, 3,177 have P10 values between 5% and 10%, 3,051 properties have P10 values between 10% and 20%, and 2,805 properties have P10 values greater than 20%.
- The location of properties with P10 values greater than the health-based goal of 5% were widespread across the OLS final focus area and were frequently

found within all zip codes, with the exception of 68117 (which only had 2 properties).

These results indicate that a number of homes or parcels within the final focus area have soil lead levels that are of potential health concern to children who may reside there, now or in the future.

Risks from Non-Lead Contaminants

Although lead was the primary contaminant released to the environment from the historic operation of the smelters in the OLS, other metal and metalloid contaminants may also have been released. Exposure of residents (adults and children) to non-lead chemicals of potential concern in site soils and dusts was evaluated on a property-by-property basis.

Exposure was calculated in accord with standard equations recommended by EPA. In brief, the amount of chemical ingested or absorbed per day from each medium was calculated from information on the concentration of the chemical in the medium and the amount of medium that is ingested or contacted. Because there are usually differences between individuals in the level of exposure due to differences in intake rates, body weights, exposure frequencies, and exposure durations, calculations were performed for individuals that are "average" or are otherwise near the central portion of the range, and on intakes that are near the upper end of the range (e.g., the 95th percentile). These two exposure estimates are referred to as Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME), respectively. Values of CTE and RME parameters for soil and dust were in accord with standard default values recommended by EPA for evaluation of residents.

The estimated non-cancer risks from most COPCs in surface soils for residential CTE and RME scenarios, including both children (age 0-6 years) and adults (age 7-30 years), are below a level of potential concern ($HQ \leq 1$) for both child and adult residents. An exception is arsenic, which results in an $HQ > 1$ at about 10 percent of the properties. In addition, there are a small number of properties (< 1 percent of the total) where antimony, mercury and/or thallium yield HQ values above 1. Summation of non-cancer HQ values for chemicals that act on the same target tissue does not result in a substantial increase in non-cancer risk at most properties.

The only COPC at this site that is carcinogenic by the oral or dermal route is arsenic. As seen, estimated cancer risks to CTE residents are within EPA's target risk range (1E-06 to 1E-04) at all properties. Estimated risks to RME residents are also within EPA's target risk range at most properties, although risks exceed 1E-04 at 141 locations (5% of the properties with data). The excess individual lifetime cancer risks at these 141 properties range from 1E-04 to 1E-03.

1.0 Introduction

The U.S. Environmental Protection Agency (EPA) initiated a remedial investigation (RI) of the Omaha Lead Site in Omaha, Nebraska (CERCLIS Identification NESFN0703481) in 2001. The RI is the methodology that the Superfund program has established for investigating the risks posed by uncontrolled hazardous waste sites. The RI at the Omaha Lead Site was conducted for EPA by Black & Veatch Special Projects Corp. (BVSPC) under EPA Work Assignment No. 07-RICO-07ZY, Contract No. 68-W5-004, and Task Orders 0031, 0091 and 0101, Contract No. EP-S7-05-06.

In 2004, BVSPC prepared an interim Remedial Investigation/Feasibility Study (RI/FS) Report to address the soil contamination at the site to support EPA's Interim Record of Decision (ROD). The Interim ROD contained the interim action levels that EPA is presently using to perform remedial actions at residential properties. This Final RI Report has been prepared to provide additional information to support the final ROD.

Prior investigations, which are discussed later, demonstrated that the sources of lead contamination being addressed by this site did not adversely affect the surface water or groundwater exposure pathways for residents at this site. Therefore, this investigation focused on the soil contamination pathway. There were two main objectives for the RI. First, data was collected to develop a risk assessment for metal contaminants and to calculate a site specific clean-up level for the metal contaminants. Media evaluated for the risk assessment included surface soil, interior dust, and potable water. The second objective was to collect data to define the extent of contamination. Over 37,076 residential properties within the site have been sampled in order to provide the data necessary to complete these objectives. The scope of the activities conducted for the 2004 Interim RI Report included:

- Sampled surface soil (1 inch depth) from residential properties in the area of investigation.
- Sampled subsurface soil (maximum depth 24 inches) from approximately 550 residential yards in the area of investigation.
- Sampled 159 randomly selected residential properties for interior dust in 2003.
- Conducted a demographic survey.
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The scope of the activities conducted for this Final RI Report included:

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- Conducted a drip zone width contamination study.
- Collected dust samples and potable water samples from 98 residential homes in 2007.
- Performed Lead Based Paint (LBP) assessments on properties determined to be eligible for soil remediation.
- Performed a LBP recontamination study in 2008 to determine the potential for elevated soil lead levels to develop in the drip zone area of homes due to deteriorating LBP where surface soils and drip zones had been remediated.
- Performed a bench scale treatability study in 2007 to evaluate the influence of phosphate treatment on the bioaccessability of lead contamination in OLS soils.

1.1 Site Background

1.1.1 Site Description

The site is occupied by numerous residences and residential-type properties which have been contaminated as a result of air emissions from lead smelting and refining industrial operations (Ref. 1, p. 1). The ASARCO facility, which operated as a lead smelter/refinery, from the 1870s to 1997, was located at 500 Douglas Street at the intersection of I-480 and Abbott Drive in the eastern portion of Omaha, Nebraska or more specifically, at 41° 15' 64" north latitude and 95° 55' 47" west longitude (Ref. 1 pp. 1, 2; 2 and 3). The ASARCO property was cleaned up under the State of Nebraska Remedial Action Plan Monitoring Act (RAPMA) program. The former Gould facility, located at 555 Farnam Street, operated as a secondary lead smelter, was cleaned up and is now a county park. In addition, LBP and leaded fuel emissions, which would be expected to be found in urban areas such as Omaha, may have contributed to the soil contamination. Land use within a 4-mile radius of the site area is residential, commercial, and industrial (Ref. 5, p. 1-1).

The original boundaries of the OLS focus Area were established at the time the Site was listed on the EPA National Priorities List (NPL). During the 2004 RI (Ref. 50), the OLS Focus Area was expanded to include an area south of L Street to the Sarpy County Line (Harrison Street), an area north of Ames Avenue to Redick Avenue, and an area to the west of 45th Street. The focus area was expanded in 2008 to include an area north to Read Street, and west to 56th Street. A map of the present Focus Area is presented in Figure 1-1.

1.1.2 Site History

The ASARCO facility, which was in operation from 1871 until 1997, was located in downtown Omaha on an approximately 23-acre site on the west bank of the Missouri River (Ref. 1, p.1). The land where the ASARCO plant operated was owned by Union Pacific Railroad from the 1860s until it was sold to ASARCO in 1946. It processed lead bullion containing recoverable amounts of gold, silver, antimony, and bismuth using the traditional pyrometallurgical process, which consisted of adding metallic and non-metallic compounds to molten lead, separation of the lead from the other metals, and removing impurities. The products of this process included refined lead and specialty metal by-products such as antimony-rich lead, bismuth, dore (silver-rich material), and antimony oxide (Ref. 5, pp. 1-3, 1-4). The fully refined lead, with all other metals and impurities removed, was formed into 100 pound castings or 1-ton blocks, which were then shipped to industries which used lead in manufacturing (Ref. 5, p. 1-4). While the ASARCO plant was in operation, lead and other metals were emitted into the atmosphere through smoke stacks and were transported downwind to be deposited on the ground surface by the combined action of turbulent diffusion and gravitational settling (Ref. 6, p. 1). The facility was closed in 1997 and the property was transferred to the City of Omaha after it was remediated. The City now uses the property for commercial and public purposes.

Aaron Ferer and Sons Co. constructed a secondary lead smelter and a lead recycling facility in the early 1950s at 555 Farnam Street in Omaha, NE. Aaron Ferer operated this facility until 1963 when the facility was purchased by a predecessor of Gould Electronics, Inc. (Gould). Gould operated the facility until it was closed in 1982 (Ref. 7). While this facility was in operation, lead was emitted into the atmosphere through a stack and transported downwind to be deposited on the ground surface by the combined action of turbulent diffusion and gravitational settling. The property where the Gould facility was located was sold after the facility closed to Douglas County. Douglas County performed a clean up at the property and it is now a county park. Several other businesses in the Omaha area utilized lead in their manufacturing processes.

In 1998, the Omaha City Council solicited assistance from the EPA in addressing the problems with lead contamination in the area. The EPA initiated an investigation into the lead contamination under the authority of Comprehensive Environmental Response Compensation and Liability Act (CERCLA) in 1999 (Ref. 7).

The EPA began sampling residential properties used for licensed child-care services in March 1999. Between March 1999 and February 2009, surface soil samples were collected from 37,076 residential properties. In 2004, BVSPC prepared an RI/FS Report to evaluate the soil contamination at the site. Following preparation of the RI/FS, EPA issued an interim ROD on December 15, 2004. The selected remedy in the interim ROD required the excavation and removal of lead-contaminated soils, backfilling the excavated areas to original grade with clean topsoil, and restoring a grass lawn. Generally, the properties that were designated for an interim response included:

- Any residential-type property where at least one non-foundation soil sample exceeded 800 parts per million (ppm) lead;
- Residences with any non-foundation sample exceeding 400 ppm lead where a child identified with an elevated blood lead level resides; and
- Child-care facilities and other high child-impact areas with any non-foundation sample exceeding 400 ppm lead.

When a remedial response action was initiated at a property meeting any of the above criteria, soil excavation and replacement was performed in all portions of the property where soils concentrations of 400 ppm or higher were detected, including drip zones. As of February 2009, the EPA has completed soil remediations at 4,611 properties at the OLS.

The interim remedy now underway also includes stabilization of deteriorating exterior LBP in cases where the continued effectiveness of the remedy is threatened because remediated soils could become recontaminated by small paint particles mixing with soil. Lead levels in exterior mid-yard samples must exceed the soil action levels specified in the Interim ROD for the property to be potentially eligible for stabilization of deteriorating LBP. If the soil action levels are exceeded at a property, then structures on that property are potentially eligible for stabilization of deteriorating LBP based upon the results of a LBP assessment. The Interim ROD did not specify quantitative criteria for deteriorated LBP that would be used as an action level to determine eligibility for paint stabilization. Instead, EPA intended that the criteria to be used to determine eligibility for LBP stabilization would be developed during implementation of the interim remedial action. Until criteria are finalized, properties are being prioritized for LBP stabilization based upon deteriorating LBP problems detected during screening and the presence of children under the age of seven. As of February 2009, LBP assessments had been performed on structures at 2,894 properties.

The EPA and the City of Omaha Lead Hazard Control Program (LHCP) are performing paint stabilization at homes where the remediated soils could become recontaminated by deteriorating LBP particles mixing with the soil. Lead-safe procedures are used to prepare the deteriorated surfaces, followed by priming and painting of all previously painted surfaces on eligible structures. Yard surfaces are vacuumed using high efficiency particulate air (HEPA) fitted equipment to remove visible paint chips following stabilization. The LBP stabilization program was initiated by the Omaha LHCP in 2007. EPA and LHCP are continuing stabilization in 2008. As of February 2009, EPA contractors had completed LBP stabilizations at 930 properties and Omaha LHCP contractors had completed stabilizations at 257 properties.

1.1.3 Previous Investigations

This section of the RI Report describes the previous investigations performed by the potentially responsible parties (PRPs) at the ASARCO facility and the investigations performed at the OLS by EPA or others. The discussion includes those investigations performed prior to the remedial investigation as well as those investigations that were performed following initiation of the remedial investigation.

1.1.3.1 Previous Investigations at ASARCO Facility

In March 1995, Hydrometrics, Inc. prepared a Phase I Detailed Site Assessment for Groundwater at the ASARCO facility on behalf of ASARCO (Ref. 5) which was conducted in accordance with a site assessment work plan for groundwater.

Seven monitoring wells were installed and soil samples were collected using standard split spoons. Soil samples were sent to a laboratory for X-ray fluorescence spectrographic (XRF) analysis. Arsenic, lead, antimony, copper and zinc were detected in the samples. Concentrations of these metals exceeded 1,000 milligrams per kilograms (mg/kg). In the groundwater samples, arsenic had the highest dissolved (filtered) metal concentrations, and with the exception of well MW-6D, arsenic concentrations in all monitoring wells exceeded the EPA Maximum Contaminant Level (MCL) for drinking water of 0.05 milligrams per liter (mg/L). The results of this investigation indicated that additional information was needed to adequately characterize the facility for remedial action (Ref. 5, p. 5-2).

In November 1995, Parametrix, Inc., prepared a report on behalf of ASARCO, titled "*Ecological Risks Associated with Releases of ASARCO Omaha Refinery Groundwater into the Missouri River*" (Ref. 8), which concluded that groundwater from the ASARCO facility contained concentrations of cadmium, copper, iron, lead, manganese, zinc, antimony, and arsenic. The report evaluated the potential risk of chronic toxicity to aquatic life based on the concentrations of metals and metalloids in the Missouri River water. Results of this evaluation indicated that groundwater infiltration posed no significant risks to the Missouri River aquatic life (Ref. 8, pp. 1, 11).

In November 1995, Hydrometrics, Inc., conducted a Soil and Groundwater Characterization investigation and prepared a report for the ASARCO Omaha plant site on behalf of ASARCO. The investigation consisted of collection of stratigraphic samples from 30 monitoring wells and 32 test holes, the installation of 30 monitoring wells, and aquifer testing using pumping and non-pumping methods. Surface water samples were collected from five stations to assess the potential impacts from groundwater on the Missouri River. All data collected during the 1995 Phase I Detailed Site Assessment of Groundwater report (Ref. 5) and the 1995 Phase II Groundwater Detailed Site Assessment report (Ref. 9) are summarized in the report for ASARCO. Soil testing results indicated that of all stratigraphic types, shallow fill contained the highest concentrations of arsenic and metals, and that some fill and shallow alluvial soils may contribute metals to the groundwater, because they were found to be saturated. Arsenic concentrations exceeded the MCL in 29 of the 32 monitoring wells, while lead and cadmium concentrations exceeded MCLs at some locations. Only slight increases in dissolved lead concentrations were observed at two surface water stations (Ref. 9).

In January 1997, ASARCO and the Nebraska Department of Environmental Quality (NDEQ) entered into a Consent Order. ASARCO agreed to completely and permanently terminate all pyrometallurgical processing and smelting of lead materials at the plant by July 1, 1997, and thereafter agreed to employ all reasonable means to limit emissions (Ref. 10).

In February 1997, Kleinfelder, Inc. prepared a Risk Evaluation Closure Activities report for the NDEQ, which stated that after the closure of the ASARCO plant, the site would be remediated, and subsequently the property would be developed as a park. The report evaluated the potential health effects during the operational period and the plant closure activities, demolition, select material cleanup, site regrading, construction of an engineered cap, provision for site utility corridors, stormwater controls, shoreline designs, institutional controls, and long term monitoring. This evaluation focused on human exposure to chemicals in soil at the ASARCO plant during remediation. According to previous evaluations, exposure to groundwater and ecological receptors in the Missouri River was not found (Ref. 11, pp. i, 1-1). The results of this evaluation indicated that risks could be effectively managed during and after redevelopment of the site as a park (Ref. 11, p. 6-2).

1.1.3.2 Previous Investigations at the OLS

In 1997, the Centers for Disease Control (CDC) issued a recommendation for local governments to analyze data pertinent to lead poisoning and to issue targeted screening guidelines that reflect the lead risk at the local level. In November 1998, the Douglas County Health Department (DCHD) published the results of an early childhood blood screening study that indicated that lead concentrations in the blood samples tested exceeded the national average. (Ref. 38). From July 1, 1997, to June 30, 1998, the DCHD Childhood Lead Poisoning Prevention Program screened 2,843 children for blood lead levels. The screening results indicated that 596 children had blood lead levels of 10 micrograms per deciliter (µg/dl) or higher (Ref. 12, p. 1).

In October 1998, the National Exposure Research Laboratory (NERL) issued an internal memorandum that served as documentation of initial contour plots of relative annual wet and dry deposition rates from the 180-foot black stack at the ASARCO facility. The contour plots are relative to historical deposition and indicate annual variability. EPA recommended that deposition rates from the 310-foot stack at ASARCO, which had been demolished, should also be evaluated (Ref. 13, p. 1).

On September 7, 1999, the Idaho National Environmental and Engineering Laboratory submitted a report titled *Dispersion Modeling of Atmospheric Deposition Patterns around the ASARCO Omaha Lead Refinery* to the EPA (Ref. 6). The air deposition modeling on the smokestack at the former ASARCO Refinery was performed in an attempt to focus soil testing to areas where contamination was likely to be greatest, but because important site-specific information such as stack exit velocity, exit temperature and particulate distribution was not available, the results of the modeling could not be used to predict lead concentrations in soil. However, the modeling did indicate that the highest concentrations of lead were likely to be found along the direction of prevailing winds. This information was used to select the direction of the sampling corridors (Ref. 6).

In January 2000, Jacobs Engineering prepared the Omaha Lead Site Investigation Background Summary Report on behalf of EPA (Ref. 14). Thirty background soil samples were collected approximately 8 miles north of the former ASARCO facility to determine the presence or absence of elevated concentrations of metals. The background samples were collected from a physical and environmental setting similar to the setting in the Omaha metropolitan area. The samples were tested using the upper tolerance limit (UTL) methodology, which is based on the EPA guidance for statistical analysis of background samples. The test results revealed that the average background lead concentration in the soil was 26 ppm (Ref. 14). These background samples were outside the affected areas of LBP and leaded fuel emissions, which can potentially be found in urban areas such as Omaha.

On August 2, 2000, ASARCO submitted a letter describing the findings of a report prepared by the EnviroGroup Limited. Intensive lead paint and soil testing was conducted at 1819 Wirt Street in Omaha, the location of a child care facility identified by EPA for emergency soil removal. The report concluded that chips of lead paint might be responsible for the elevated lead concentrations in soil beyond the drip line of this facility (Ref. 18, pp. 1, 2).

In December 2001, the U.S. Geological Survey (USGS) published a report titled *Toxicity and Bioavailability of Metals in the Missouri River Adjacent to a Metal Refinery*. The report was prepared for EPA by USGS to determine the concentration, bioavailability and toxicity of metals entering the Missouri River from the groundwater at the ASARCO facility. Surface water, sediment, and sediment pore water samples were collected from six different locations around the facility. A groundwater monitoring well at the facility was also sampled. The results indicated that the groundwater from the onsite monitoring well was highly toxic, but metals of toxicological concern were not highly elevated in sediments, sediment pore waters, or river waters. The dilution factor of the Missouri River is immense, and apparently sediment does not linger long at the site before passing on downstream. Water quality variables for the surface and sediment pore water were within acceptable limits for *Ceriodaphnia dubia* (macroinvertibrate) growth and reproduction (Ref. 19).

1.1.4 Removal Actions

On August 2, 1999, EPA executed an Action Memorandum describing the time-critical removal action initiated at child care facilities and residences at the OLS occupied by children with elevated blood level (EBL) concentrations of 15 µg/dl or higher and requested exemption from the 12-month and $2 million statutory limits (Ref. 7). This action memorandum was amended August 3, 2001 (Ref. 7). The removal action encompassed the eastern portions of Omaha, Nebraska and Council Bluffs, Iowa. Child care facilities and residences occupied by children with elevated blood lead (EBL) concentrations of 10 µg/dl or higher were included in the amended removal action if the soil on the property contained lead at concentrations equal to or greater than 400 mg/kg. The objective of the removal action was to eliminate or reduce ingestion exposure due to the presence of lead in soil (Ref. 7).

A second Action Memorandum was executed by EPA on August 22, 2002, describing a time-critical removal action to address highly contaminated residential properties with mid-yard lead concentrations greater than 2,500 ppm at the Omaha Lead Site. The removal action encompassed eastern Omaha, Nebraska, Council Bluffs and Carter Lake, Iowa. This action memorandum was amended in November 2003 to reduce the action level to 1,200 ppm (Ref. 7). Again the objective was to eliminate or reduce ingestion exposure due to the presence of lead in soil. On March 25, 2004, the EPA amended this action memorandum again to combine the two removal actions and allow them to be funded as a single response action (Ref. 7).

The EPA implemented one action memorandum to address childcare facilities and EBLs with soil lead concentrations greater than 400 mg/kg and residential properties with soil lead concentrations equal to or greater than 1,200 mg/kg. This action memorandum was amended on March 31, 2005 to incorporate elements of the interim remedy selected in the interim ROD, including lowering the action level to 800 ppm, providing for LBP stabilization and high efficiency interior dust cleaning.

As indicated previously, after issuance of the interim ROD in 2004, residential properties that were eligible for an interim response included:

- Any residential-type property where at least on non-foundation soil sample exceeded 800 parts per million (ppm) lead;
- Residences with any non-foundation sample exceeding 400 ppm lead where a child identified with an elevated blood lead level resides; and
- Child-care facilities and other high child-impact areas with any non-foundation sample exceeding 400 ppm lead.

1.1.5 Preliminary Assessment/Site Inspection

In August 2001, BVSPC submitted a Preliminary Assessment/Site Inspection (PA/SI) Report to EPA (Ref. 39), which included all data collected for EPA by Jacobs Engineering prior to July 2000 and data collected for EPA by BVSPC from July 2000 through April 2001. A preliminary Hazard Ranking System (HRS) score was also prepared to determine the need for future activities at the site. In addition to testing child care facilities and EBL properties, EPA tested other residential properties in an effort to identify the extent of lead contamination from the industrial emission sources in downtown Omaha. Sampling corridors were drawn leading from downtown Omaha in north, south, east and west directions. Approximately eight properties were tested every tenth of a mile within each of these corridors until lead concentrations were consistently found to be below 400 parts per million. EPA designed its testing protocol to identify geographic trends in soil lead contamination in the Omaha area. An average of 5 soil samples were collected from each property, four samples were collected within the property boundaries but away from the house foundation to minimize the influence of LBP on the soil lead concentration, and the fifth sample was collected within 3 feet of the house foundation. The sample within 3 feet of the house may reflect an additional effect deteriorating lead paint might have on the soil lead concentrations.

During the PA/SI for the OLS, subsurface soil samples were collected at approximately 550 properties where surface soil samples were collected at the same location. The subsurface soil samples were collected from the 0-8 inch, 8-16 inch, and 16-24 inch ranges. The number of samples in which lead was detected decreased at each downward depth interval. The average, maximum, and median lead concentrations also decreased as depth increased, indicating little to no migration downward from surface soils. The results of the subsurface sampling are presented in Table 5-1. The results indicate that, in general, if the surface soil lead concentrations are low there is no reason to believe that the concentrations would increase with depth. This is consistent with airborne deposition of lead contamination. These results lead EPA to discontinue depth sampling at the end of the SI.

The PA/SI report recommended further investigation of lead concentrations in surface soils at the Omaha Lead Site. However, EPA decided that further investigation of subsurface soil was not warranted based on the results of depth samples.

Also as part of the PA/SI, laboratory analysis was performed on 10 percent of the soil samples to determine the presence of other toxic metals in addition to lead (approximately 1,125 samples). Additional soil volume was collected from each sample. After preparation of the portion of the sample for XRF analysis, the extra volume was sent to the PDP Laboratories for analysis. The results of this analysis show that eight other metals (besides lead) were identified as chemicals of potential concern, including aluminum, antimony, arsenic, barium, cadmium, iron, manganese and thallium.

1.1.6 ATSDR Health Consultations

The US Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry (ATSDR) conducted 4 health consultations for the Omaha Lead Site. The first consultation conducted in March 2000 discussed the overall risks involved with the Omaha Lead Site. This consultation concluded that remediation of soils would most likely result in reduced blood lead levels in the exposed population, and that blood lead levels should continue to be monitored for children in areas where soil concentrations are found to exceed the established cleanup level.

The second consultation was prepared by the ATSDR in June 2004 and focused upon the proposed soil remediation plan which would involve soil excavation in the contaminated areas. This report concluded that the proposed excavation plan would be protective of public health. An educational program was also recommended which would provide information to residents on the methods to deal with the installation of new gardens and lawns.

The third consultation was prepared in May 2005. For this consultation, the ATSDR reviewed the data from 2 databases on child blood lead levels from the DCHD and 2 databases from provided by EPA containing the results from lead sampling of residential properties. ATSDR concluded that the main sources for the lead in children are soils contaminated with lead emitted from the operation of the ASARCO refinery and lead-based paint. ATSDR recommended that EPA continue to investigate and remove soil contaminated with lead from properties, particularly homes with children 6 years of age and under, homes with children with EBLs, schools, and daycare facilities.

The fourth consultation was prepared in March 2007. The consultation addressed arsenic levels in soil in east Omaha. ATSDR reviewed arsenic concentrations in the soil samples from residential yards and concluded that the properties with elevated arsenic levels in soils are randomly distributed throughout east Omaha neighborhoods. The source of arsenic was thought to have resulted from the application of an arsenic-containing weed killer. The report indicated that children who ingested 5,000 mg of soil at a frequency of 3 days per week would exceed ATSDR's health guideline for short term exposure to arsenic. However, children with average soil intake (30 mg/day) are not at risk of harmful effects from exposure to arsenic in soil, even at the most contaminated properties.

All of these ATSDR health consultations are presented in Appendix E of this report.

1.1.7 Douglas County Health Department

The DCHD's Childhood Lead Poisoning Prevention Program evaluated the impacts to children exposed to lead contamination by collecting blood lead data in 11 DCHD target zip code areas (which include the Omaha Lead Superfund Site) in the eastern part of Omaha. From 1992-1998 the percentage of children with elevated blood lead levels, blood lead levels greater than or equal to 10 µg/dL (EBLs), ranged from 29% - 42% in this part of the city. Year 2000 statistics for Douglas County (in general) indicate that 1 in 18 children tested had EBLs compared to the rest of the State where the rate is 1 in 38 children tested. Year 2002 blood lead screening results for Douglas County indicate that 437 children of 9,521 tested had EBLs, and 410 of these 437 EBL children resided on the site. Overall, the percentage of children with EBLs ranged from 5.6% to 11.8% in the DCHD target areas. In 2003, of 9,598 children that were tested in the county, 339 had blood lead levels at 10 µg/dL or greater and 303 of these 339 EBL children resided on the site. The percent EBLs in 2003 ranged from 0.6% to 8.7% in the DCHD target zip code areas. In 2004, 293 of 10,171 children test had blood lead levels of 10 μg/dL or greater. In 2005, 280 of 10,663 (2.6 percent) children tested had blood lead levels of 10 μg/dL or greater. In 2006, 238 of 10,753 (2.2 percent) children tested had blood lead levels of 10 μg/dL or greater.

1.1.8 Apportionment Study

On April 5, 2000, the EPA initiated an apportionment investigation in an effort to determine the sources of lead contamination found in the soil of residential properties at the site (Ref. 15). The EPA collected soil samples from the former ASARCO refinery property and the former Gould property and compared the lead in these samples to that found in the soils of residential properties. A report of this activity was finalized in September 2002 (Ref. 46).

On April 19-20, 2000, Jacobs Engineering, on behalf of EPA, collected twenty soil samples from borings and trenches at the former ASARCO facility. In addition 21 soil samples were collected from an ASARCO warehouse where they had archived soil samples from their former facility. The twenty samples collected from the facility were collected using a stainless steel auger and consisted of approximately 100 grams of soil. The samples were dried, if necessary, and sieved through a 10 mesh screen. The sieved soil was homogenized and analyzed by XRF. In November 2001, boring samples were collected from the location of the former Gould facility, which is now part of Heartland of America Park. Soil samples were also collected from residential properties in the surrounding communities.

The apportionment study was conducted by personnel from the Laboratory for Environmental and Geological Studies (LEGS), University of Colorado, in Boulder, Colorado for EPA and finalized on September 22, 2002 (Ref. 46). The objective of the lead apportionment study was to compare the sample results from the ASARCO facility and the Gould facility with the results of the residential soil samples, in an effort to identify the sources of elevated lead concentrations above background levels in residential soils (Ref. 16, pp. 2-5).

Twenty four samples from the ASARCO facility and 8 samples from the Gould facility were speciated for lead using electron microprobe (EMPA) techniques. In addition, 28 soil samples from the community were also speciated for lead using EMPA techniques.

The community soil samples included soils with varied lead concentrations (60-2,400 mg/kg). These samples contained lead masses almost exclusively (74 percent of the relative lead mass) dominated by phosphates, cerussite ($PbCO_3$), manganite (MnOOH), and a mixed lead, with minor contributions from other forms of lead. The particle size distribution for all lead species was near log normal. The phosphate and $PbCO_3$, particles were smaller, and generally cemented, with a median size of 2 microns, while the mixed lead (a combination of $PbCO_3$, lead sulfate ($PbSO_4$), and lead monoxide (PbO)), and the MnOOH were generally much coarser at 95 microns.

The community soils were found to contain lead in the form of slag, lead chloride, lead arsenate, PbMnO, lead antimony oxide (PbSbO), and lead metasilicate ($PbSiO_4$). The Final Study provides the results of the lead speciation study and evidence that smelting activity contributed to the elevated lead concentrations.

The 2002 apportionment calculation, based only on speciation results, indicated that on average a minimum of 38 percent of the bulk lead concentration in community yards would have a pyrometallurgical source, such as those activities that were performed at the ASARCO plant. This proportion could exceed 60 percent on average if only half of the non-source specific lead is attributed to pyrometallurgical activity. More than 80 percent of the community soils studied contained pyrometallurgical lead in the 2002 study.

EPA performed an additional study in 2007 that expanded the areal distribution of lead speciation characteristics for community soils (Ref. 51). An additional 49 samples were collected from the OLS, primarily from the northern and southern portion of the Focus Area. The samples were collected from residential properties, parks, and vacant lots.

Samples from the 2007 study had lead masses almost exclusively (78 percent of the relative lead mass) dominated by phosphates, $PbCO_3$, MnOOH, and $PbSO_4$, with minor contributions from other lead forms including many of the source-traceable forms found in the 2002 study. The particle size distribution for all lead species was nearly log normal.

The 2002 and 2007 data were combined and provided soils with bulk lead concentrations (66 to 5,788 mg/kg) averaging approximately 800 mg/kg lead. These combined samples had lead masses almost exclusively (83 percent of the relative lead mass) dominated by phosphates, $PbCO_3$, MnOOH, and $PbSO_4$, and a mixed lead, with minor contributions from other lead forms. The particle size distribution for all lead species was again nearly log normal. The community soils contained source-traceable lead forms (slag, $PbCl_2$, PbAsO, PbMO, PbSbO, and $PBSiO_4$), providing good evidence that pyrometallurgical activity contributed to the elevated lead concentrations (Ref. 51).

The 2007 report (Ref. 51) contained the following conclusions.

- Pyrometallurgical forms of lead were the largest identifiable lead source in residential yards;
- More than 90 percent of the yard samples speciated had pyrometallurgically apportioned lead;

- At least 32 percent of the bulk lead found in community soils is from a pyrometallurgical source;
- There is a strong lead isotopic correlation between community soils and the ASARCO plant with apparent limited input from the Gould facility or leaded gasoline;
- Lead paint can not be isotopically ruled out as a source of lead, but isotopes suggest its significance is also limited (Ref. 51).

1.1.9 Bio-Availability Study

EPA measured the bioavailability of lead in two soil samples collected from the Omaha Lead Site. One of the soil samples was composed of soil collected from two different residential properties located within the site. The same amount of soil was collected from each property and homogenized. This soil sample was sent to the University of Missouri for bioavailability analysis. The second soil sample was collected from two other properties within the site. This sample was also homogenized and sent to the University of Missouri for bioavailability analysis. The bioavailability study was performed in accordance with the *Project Manual for Systemic Availability of Lead to Young Swine From Subchronic Administration of Lead-Contaminated Soil* prepared by Stan W. Casteel, DVM, PhD, Veterinary Medical Diagnostic Laboratory, University of Missouri-Columbia, Columbia, Missouri for Submission to the USEPA Region VIII, Denver, Colorado.

The investigation used juvenile swine as test animals and was performed to measure the gastrointestinal absorption of lead from the two test materials (Test Material 1 and Test Material 2). The relative bioavailability (RBA) of lead was assessed by comparing the absorption of lead from the test materials to that of a reference material (lead acetate). The measured lead concentrations of Test Material 1 and Test Material 2 were 1,650 µg/g and 1,630 µg/g, respectively. Groups of five swine were given oral doses of lead acetate or a test material twice a day for 15 days. The amount of lead absorbed by each animal was evaluated by measuring the amount of lead in the blood (measured on days 0, 1, 2, 3, 5, 7, 9, 12, and 15) and the amount of lead in liver kidney and bone measured on day 15 at the termination of the study. The total amount of lead absorbed was measured by calculating the area under the curve (AUC) for blood lead vs. time. The amount of lead present in blood or tissues of animals exposed to test materials was compared to that for animals exposed to lead acetate, and the results were expressed as RBA.

An initial report titled *"Relative Bioavailability of Lead in Test Materials from a Superfund Site in Omaha, Nebraska"*, was prepared by personnel from the University of Missouri, Columbia and the Syracuse Research Corporation, Denver, Colorado (Ref 66). This report was submitted to EPA in January 2004.The RBA results for the two samples in this study are summarized below:

Measurement Endpoint	Estimated Soil RBA	
	Test Material 1	Test Material 2
Blood Lead AUC	1.01	0.76
Liver Lead	1.07	0.74
Kidney Lead	1.04	0.66
Bone Lead	0.98	0.64

Because the estimates of RBA based on blood, liver, kidney, and bone do not agree in all cases, judgment was used to interpret the data and establish a point estimate of the RBA as presented below:

Uncertainty Range	Estimated Soil RBA	
	Test Material 1	Test Material 2
Plausible Range	1.01 - 1.03	0.68 - 0.76
Preferred Range	1.01 - 1.02	0.72 - 0.76
Suggested Point Estimate	1.01	0.74

Absolute bioavailability (ABA) is the amount of substance entering the blood via a particular biological pathway relative to the absolute amount that has been ingested. The RBA estimates shown above may be used to assess lead risk at the OLS site by refining the estimate of ABA of lead in soil as follows:

$$ABA_{soil} = ABA_{soluble} \times RBA_{soil}$$

Available data indicate that fully soluble forms of lead are about 50 percent absorbed by a child. Thus, the estimated ABA of lead in the site sample is as follows:

Absolute Bioavailability of Lead	Test Material	
Lead	Test Material 1	Test Material 2
Plausible Range	0.50 - 0.52	0.34 - 0.38
Preferred Range	0.50 - 0.51	0.36 - 0.38
Suggested Point Estimate	0.51	0.37

More recently, EPA (Ref. 65) described a new statistical approach for estimating the RBA of lead in soil from *in vivo* studies. In accordance with this guidance, the RBA data from the OLS were reanalyzed using EPA's new recommended statistical method. In addition, the concentrations of lead in the two test soils were revised based on quintuplicate measurements of each soil and were found to be 2,003 µg/g for Test Material 1 and 1,613 µg/g for Test Material 2. The revised RBA results are presented below.

Measurement Endpoint	Estimated Soil RBA (90% Confidence Interval)	
	Test Material 1	Test Material 2
Blood Lead AUC	1.04 (0.58 – 1.43)	0.87 (0.57 – 1.24)
Liver Lead (a)	0.91 (0.62 – 1.36)	0.82 (0.55 – 1.22)
Kidney Lead	0.83 (0.62 – 1.10)	0.75 (0.56 – 1.00)
Bone Lead	1.07 (0.85 – 1.37)	0.89 (0.70 – 1.15)
Combined	0.96 (0.64 – 1.29)	0.83 (0.58 – 1.10)

As seen from the data, the new statistical method yields point estimates and 90 percent confidence intervals for RBA of 0.96 (0.64 – 1.29) and 0.83 (0.58 – 1.10) for Test Materials 1 and 2, respectively.

These ABA estimates are appropriate for site specific use in EPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK), although it is clear that there is both natural variability and uncertainty associated with physiological differences in individual animals and the extrapolation between swine and humans.

1.1.10 In-Vitro Bioavailability Sample Analysis

The University of Colorado Laboratory for Environmental and Geological Studies conducted an in vitro test on community soils using the Relative Bioavailability and Leaching Procedure (RBALP). The RBALP has been calibrated to the EPA Region VIII swine model discussed previously in section 1.1.9 of this report, and has been independently validated. The in vitro test involves the introduction of a contaminant into an aqueous solution to simulate natural gastrointestinal conditions. The fraction of contamination liberated into the aqueous phase is defined as the bioavailable fraction in the test media.

In vitro bioaccessability (IVBA) testing was conducted during the 2002 Apportionment Study discussed previously in section 1.1.8 of this report. No additional in vitro tests were performed during the 2007 Apportionment Study. IVBA was determined for 25 samples from the potential source areas and 28 samples for the community soils. The average RBA estimated from the IVBA results (in accordance with EPA protocols, Ref. 65), for the 28 community soils was determined to be 68 percent (Ref. 46). Available data indicate that fully soluble forms of lead are about 50 percent absorbed by a child. Thus, the estimated ABA of lead in the site sample is 50 percent of the RBA values, or 34 percent. The RBA and ABA values from the in vitro testing for the community soils are summarized and appear in the Baseline Human Health Risk Assessment (BHHRA) (Ref. 62) prepared by the Syracuse Research Corporation.

Additional IVBA testing was performed on 19 community soil samples collected by BVSPC in February 2004. These samples were splits of mid-yard samples collected for lead soil analysis. The average RBA, estimated from IVBA (in accordance with Ref. 65), for the analysis on this set of samples was found to be 69 percent. Again, the ABA value would be 50 percent of the RBA value, or 34.5 percent. These values are also summarized in the BHHRA (Ref. 62). The 2004 in vitro report on community soils is presented in Appendix F of this report.

1.1.11 Treatability Study

A bench scale treatability study was performed in 2007 to provide data to support a decision regarding the use of phosphate-based soil amendments at the OLS (Ref. 53). The treatability study evaluated the effectiveness of various phosphate amendments on the bioaccessability of lead contaminated soils from the OLS. Studies conducted at other Superfund sites contaminated with similar forms of lead have concluded that the application of certain phosphate-based compounds may result in the conversion of lead in surface soils to relatively insoluble minerals with reduced bioavailability.

The following three types of soil from the OLS site were used in the bench scale treatability study: soil from mid yards (away from the drip zone) with lead concentrations between 400 and 800 ppm; soil from mid yards with lead concentrations greater than 1,000 ppm; and soils from drip zones with lead concentrations greater than 1,000 ppm. Soil used for the bench scale treatability study was collected from residential properties in the OLS Focus Area and prepared in accordance with the Treatability Study Work Plan (Ref. 52).

Soil was excavated from six of the candidate properties and transported to the OLS staging area and separated into three piles according to the lead concentration in the soil. The soil piles were thoroughly mixed and grab samples were collected from different locations in the piles of soil to confirm average lead levels in the soil. Soil from these piles was sent to the Laboratory for Environmental and Geological Studies at the University of Colorado for testing in the bench scale treatability study. Average lead concentrations in the three soil piles, measured from grab samples taken directly from the piles, were 568 ppm, 1,247 ppm, and 1,418 ppm.

Soil characterization testing and analyses of the soils included the following parameters: metals, soil pH, acidity, particle size distribution, soil classification, phosphorous, nitrogen, total organic carbon, cation exchange capacity, and lead mineral speciation using an electron microprobe. Soils from each of the different types of soil were amended with different concentrations of phosphate rock, triple super phosphate, and phosphoric acid. All amended soils had lime added to adjust the pH back to a near normal value. The amended soil was sampled after 2, 7, and 14 days intervals. The treated soils were analyzed using the RBALP developed by the University of Colorado. The treated soils were also analyzed for total, extractable, and leachable phosphorous.

The results of the bench scale treatability indicated the soils treated with 1.5 percent phosphoric acid plus hydrous ferric oxide provided the largest reduction in bioaccessability. The soils tested at pH of 1.5, which is the pH at which the RBALP test was validated, did not show a significant reduction in bioaccessability. In general, a 20 percent reduction in bioaccessability was the highest reduction achieved when the test was performed at pH 1.5.

1.2 Report Organization

The remainder of this RI Report is organized as shown below.

- Section 2.0 - Remedial Investigation Activities
- Section 3.0 - Physical Characteristics of the Site
- Section 4.0 - Nature and Extent of Contamination
- Section 5.0 - Contaminant Fate and Transport
- Section 6.0 - Baseline Human Health Risk Assessment
- Section 7.0 - Summary and Conclusions

2.0 Remedial Investigation Activities

Field investigation studies have been performed at the OLS site since 1999. The RI commenced in 2001, following completion of the PA/SI. This section of the RI Report discusses the field investigation activities that were performed prior the beginning of the formal RI as well as the activities that were performed following commencement of the RI. Field activities performed at the site since 1999 include sampling soil at residential properties, sampling indoor dust and potable water at residential homes, conducting a drip zone width study to evaluate the influence of LBP and other factors affecting lead concentrations in soil near structures, conducting a LBP recontamination study to evaluate the potential for lead based paint to recontaminate residential properties where clean up of the soils had occurred, and conducting soil sampling at public parks within the site boundaries. This section of the RI Report also discusses the sampling procedures, the sample numbering system, and documentation of all of the field activities.

2.1 Residential Property Soil Sampling

As previously discussed in Section 1.1.5, EPA issued a PA/SI in 2001 to further define the nature and extent of contamination at the OLS. On the sampling results, the PA/SI report recommended further investigation at the OLS site. Prior to beginning its soil sampling activities at residential properties, BVSPC obtained a database from the Office of the Douglas County Assessor that included all properties in the 13 zip code areas that cover east Omaha (68102, 68104, 68105, 68106, 68107, 68108, 68110, 68111, 68112, 68117, 68131, 68132, and 68147). Non-residential properties were filtered out of the list of properties to be sampled. The residential properties were then checked against the database of properties that had already had surface soil samples collected in a previous investigation. Owners of residential properties that had not already been sampled were sent a letter requesting permission to sample the property.

After obtaining access to sample, surface soil samples were collected at each residence. Soil samples were collected in accordance with the Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPP) prepared by Sverdrup Environmental (Refs. 37 and 63), as amended by BVSPC (Refs. 47, 55 and 56). Each property was divided into four quadrants of roughly equal surface area. First, the property was divided into front and back yard halves. Then the front and back yard halves were each divided into two equal quadrants. At the discretion of the field team, smaller yards were divided into fewer sampling areas.

One composite sample composed of five aliquots of equal mass was collected from each quadrant. Each aliquot was collected from a randomly selected location in the quadrant and from the top 1 inch of soil away from influences of the drip zone. The drip zone included the area within 6 inches to 30 inches of the foundation of all buildings on the property. A drip zone sample was also collected. In addition, one sample was collected from the discrete play area and one sample from the garden area if they existed. If there was more than one play area or garden, at least one aliquot was collected from each play or garden area. These aliquots were composited to form one garden sample and one play area sample for each property.

Prior to sampling, an aerial view scaled sketch was made of each sampled property on the field sampling forms. An example of a field sampling sheet is included in Appendix B.1. The sketch showed the locations of all structures and major features, including child play areas and gardens. Digital photographs of the front yard and back yard of each sampled property were originally taken. A computer disk containing the photographs for each property was filed with the access sheet for that property. Photographs of the sampled properties were discontinued in 2004. Pertinent information regarding the sampling of the property was recorded on the field sheet and in the field logbook.

A composite drip zone sample was collected from each residence. The sample consisted of a minimum of four aliquots collected between 6 inches to 30 inches from the exterior wall of each house. Each aliquot was collected from the midpoint of each side of the home. One of the four aliquots was collected from a bare spot instead of from the midpoint in the event there were bare, non-vegetated areas within the drip zone sampling area.

All soil samples were completely homogenized to ensure that samples were representative of the entire quadrant or drip zone. Grass and rocks were removed from the sample. Prior to analysis, soil was sieved through a No. 10 (2 mm) mesh screen.

Prior to the 2005 sampling season, the soil samples were placed in an XRF specimen cup and covered with Mylar film. Niton XRF spectrometers (an instrument used to resolve radiation into spectra to determine metal concentration measurements) were used to analyze soils for lead contamination. The Niton was internally calibrated before each day of field activities and whenever the operator determined there was a need to recalibrate. In addition, during bulk soil sampling (a mode in the Niton notifying the machine that the sample has depth), a set of three soil standards from the National Institute of Standards and Testing (i.e., low, medium, and high concentrations) was used to check the calibration of the Niton. At a minimum, the standards were analyzed after the initial calibration test and at the end of the day's field activities. The results were recorded in the field logbook assigned to that unit and on the standards check record sheet. The Niton XRF spectrometer has the ability to generate soil concentration data for other metals. However, the Niton was calibrated using a lead standard and therefore, laboratory data may be more reliable for concentrations of metals other than lead.

During the 2005 sampling season, BVSPC began using an XRF manufactured by Innov-X Systems (Innovex XRF). The Innovex XRF units were calibrated in accordance with the manufacturer's recommendations using standards for lead, cadmium, and zinc. At the time the Niton XRF units were discontinued, BVSPC also discontinued using the specimen cup for the XRF reading. Instead, BVSPC placed the homogenized soil sample in a 2 ounce Whirl-Pak® and analyzed the soil in the Whirl-Pak®.

When the Niton XRF unit was used, additional volume was collected for 5 percent of samples. After preparation of the portion of the sample for XRF analysis, the extra volume was sent to the EPA Region 7 Laboratory in Kansas City, Kansas, for analysis. When the Innovex XRF unit was used, the Whirl-Pak® bag that was analyzed by the XRF was sent to the EPA Region 7 laboratory in Kansas City, Kansas, for analysis. These results were then compared to the field XRF results for the sample to confirm the accuracy of field equipment.

One soil sample per day was also sieved through a No. 60 sieve (0.25 mm) and analyzed with the XRF unit. This testing provided a correlation between the soil samples that were routinely analyzed (No. 10 mesh sieve) and the fine fraction of the soil obtained using a No. 60 mesh sieve. The fine fraction of soil was analyzed because it represents the soil fraction that is more likely ingested by children.

For a number of samples, additional volume was collected to perform in vitro tests using the RBALP as previously described in Section 1.1.10. After preparation of the portion of the sample for XRF analysis, the extra volume was sent to University of Colorado Laboratory for Environmental and Geological Studies for analysis.

2.2 Home Interior Investigations

The Syracuse Research Corporation prepared a BHHRA for this final RI. The BHHRA is summarized in Section 6.0 of this RI Report. To support the BHHRA, BVSPC collected indoor dust samples using a floor vacuum and wipe samples from 98 residences during November and December of 2007. BVSPC also collected indoor dust samples and wipe samples from 159 homes in October and November of 2003 to support a risk assessment conducted by the Nebraska Health and Human Services System (NHHS) and EPA. In addition BVSPC collected demographic information about the residents during the 2003 sampling event.

The results of the 2003 investigation were presented in the 2004 RI Report and are summarized in this final RI Report. The results from the 2007 dust sampling activities are also presented in this RI Report. Each of the two investigations is discussed separately in this RI Report because the field activities varied slightly during the investigations.

2.2.1 2003 Home Interior Sampling Investigation and Demographic Survey

As requested by NHHS, 159 homes were sampled for interior dust, the University of Nebraska, Omaha (UNO) administered a demographic survey, and DCHD offered free blood lead screening for child residents 0-6 years of age in these homes.

The amount of lead in settled dust samples may be expressed as a lead loading or as a lead concentration. Lead loading is the weight of lead per area sampled and the typical units are µg/ft^2 (Ref. 45). Lead concentration is the weight of lead per weight of sample and is typically reported as µg/g (Ref. 45). When collecting a wipe dust sample, the results are reported in lead loading terms. Vacuum dust collection is able to generate both lead loading and lead concentration results. Only the lead concentration data is used in the risk assessment calculations in the IEUBK lead risk model.

At each residence where a dust sample was collected, a demographic survey was also taken. The survey was general and included such questions as the number of residents in the home, the age and sex of the residents, and the length of time the occupants have lived at the residence. This survey was completed before dust sample collection at each residence. A copy of the survey is provided in Appendix C.

At each residence parents had the option of having the DCHD collect blood samples for blood lead measurement from children under six who lived at the residence. Although many parents expressed interest in having their children's blood lead concentrations measured, none were interested in having the test conducted as part of this investigation.

2.2.1.1 Wipe Sampling Procedures

One wipe sample was collected from the interior window sill of each residence in accordance with the Field Sampling Plan Addendum prepared by BVSPC (Ref. 47). The wipe sampling method provided for the collection of settled dust samples from hard, relatively smooth, nonporous surfaces. This sampling method produced lead results that were expressed in loading terms (µg/ft^2).

The confined area sampling procedure (Ref. 44) was used to collect the wipe samples from the window sills during the 2003 investigation. The confined area sampling procedure assumes the operator can be orientated to a collection position where the sampling location's width is greater than its depth. It also assumes that the depth is no longer than the dimensions of the wipe.

2.2.1.2 Vacuum Dust Sampling procedures

The vacuum method of dust sampling was used to collect dust samples from the floor surfaces during the 2003 investigation. Separate vacuum samples were collected from the floors of the entry way, living area and one bedroom of the home. This sampling method produced lead results expressed in concentration (µg/g).

The vacuum sampling procedures were based on the 2002 American Society for Testing and Materials (ASTM) Standard Practice for Collection of Floor Dust for Chemical Analysis (Ref 43). A field sheet was completed (Appendix B.2) containing the information obtained at each home.

2.2.2 2007 Home Interior Investigation

During November and December of 2007, BVSPC collected vacuum samples, wipe samples and potable water samples from 98 residential properties. The samples were collected in accordance with the Remedial Investigation Field Sampling Plan and QAPP prepared by BVSPC (Refs 48 and 67). The purpose of the sampling effort was to collect additional pairs of yard soil and indoor dust samples, and tap water from residences at the Omaha Lead Site to support preparation of the final BHHRA at the site.

To predict indoor dust concentrations at a property from measurements of lead in outdoor soil, paired soil-dust measurements were collected from properties that had a wide range of soil concentrations. Sampling locations were selected using a stratified random approach. That is, properties were grouped into a series of "bins" depending on the average concentration of lead in outdoor soil, and 20 properties from each bin were selected at random for sampling. The bins are summarized below.

Bin Number	Lead Concentration in Soil (mg/kg)
1	< 250
2	>250 - 500
3	>500 - 750
4	>750 – 1,000
5	>1,000 – 1,250
6	>1,250

Only properties that had not had soil remediated were eligible for sampling. A list of potential properties was developed and the owners of the properties were contacted in person or via telephone to request permission to collect the samples. Consent to perform the sampling was obtained from 98 property owners. The goal of sampling 120 homes was not reached because (1) there were a limited number of homes in the higher lead concentration ranges that had not been remediated, (2) some property owners would not consent to sampling, and (3) some property owners cancelled the scheduled sampling without sufficient notice to find a substitute property. The following sampling activities were conducted at each property.

- Surface soil sampling [0-1 inches below ground surface (bgs)].
- Sampling of indoor dust using vacuum and wipe sampling techniques at each of the residences.
- Sampling of indoor tap water from each residence where dust samples were collected.

2.2.2.1 Soil Sampling Protocols

Soil samples were collected from each property where dust sampling was performed. Surface soil samples were collected at each residence in accordance with the FSP. One composite surface soil sample was collected at each property. Five soil aliquots were collected from four different quadrants (defined below) in the yard and the 20 aliquots were composited into a single sample. Pertinent information regarding the sampling of the property was recorded on the field sheet and in the field logbook.

Each property was divided into the same four quadrants that were previously sampled by either BVSPC or Sverdrup. First, the property was divided into front and back yard halves. Then the front and back yard halves were divided into two approximately equal quadrants. Each sampling team was provided with the previously completed field sheet for the residence. One composite sample composed of five aliquots of equal mass was collected from each quadrant. Each aliquot was collected from a randomly selected location in the quadrant and from the top 1 inch of soil away from influences of the drip zone (area within 3 feet of the foundation of all buildings). A drip zone sample was not collected. The soil aliquots were thoroughly mixed into one composite soil sample. The soil samples were sieved through a No. 60 mesh sieve and were submitted to the EPA Region 7 laboratory for analysis of target analyte list (TAL) metals along with silicon, titanium, and zirconium. The samples were analyzed by Method SW-846-6010 and 7471 (mercury) using inductively coupled plasma-atomic emission spectrometry (ICP-AES).

2.2.2.2 *Vacuum Dust Sampling Protocols*

One composite vacuum dust sample was collected from each residence. The dust sample consisted of dust collected from the floor at three locations in the home. The following is a list of the three general sample areas with a description of sample location criteria based on each residence's characteristics:

1) Entry Way: A portion of the composite vacuum sample was collected from the most frequently used entry way to the residence at least 1 meter (3 feet) from the door. If there was an option between a hard floor surface and a carpeted floor surface, the hard floor surface area was chosen over the carpeted surface due to the potential for better sample collection on a hard floor surface. The sample was collected using the appropriate vacuum method for a carpeted or bare floor. Dust samples from carpeted floors were collected in accordance with Paragraph 11.1 of ASTM D5438-05. Dust samples from hard surface floors were collected in accordance with Paragraph 11.2 of ASTM D5438-05. The sampling methods are similar except for the air flow rate and the pressure drop at the nozzle of the vacuum.
2) Floor: A portion of the composite sample was collected from the most commonly used room in the residence other than a bedroom. The selection of the sample location was based on whether or not a child or children lived at the residence. If children lived at the residence, the room, other than the bedroom, where the children spent the most

time on the floor in was chosen. If no children lived at the residence, the room, other than the bedroom, where residents spent the most time was chosen. Sample locations were based on the floor type(s) in the room. If there was a hard floor surface and a carpeted floor surface in the room, the hard floor surface was sampled. If possible, a sample location that was not in the main walking pathway of the room and was also large enough to accommodate the sampling requirements was chosen as the sample location. The sample was collected using the appropriate vacuum method for the floor type.

3) Bedroom: A portion of the composite vacuum sample was collected from one bedroom in the residence. The selection of the sample location was based on whether or not a child or children live at the residence. If there was one child living at the residence, their bedroom was selected. If there was more than one child living at the residence, the youngest child's bedroom was selected. If there were no children living at the residence, the bedroom where the most time was spent was selected. If a child's room was selected, regardless of floor type, the sample location was chosen based on where the child's play area was in the room or where they spent the most time on the floor in the room. If an adult bedroom was selected, the sample was collected based on floor type. In that bedroom, if there was a hard floor surface and a carpeted floor surface in the room, the hard floor surface was sampled. Once the sample location was determined, the sample was then collected using the appropriate vacuum method for the floor type.
4) The size of the area sampled in each room was approximately 9 square feet.

The following is a list of sampling equipment used to collect vacuum samples:

1) High Volume Small Surface Sampler (HVS3) as described in the 2005 ASTM Standard D5438-05 (Ref 49) and the BVSPC FSP (Ref 48).
2) Measuring tape used for defining the location of the area to be sampled.
3) Sample collection container for storing the sample until the laboratory is able to run the necessary analyses.
4) Thermometer for determining the temperature in the area sampled.
5) Relative Humidity Meter to determine the relative humidity in the area sampled.
6) Shaker Sieve that was used to sieve the dust samples; a 60-mesh screen is placed above the pan that is used to collect the sieved dust. The dust that collects in the pan is used to determine the weight of fine dust below 250 µm mean diameter (the

diameter of the particles that pass through a 60-mesh sieve).

7) Analytical Balance used to weigh the sieved dust sample; a balance that is accurate to 0.1 mg was needed.

The dust vacuum sampling method produced lead results in both loading (µg/ft^2) and concentration (µg/g). A field sheet, shown in Appendix B.3 was completed during sampling. The dust sample was collected in a clean, polyethylene sample bottle attached to the vacuum and taken to the BVSPC field office where it was sieved with a 60-mesh sieve and weighted. The sieved portion of the sample was transferred to a clean 8-oz. wide mouth jar and shipped to the EPA Region 7 laboratory for analysis of TAL metals, silicon, titanium, and zirconium using ICP-AES.

2.2.2.3 Wipe Sampling Protocols

Three composite wipe samples were collected from each residence in this sampling effort. The wipe samples consisted of one composite window sill wipe sample, one composite window trough wipe sample, and one composite floor wipe sample. Each composite sample consisted of individual wipes collected from the living area and two bedrooms in the home. All three wipes representing similar surfaces, such as window sills, etc., were placed in the same sample container.

Window Sill: A composite wipe sample was collected from three window sills in the residence. If there were children living at the residence, the window sills that were most frequently contacted by the children were sampled. If there were no children living at the residence, window sills that were most frequently operated/contacted were sampled. The sample was collected using the confined area sampling procedure described in the FSP (Ref 48).

Window Trough: A composite wipe sample was collected from three window troughs in the residence. If there were children living at the residence, the windows that were most frequently contacted by the children were sampled. If there were no children living at the residence, windows that were most frequently operated/contacted were sampled. The sample was collected using the confined area sampling procedure described in the FSP (Ref 48).

Floor: A composite wipe sample was collected from three floors in the residence, if possible. If possible, the floor wipe sample was collected from the same rooms where the wipe samples were collected from the windows. If there were children living at the residence, the floors that were most frequently contacted by the children were sampled. If there were no children living at the residence, floors that were most frequently contacted were sampled. The sample was collected using the template assisted sampling procedure described in the FSP (Ref. 48). Whenever possible, dust samples from floors were collected from hard surfaces.

All three wipes representing each type of surface, such as window sill, etc., were placed in the same 8 ounce glass jar and submitted to the EPA Region 7 laboratory for analysis of lead using ICP-AES.

2.2.2.4 Potable Water Sampling Protocols

Two potable water samples were collected at each home where dust/soil sampling was performed. These two samples are referred to as "First-Flush" and "Post-Flush" and are defined below.

First-Flush Sample. The first flush water sample was collected in the morning, prior to using any water sources in the home (i.e., before flushing the toilet or running the sink).

Post-Flush Sample. The post-flush sample was collected after allowing the water to run. Samples were collected after the kitchen sink had been allowed to flush for 5 minutes.

Both samples were collected from the main kitchen sink. Samples were collected by the residents in accordance with the procedures described below. Sampling containers were left with the residents when the dust sampling was completed and the sampling procedures were discussed with the residents. A copy of the directions for collecting the sample was given to the residents along with two 1-liter, high density polyethylene, pre-marked sample bottles. No preservative was placed in the sample containers given to the residents.

The samples were picked up from the residents the next day after the samples were collected. One milliliter of nitric acid was added to preserve the water samples after collecting the containers from the residents and the samples were submitted to the EPA Region 7 laboratory for analysis of lead using EPA Method 200.8.

2.3 Lead Based Paint Assessments

In order to prevent the recontamination of the clean soil placed in yards after excavation, the Interim ROD included stabilization of loose and flaking exterior LBP that threatens the continued protectiveness of the remedy. The Interim ROD indicated only those homes and other structures where LBP is visibly flaking and deteriorating will be addressed. The Interim ROD did not specify the criteria that would be used to determine if a structure would be eligible for paint stabilization.

BVSPC prepared a work plan in 2006 that developed interim protocols that could be used to assess the eligibility for LBP stabilization at residential properties that are eligible for soil remediation (Ref. 56). The work plan is presented in Appendix H of this RI Report. The work plan developed both quantitative and qualitative criteria for determining the eligibility of structures for paint stabilization. The quantitative approach for assessing eligibility for paint stabilization involved measuring the amount of deteriorated LBP on a structure, and calculating the concentration of lead in surrounding soils that would result if all of the identified deteriorated paint were to fall to the ground and be uniformly mixed with soil under certain assumptions.

The quantitative approach for determining eligibility for paint stabilization involved a two-step process. Initially, a LBP assessment was performed at properties that were eligible for soil remediation under the interim remedy. This LBP assessment measured the lead content and estimated the areal extent of the deteriorated paint observed on structure surfaces. All similarly painted surfaces were assessed together, i.e., all siding, all trim, etc., if they were painted alike. Lead measurements on the structure were taken using a hand-held XRF instrument. The lead loading of each similarly-painted surface was recorded on the LBP assessment form, and the area of deteriorated paint for each type of similarly-painted surface was also recorded. The LBP assessment also measured the footprint of each structure on the property.

The second step of the process involved using the data gathered during the LBP assessment to calculate the increase in soil-lead concentration that would result if all of the deteriorating paint identified in the assessment were to uniformly mix with surface soil surrounding the foundation. This soil mixing calculation, presented in the work plan, generated a quantitative measure of the potential increase in the soil-lead concentration. The potential increase could then be compared to established soil-lead criteria. For purposes of this LBP calculation, the deteriorating LBP on a structure was assumed to fall onto the ground surface within 6 feet of the foundation and be uniformly mixed with the top 1 inch of soil. The resulting increase in soil lead concentration could then be compared to the increase in soil lead concentration that could occur at other properties where LBP assessments were performed. This comparison could be used to determine where the threat to the continued effectiveness of remediated soils was greatest in order to prioritize properties for LBP stabilization.

The LBP assessment also included a qualitative assessment describing any significant deteriorated paint problem that was observed for each structure. In some cases, a significant LBP problem may not have been identified using the quantitative approach. For example, severely deteriorated LBP might have been observed, but not tested for lead content, on a component of a structure such as an upper-floor eave or soffit that was inaccessible during the quantitative LBP assessment. Without characterizing the lead content of the inaccessible surface, it would not have been possible to quantitatively assess the potential impact of any deteriorating paint present on surrounding soil lead concentrations. For this reason, the LBP assessment also included a qualitative assessment describing any significant deteriorated paint problem that was observed for each structure on remediated properties. If a structure was not determined to be potentially eligible for paint stabilization on the basis of the quantitative approach, but a significant deteriorated paint problem was documented during the lead paint assessment, then the property could be revisited by an experienced lead hazard control professional to determine if paint stabilization was warranted at a property.

To conduct the LBP assessment, the field team conducted an initial visual inspection of exterior painted surfaces to assess whether significant chipping, peeling, or otherwise deteriorated paint was observed. If significant paint deterioration was not observed, the field team made a minimum of one XRF reading on each similarly painted surface, and if the XRF reading did not indicate that LBP was present, they prepared documentation consisting of the XRF readings, the condition of the structures, the condition of the areas that could not be accessed with the XRF instrument, and digital photos. If the field team observed deteriorating exterior painted surfaces, one reading of the deteriorated surface was taken with the hand-held XRF detector to measure the lead content of similarly-painted surfaces.

The field team completed a field sheet that included a general description of structures present on each property and provided a discussion of the overall condition of painted surfaces on each structure. The LBP assessment field sheet provided a plan view sketch of the property showing dimensions of all structures and major features such as sidewalks, driveways, outbuildings, and patios. The documentation also included a description and/or diagram of the roof eave system (if present) and any other factors or relevant observations that are pertinent to paint conditions at the property. An example LBP assessment field sheet is presented in Appendix B.4.

2.4 Drip Zone Width Study

In October 2005, BVSPC conducted a study to evaluate the drip zone width within the OLS Focus Area. The drip zone is the area surrounding a residence that can be most readily impacted by exterior LBP. Soil lead levels in drip zones can also be impacted by deposited or impinged airborne contaminants that wash from the roof or siding of structures. The drip zone includes the area adjacent to the exterior walls, overhung by eaves and guttering, if present. The Superfund Lead-Contaminated Residential Sites Handbook (Ref. 58) indirectly characterizes the width of the drip zone by stating that drip zone samples should be collected from the area "between 6 and 30 inches from the exterior walls of the house." The objectives of the Drip Zone Width Study were to characterize the drip zone widths in the OLS focus area for a representative group of homes in terms of age, location, construction type, and exterior finish and identify a single drip zone width applicable to all residences.

BVSPC developed a field sampling protocol for the study and, after obtaining signed access agreements from the property owner, conducted field sampling of drip zones at 30 homes in December 2005. Soil samples were collected at 6-inch intervals on two adjacent sides of the home from the exterior wall to 10 feet from the home. The soil samples were processed at the BVSPC field office in the same manner as other residential soil samples and were analyzed using an XRF instrument. The results of the Drip Zone Width Study were presented in a March 2006 report that is presented in Appendix I.

2.4.1 Sampling Protocols

This section summarizes the sampling protocols used during the Drip Zone Width Study. More detailed descriptions of the sampling protocols for the Drip Zone Width Study are presented in Appendix A of the Drip Zone Width Study Report that is included in Appendix I. Soil samples were collected from 30 homes during the study. The criteria for selecting a home for inclusion in the study were as follows:

- Collection of samples from the foundation to 10 feet from the foundation was possible on two adjacent sides of the dwelling.
- Walkways or driveways that occupied less than 2 to 3 feet of the 10 feet area were acceptable.

- The residence should be pre-1960 construction.

The rationale for collecting two drip zone series at each residence was based on the assumption that paint and substrate exposure and weathering might cause variation in drip zone soil lead concentrations on different sides of the structures. The requirement that the drip zone samples be from adjacent sides of the structure was based on the observation that eave and gutter systems typically differ on adjacent sides, but are similar on opposite sides of a residence.

The following sampling protocols were followed to collect the soil samples for the study:

- Soil samples were collected at 6-inch intervals from the foundation to a maximum of 10-feet using a marked rope. Samples were collected in accordance with OLS residential soil sampling procedures. The soil samples consisted of three aliquots, 0 to 1-inch depth. One aliquot was collected at the rope and the remaining two aliquots were collected within 1 foot of the rope at an equal distance from the foundation.
- Sample identification was as follows: DZ - ## - N (S, E, W) – Black & Veatch Identification Number (BVID). N, S, E, W refers to exterior wall orientation.
- Decontamination procedures were the same as those used to collect residential soil samples. Dry, decontaminated spoons or trowels were used to collect the soil samples. New nitrile gloves were donned at each new sampling location.
- The soil samples were sieved using a No. 10 sieve and analyzed using an Innovex XRF instrument at the BVSPC field office in Omaha. Existing quality assurance/quality control (QA/QC) procedures for residential soil sampling were followed.
- The sampling team recorded the following information on the Drip Zone Study Field Sheet:
    a. Site grading and drainage (positive, away from structure or negative).
    b. Number of stories, roof overhang (measured if possible) and distance from ground to soffit.
    c. Presence of gutters, location of downspouts and drainage swales.
    d. Exterior finish (paint, vinyl siding, brick).
    e. Paint condition, and field XRF results from the soil and paint.
    f. Drip zone features such as presence of vegetation, mulch, bare ground, visible paint chips, etc.
    g. Drip zone sample locations and wall orientation (N, S, E, W).

- Digital photos were taken at each sampling location.

An example bland Drip Zone Study Field Sheet is presented in Appendix B.5.

2.5 Lead Based Paint Recontamination Study

BVSPC conducted a LBP Recontamination Study in 2008 to determine the potential for deteriorating LBP on residential homes to elevate soil lead levels at previously remediated properties. A LBP Recontamination Study Work Plan was prepared (Ref. 59) that addressed the criteria for selecting residential properties to sample and the sampling protocols that would be used to implement the study.

A total of 42 homes where soil remediation was completed, but had not had paint stabilization performed were targeted for drip zone sampling based on the following criteria:

- The drip zones that would be sampled would be located on properties where EPA has previously remediated the soil. To evaluate if the length of time from the remediation of the property had an effect on whether the property became recontaminated, a similar number of remediated properties were targeted from every year (2000 and 2002-2007) that EPA had remediated properties (EPA did not remediate properties in 2001).
- Only drip zones adjacent to residential yard quadrants that had been remediated would be sampled. If possible, homes that had 2 quadrants remediated would be selected and the drip zones adjacent to each of the quadrants would be sampled.
- Structures included only those with painted sidings. Homes with brick or other permanent or factory finished sidings were not sampled unless the house had trim with deteriorated paint.

As previously discussed, BVSPC performed LBP assessments on residential structures in the OLS that were eligible for remediation. The LBP assessment calculation sheet estimates the mass of lead in drip zone soils that would equate to a lead concentration of 400 ppm in the drip zone of each structure. The LBP assessment also estimates the total mass of lead that is present in deteriorating paint at each home. The total mass of lead in deteriorated surfaces is then compared to the mass of lead corresponding to a 400 ppm drip zone lead concentration for that particular structure. When the total mass of lead present in the deteriorating paint is larger than the lead mass that would equate to a soil lead concentration of 400 ppm in the drip zone, the lead concentration in the drip zone could become greater than 400 ppm if all of the deteriorated paint were to fall to the ground and uniformly mix with the soil under certain assumptions. As the difference in the two numbers becomes larger, the potential for lead recontamination of the drip zone becomes greater. Using this information, the following types of properties were targeted for the LBP Recontamination Study.

- Two homes that were remediated in each year (2000 and 2002-2007) at properties with the largest difference between the mass of lead in deteriorated paint and the 400 ppm- equivalent drip zone lead mass. These properties should have the greatest potential for recontamination of the drip zone.
- Two homes from each year (2000 and 2002-2007) where the mass of lead in deteriorated paint is only slightly greater than the 400 ppm-equivalent drip zone lead mass. These homes would provide information on drip zone recontamination when smaller amounts of deteriorating LBP are present on the home.
- Two homes from each year (2000 and 2002-2007) where the mass of lead in deteriorated paint is 6 to 8 times greater than the 400 ppm-equivalent drip zone lead mass. These properties would provide information on potential drip zone recontamination of properties that fall between the other two groups.

As previously indicated, the EPA and the City of Omaha LHCP are performing paint stabilization at homes where the remediated soils could become recontaminated by paint particles mixing with the soil. The LBP stabilization program was initiated by the Omaha LHCP in 2007. EPA and LHCP continued paint stabilization in 2008.

Properties were also sampled for the Recontamination Study where the EPA or the City of Omaha LHCP had performed paint stabilization. The purpose of sampling homes that had paint stabilization performed was to assess the soil in the drip zone following the paint stabilization activities. Twenty-one homes that had paint stabilization performed were targeted for drip zone sampling based on the following criteria.

- The drip zones sampled would be located on properties where EPA had previously remediated the soil and performed LBP stabilization.
- If possible, homes that had 2 quadrants remediated were selected and the drip zones adjacent to each of the quadrants were sampled.
- The house had painted sidings or trim with deteriorated paint.
- Seven homes that had paint stabilization performed and had the largest difference between the mass of lead in deteriorated paint and the 400 ppm- equivalent drip zone lead mass were selected for drip zone sampling.

- Seven homes that had paint stabilization performed where the mass of lead in deteriorated paint is only slightly greater than the 400 ppm-equivalent drip zone lead mass were selected for drip zone sampling.
- Seven homes that had paint stabilization performed where the mass of lead in deteriorated paint is 6 to 8 times greater than the 400 ppm-equivalent drip zone lead mass were selected for drip zone sampling.

2.5.1 Sampling Procedures

Sampling protocols used to conduct the LBP Recontamination Study were consistent with the protocols historically used to collect soil samples from residential properties and those used in the Drip Zone Width Determination Study. All soil sampling was performed in accordance with the QAPP prepared by BVSPC for the OLS (Ref.60). The sampling protocols were as follows:

- To the extent possible, at least two drip zone sample areas with exposed soil to 10 feet from the foundation are present on adjacent sides of the dwelling. Walkways or driveways that occupied no more than 2- 3 feet of the 10-foot area were acceptable.
- Homes with brick or other permanent or factory finished sidings were not sampled.
- Soil samples were collected at 6-inch intervals from the foundation to a maximum of 10-feet. Sample collection methods were the same as the OLS residential soil sampling procedures (Ref. 55) and the sampling procedures described in the Drip Zone Width Determination Study Field Sampling Protocols (Ref. 57). Samples consisted of 3 aliquots, 0 to 1-inch depth, located within 1 foot of the marked rope.
- Visible paint chips lying on the surface of the soil were not collected with the soil sample or mixed with the soil sample. Paint chips are not a component of the soil. Mixing of paint chips with the soil sample would not provide information as to whether deteriorated paint particles have resulted in elevated soil lead concentrations; it would only indicate whether the paint chips contained lead.
- Sample labeling was as follows: Sample labeling: RSDZ - ## - N (S, E, W) – BVID#. N, S, E, W refers to exterior wall orientation.
- Decontamination procedures were the same as those used for residential soil sampling. Dry, decontaminated spoons or trowels were used to collect every soil sample. New nitrile gloves were donned at each new sampling location.
- The soil samples were sieved using a No. 10 sieve and analyzed using an Innovex XRF instrument at the BVSPC field office in Omaha. Existing QA/QC procedures for residential soil sampling were followed.

- The sampling team recorded the following information on the Recontamination Study Field Sheet:
    a. Site grading and drainage (positive [away from structure] or negative).
    b. Number of stories, roof overhang (measured if possible) and distance from ground to soffit.
    c. Presence of gutters, location of downspouts and drainage swales.
    d. Exterior finish.
    e. Paint condition and XRF results.
    f. Drip zone features such as presence of vegetation, mulch, bare ground, visible paint chips, etc.
    g. Drip zone sample locations and wall orientation (N, S, E, W).

An example LBP Recontamination Study Field Sheet is presented in Appendix B.6.

2.6 Small Park Investigation

All public parks within the OLS Focus Area were sampled consistent with the Superfund Lead-Contaminated Residential Sites Handbook (Ref. 58), which includes parks in the definition of residential properties. The objectives of this sampling effort were to determine whether any of the small public parks (defined as parks less than 10 acres), within the OLS Focus Area posed an unacceptable risk to human health, to determine whether surface soils within the public parks contained lead concentrations above the screening level of 400 ppm, and to determine whether any areas of the public parks within the OLS Focus Area were eligible for cleanup under the Interim ROD. The Small Park Surface Soil Investigation Report is presented in Appendix J.

BVSPC collected soil samples from 39 small parks during April 2006 through June 2006. The 39 small parks that were included in the sampling effort are shown on Figure 2-1 and are listed below in Table 2-1. The parks were sampled in accordance with the sampling protocols presented in the Small Park Surface Soil Investigation Report in Appendix J. In addition, Sverdrup Environmental, Inc., sampled the following four small parks in 1999: Christie Heights Park, Columbus Park Community Center, Himebaugh Park, and Sherman Community Center. These 4 parks were excluded from the 2006 sampling effort.

Table 2-1
List of Small Parks Sampled
Omaha, Nebraska

29th & Blondo	Gifford Park
32nd & Franklin	Harrison Heights Park
A. V. Sorensen Community Center	Highland Park
Albright Park	Keith, Miguel Park
Bedford Place Park	Kellom Greenbelt
Bemis Park	Leavenworth Park
Binney/Wirt/Spencer Park	Logan-Fontenelle Park
Bluff View Park	McKinley Park
Clarkson Park	Mercer Park
Columbus Park	Miami Playground
Conestoga Park	Morton Park
Crown Point Park	Park East Park
Cumming Park	Prospect Hill Park
Dahlman Park	Pulaski Park
Dewey Park	Spaulding Park
Erskine Park	Turner Park & Parkway
Essex Park	Unity Park
Ford, Gerald Birthplace	Walnut Hill Park
Forest Lawn Park	Yale Park
Gene Leahy Mall	

The number of samples collected at each park is presented in Table 2-2. The number of samples varied from park to park depending upon the size and number of potential high child-impact areas. The BVID, park address, and park acreage are also included in Table 2-2.

2.6.1 Sampling Protocols

The 39 small parks were sampled in April through June 2006 using the sampling protocol developed for residential soil sampling. The parks were divided into multiple cells that were ¼ acre or less. One 5-point composite sample was collected from each cell. The samples were transported to the BVSPC field office in Omaha, Nebraska where they were sieved with a No. 10 sieve and analyzed for lead using an Innovex XRF instrument.

Play areas were sampled separately. Play areas included bare earth and sand that young children might use for digging or playing. Bare earth baseball diamond infields were sampled separately unless already identified as a separate cell.

One confirmation sample from 37 of the parks was sent to the EPA Region 7 laboratory for analysis.

2.7 Large Park Investigation

All large public parks (defined as parks greater than 10 acres) within the OLS Focus Area were sampled consistent with the Superfund Lead-Contaminated Residential Sites Handbook (Ref. 58). The objectives of this sampling effort were to determine whether any of the large public parks within the OLS Focus Area posed an unacceptable risk to human health, to determine whether surface soils within the public parks contained lead concentrations above the screening level of 400 ppm, and to determine whether any areas of the public parks within the OLS Focus Area were eligible for cleanup under the Interim ROD. The Large Park Surface Soil Investigation Report is presented in Appendix K.

A FSP (Ref. 61) for the large parks was prepared that was based on a traditional soil sampling approach that follows the Superfund Lead-Contaminated Residential Sites Handbook (Ref. 58). Surface soil samples were collected from the large parks in July and August 2007, and were analyzed for lead at the BVSPC Omaha field office using an XRF instrument.

The 15 large parks that are included in this sampling effort are shown on Figure 2-2 and are listed below in Table 2-3.

Table 2-3
List of Large Parks Sampled
Omaha, Nebraska

Adams Park	Brown Park
Fontenelle Park	Deer Hollow Park
Hanscom Park	James F. Lynch Park
Hitchcock Park	Mandan Park
Levi Carter Park	Miller's Landing
Miller Park	Spring Lake Park
Mount Vernon Gardens	Boyd Park
Upland Park	

The number of samples collected at each park is presented in Table 2-4. The number of samples varied from park to park depending upon the size and number of potential high child-impact areas. The park acreage and BVID number are also included in Table 2-4.

2.7.1 Sampling Protocols

The 15 large parks were sampled in July and August 2007 using the sampling protocol developed for residential soil sampling. Areas within these parks that were accessible for sampling were divided into sample cells not larger than ¼ acre in size (10,000 ft^2). One 5-point composite sample was collected from each 100 ft by 100 ft grid that did not contain an obstructed area that could not be sampled (paved areas, ponds, wooded areas, etc). In addition, one 5-point composite sample was collected from each grid that contained at least 7,500 ft^2 of unobstructed area that could be sampled. Steep and/or heavily wooded areas with dense undergrowth were not sampled due to inaccessibility. Additional samples were collected at play grounds, baseball diamond bare soil infields, and other potential high child-impact areas. The high child-impact areas were not based on a 10,000 ft^2 sample cell, but varied in size, based on the areal extent and layout of the high child-impact area. High child-impact areas were not sampled separately if a 100 ft by 100 ft sample cell was located within the high child-impact area. Sample locations are shown on the figures presented in the Large Park Surface Soil Investigation Report in Appendix K.

The sampling locations were selected using geographic information system (GIS) computer software. A computer program linked with the GIS software was used to lay a 100 ft by 100 ft grid system over the parks. The map coordinates for each 5-aliquot sampling square location and global positioning system (GPS) technology was used by sampling crew personnel to field locate the sample locations. Coordinates for the sampling locations at high child impact areas were determined in the field using GPS, and recorded in the field logbook.

2.8 Quality Assurance/Quality Control Samples

QA/QC samples are discussed in this section. The data from the QA/QC samples are discussed in Section 4.0.

2.8.1 Confirmation Samples

To evaluate the accuracy of the XRF, one of every 20 residential soil samples screened with the XRF was submitted to the EPA Region 7 laboratory for confirmation analysis of metals. Prior to the 2005 sampling season, a portion of the homogenized soil sample was analyzed using the XRF instrument and a portion of the homogenized soil sample was sent to the EPA laboratory for analysis. This procedure was followed while the Niton XRF unit was used.

Beginning in the 2005 sampling season, the soil samples were placed in a Whirl-Pak® and analyzed using an Innovex XRF. At that time, BVSPC began submitting the same Whirl-Pak® of soil to the EPA laboratory for analysis of the confirmation sample.

2.8.2 Rinsate Samples

Equipment rinsate blanks are used to determine the effectiveness of the equipment decontamination. Rinsate samples were collected during the initial investigation efforts and the analyses of the rinsate samples indicated that there were no cross contamination concerns when the applicable decontamination procedures outlined in the QAPP were followed. Soil sieves and sample collection spoons used to prepare samples for XRF analysis are thoroughly decontaminated between samples to preserve the integrity of each sample. The conclusion of the initial rinsate sampling indicated that the mass of each sieved sample would greatly exceed the mass of any remaining particle from the previous sample, thus minimizing any impact on test results. Rinsate sample collection was terminated in 2000 after the collection of soil samples from 433 properties.

2.8.3 Matrix Spike/Matrix Spike Duplicate (MS/MSD) Samples

The purpose of the matrix spike (MS) and matrix spike duplicate (MSD) samples is to evaluate the effects of the sample matrix on the accuracy of the analysis. The EPA Region 7 Laboratory has determined that sufficient soil is present in the confirmation soil samples submitted to the laboratory to perform the matrix spike analyses. Therefore, no extra volume of sample is collected. The number of MS/MSD samples is approximately 5 percent of the total number of primary samples submitted for analysis. The MS/MSD samples are identified by the EPA Region 7 laboratory and generally consist of every 20th sample received by the laboratory.

2.9 Sample Numbering System

2.9.1 Surface Soil, Dust, and Subsurface Soil Samples

A sample numbering system was used to identify each sample analyzed. The purpose of this numbering system is to provide a tracking system for retrieval of information on each sample. The sample identification numbers allocated for all sampling efforts were used on sample labels, Chain-of-Custody (COC) records, field sheets and all other applicable documentation used during the sampling activity. The sample identification number consisted of a series of eight alphabetic characters followed by a BVID number which is unique to each property. The alphabetic characters provided information about each sample in order as follows:

1) Type of property sampled
    - A ASARCO property
    - R Residential property
    - D Day care facility
    - H Railroad facility
    - C Other commercial property
    - I Other industrial property
    - P Park property
    - E Elevated Blood Level
    - W Religious Facility
    - Z Type of property not applicable
2) Sample location type
    - Y Ordinary yard sample

D	Drip line sample
G	Garden area sample
P	Play area sample
I	Interior Dust sample
L	Paint sample (for lead)
Z	Sample location type not applicable

3) Quadrant/ Sample location

A	Front yard sample, the left quadrant (when facing the front of the house) - F1
B	Front yard sample, the right quadrant (when facing the front of the house) - F2
C	Back yard sample, directly behind F1 – B1
D	Back yard sample, directly behind F2 – B2
E	Entry Way Location
F	Window sill location
G	Floor Location (No longer used)
H	Bedroom location
J	Exterior wall
K	Window/Door trim
L	Window Trough Location
M	Composite Vacuum (Entryway, bedroom, living area)
O	Composite Wipe Sample from Window Sill
P	Composite Wipe Sample from Window Trough
Q	Composite Wipe Sample from Floor
Z	Quadrant location type not applicable

4) Sample matrix

S	Soil
D	Dust
P	Paint
W	Water
Z	Sample matrix not applicable

5) Sample derivation

C	Composite
G	Grab
F	First Flush Potable Water

    - P Post Flush Potable Water
    - V Vacuum
    - W Wipe
    - Z Sample derivation not applicable

6) Sample quality control status
    - P Primary environmental sample
    - B Field Blank
    - D Field duplicate
    - E Equipment rinsate
    - M Sieved with 60 Mesh Sieve
    - Z Sample quality control status not applicable

7) Analytical method
    - X Analyzed by field XRF
    - L Analyzed by off-site laboratory
    - Z Analytical method not applicable

8) Sampled interval
    - A 0-1 inches
    - B 0-8 inches
    - C 8-16 inches
    - D 16-24 inches
    - E 0-3 inches
    - F 0-6 inches
    - G Treatability study confirmatory sample
    - Z Sampled interval not applicable

The BVID number at the end of the sample identification number ranged from 10000 to 99999. Each sampled property was assigned a unique five digit code which was assigned prior to sampling. EPA shifted to using the acronym SAID (Sample Area Identification) instead of BVID in 2007. SAID and BVID are synonymous.

Based upon the preceding, a primary composite soil sample collected from a residential property in a play area from a depth of 0-1 inches and analyzed by XRF with BVID number 10000 would have the following sample ID:

RPZSCPXA-10000

2.9.2 Exterior Lead Based Paint Assessment Samples

LBP assessments that were performed on the exterior of the home or attachment are identified as follows:

H-N-P-XX-12345

1) Structure Type: H = House, G = Garage, S = Shed, F = Fence
2) Side of Structure: N = North, S = South, E = East, W = West
3) Material: P = Paint
4) Sample Number: 00 to 99
5) BVID Number

2.9.3 Drip Zone Width Study Samples

Drip Zone Width Study samples were identified as follows:

Sample labeling: DZ - ## - N (S, E, W) – BVID

1) DZ is Drip Zone.
2) ## is the Sample Number 01 through 99.
3) N, S, E, W refers to exterior wall orientation.
4) The BVID number was placed at the end of the sample identification number and consists of a unique five digit code.

2.9.4 Park Soil Samples

Park soil samples were identified as follows:

P (01) SCPXA-12345

1) Type of Property Sampled: P = Park property
2) Sample Number: 01 through 999 (Samples 950 through 999 are from high child impact areas).
3) Sample Matrix: S = Soil
4) Sample Derivation: C = Composite
5) Sample Quality Control Status: P = Primary Sample
6) Analytical Method: X = Analyzed by XRF, L = Analyzed by Laboratory

7) Sampled Interval: A = 0 – 1 inches
8) The BVID number was placed at the end of the sample identification number and consisted of a unique five digit code.

2.9.5 *Lead Based Paint Recontamination Study Samples*

LBP Recontamination Study samples were identified as follows:

Sample labeling: RSDZ - ## - N (S, E, W) – BVID

1) RSDZ is Recontamination Study Drip Zone.
2) ## is the Sample Number 01 through 99.
3) N, S, E, W refers to exterior wall orientation.
4) The BVID number was placed at the end of the sample identification number and consisted of a unique five digit code.

2.10 Documentation

2.10.1 *Field Sheets*

Field sheets were used to track access to properties and sample collection. The field team completed a field sheet for each property sampled. The field sheets incorporated the property access, property information, the sketch of the property, and sample results. A different field sheet was used when collecting the samples for the various studies. Copies of example field sheets for the various studies are located in Appendix B.

2.10.2 *Field Book Documentation for Sampling Activities*

Bound field logbooks were maintained by the sampling teams to provide a detailed record of significant events, observations, and measurements taken during the field investigation. The field log books are intended to provide sufficient data and observations to enable the field teams to reconstruct events that occurred during the project. All information obtained during the sampling activities was recorded in a bound logbook with consecutively numbered pages. All entries in logbooks and on sample documentation forms were made in waterproof ink, and corrections consisted of line-out deletions that were initialed and dated.

2.10.3 Photographs

All sampled properties were photographed during the initial residential soil sampling investigation. At each sampled property, photographs were taken of the front and back yards. Photographs from each sampled property were saved to a disk unique to the property. The computer disk was labeled with the property number, the property address, the date, and the number of photographs saved on each disk.

2.10.4 Sample Labels

All samples sent to the laboratory for analysis were placed in labeled sample containers that were appropriate for the media sampled. The following information was included on each sample label:

- Site name.
- EPA sample identification number.
- Name of sampler.
- Sample collection date and time.
- Analysis requested and preservatives added.

2.10.5 EPA Region 7 Field Sheet

For each sample sent to the laboratory, EPA Region 7 laboratory field sheets were used in order to document sample collection time, location, and field observations. After completing the field sheet, a photocopy of the field sheet was made. The original was provided to EPA with the samples. The photocopy was retained for reference.

2.10.6 Chain-of-Custody Record

A chain-of-custody (COC) record was completed for each shipment of samples to the EPA laboratory. Standard laboratory COC records were used. After completion of the COC record, the record was photocopied and included with the shipment. The photocopy was retained for reference.

2.10.7 Custody Seals

For all shipments to the EPA laboratory, custody seals were used to ensure the integrity of the samples should they be unattended or when they are relinquished to a delivery service. All samples were shipped in an insulated shipping container and each shipping container was sealed with at least two custody seals. The seals were affixed to each shipping container so that it was necessary to break the seals to open the shipping container.

3.0 Physical Characteristics of the Study Area

3.1 Surface Water Hydrology

Surface water runoff from the site area flows easterly along the street sewer system prior to entering the Missouri River (Ref. 1). The Missouri River supports recreational fishing and boating (Ref. 30). There are wetlands located along the surface water pathway. The Missouri River is the habitat location for the blacknose shiner (*Notropis heterolepis*), finescale dace (*P. neogaeus*), lake sturgeon (*Acipenser fulvescens*), northern redbelly dace (*P. eos*), pallid sturgeon (*Scaphirhynchus albus*), and pearl dace (*Margariscus margarita*) which are designated as threatened and/or endangered species (Ref. 30, p. 5; 32; 33). The Omaha Lead Site is located outside the 500-year flood plain of the Missouri River (Ref. 35).

3.2 Geology

The Omaha Lead Site lies within the Central Lowland region of the Interior Plains physiographic province (Ref. 20, p. C3). The entire area lies within a structural feature known as the Nemaha Uplift, a north-south feature bound on the east by the Humboldt fault zone (Refs. 20, p. C9; 21, p. 1). The topography of the Omaha area is defined by a hilly upland in the western portion of the area and the Missouri River floodplain to the east. The elevation of the site ranges from approximately 1,030 to 1,200 feet above mean sea level. Geologic units in the study area include, in descending stratigraphic order: undifferentiated Pleistocene deposits, the Kansas City Group, and undifferentiated strata of Cambrian through Pennsylvanian age (Refs. 20, pp. C10; 22, pp. 4, 5).

Unconsolidated materials beneath the site consist of Pleistocene to recent alluvial deposits and Pleistocene glacially derived loess deposits. Loess is the most common surface deposit in the Omaha area. The loess is underlain by either glacial till, Cretaceous-aged sandstone, or Pennsylvanian-aged sediments (Ref. 24, pp. 1, 2). The unconsolidated material has a thickness of approximately 90 feet on the Missouri River Valley at Council Bluffs, Iowa (Ref. 22, pp. 1-5).

The Kansas City Group consists of interbedded shale and limestone and is greater than 50 feet thick in the Omaha/Council Bluffs area (Ref. 22, p. 5).

The undifferentiated strata of Cambrian through Pennsylvanian Age consists of interbedded sedimentary rock of undetermined thickness. The presence of a window in the Mississippian portion of the section across the southern Nemaha Uplift suggests that, if present, the Mississippian series is extremely thin in the Omaha area (Ref. 19, pp. C9, C10, C21, C23, C27). Lower, Cambrian rock units are present beneath the site and thicknesses generally exceed 1,000 feet in eastern Nebraska (Ref. 20, pp. C10, C19, C20).

3.3 Soils

The U.S. Soil Conservation Service (SCS) identifies soils in two distinct associations for the Omaha Lead Site. The first soil series is the Albaton Haynie Association, with deep, poorly drained to moderately well drained, nearly level clayey and silty soils on bottom land along the Missouri River. To the west and out of the river bottom, the second soil series is the Monona-Ida Association. This is classified as a deep, well drained, nearly level to very steep silty soil on bluffs adjacent to the Missouri River valley. Both of these series are primarily characterized as Peoria loess or younger loess. Approximately one-third of the Omaha Lead Site is in the Albaton-Haynie series (river bottoms) and two-thirds is in the Monona-Ida series (western upland) (Ref. 23).

3.4 Hydrogeology

The surficial aquifer in the study area is composed of glacial drift deposits in the western portion of the study area and alluvial material adjacent to the Missouri River. The average thickness of saturated alluvial material ranges from 50 to 80 feet. Water within the alluvial, stream-valley aquifer is generally under unconfined or water table conditions. Yields of wells drilled in the alluvial material range from 100 to 1,000 gallons per minute.

The thickness of glacial drift deposits is generally 100 to 200 feet. Within the glacial drift deposits, complex interbedding of fine- and coarse-grained material results in a large number of local confining units. Yields from the glacial drift aquifer are more variable and range from 10 to 1,000 gallons per minute (Ref. 24, pp. 1, 2, 7-9).

Topography in the area heavily influences the potentiometric surface of the surficial aquifer. Movement of water is from recharge areas to discharge areas along major streams. The stream valley aquifers are in direct hydraulic connection with nearby streams and water levels are, therefore, closely related to river levels. A small amount of water enters the underlying bedrock aquifers by percolating downward (Ref. 24, p. 7).

The regional or bedrock aquifer system consists of permeable limestone, dolostone, and sandstone of Late Cambrian through Late Mississippian age that are separated by slightly permeable shale or dolostone, all of which overlay the basement confining unit. The top of the upper unit in the Western Interior Plains aquifer system generally slopes away from the

Missouri River (Ref. 20, p. C19, C22). The western Interior Plains aquifer system is overlain by a confining unit of Pennsylvanian shale and limestone and is composed of three units: an upper unit, a confining unit, and lower unit. The upper, Mississippian unit may only be present as a negligible unit due to erosion of the Nemeha Uplift. The thickness of the lower unit is greater than 1,000 feet in the eastern Nebraska region. The intermediate confining unit that separates the lower units from the upper unit in the Western Interior Plains aquifer system limits regional flow between the two units (Ref. 20, pp. C9, C10, C21, C23, C27). The thickness of this unit ranges from 0 to 300 feet thick (Ref. 20, p. C22).

3.5 Meteorology

Omaha is located in the heart of the North American landmass, and as such, has a climate which is continental in character. In winter, the mean pressure of the central region is higher than that of the surrounding areas, and is accompanied by an outflow of cold, dry air. In summer the mean pressure of the central region is relatively low, and is accompanied by a general inflow of warm, moist air. Omaha has marked seasonal contrast in both temperature and precipitation which is characteristic of continental climates.

The normal annual total precipitation in the area is approximately 28 to 30 inches, and the mean annual lake evaporation is 28 inches, resulting in a net precipitation of 0 to 2 inches (Ref. 4). The 2-year, 24-hour rainfall is approximately 3.0 inches (Ref. 4, p. 95). Seasons typically consist of severe winters, wet springs, and warm summers with moderate thunderstorm activity (Ref. 5, p. 1-4).

3.6 Demography and Land Use

The Omaha Lead Site is located in eastern Omaha, Nebraska, and is bordered on the east by the Missouri River. Land use within the area of the site is residential, commercial and industrial. With the exception of limited areas and individual lots, the site is completely developed. Approximately 45,800 residential and commercial properties are included within the definition of the site (Ref. 41). This includes both single-family and multi-family residential, as well as vacant lots with residential zoning. According to the American Community Survey (ACS) conducted by the Census Bureau in 2002 (Ref. 40), the average household size in Douglas County was 2.49 people. The ACS also states that in 2002, 27 percent of the population in Douglas County was under the age of 18 and that 84 percent of the population had lived in the same residence for over one year. This information indicates that there is potentially a large population of young residents that have been exposed to conditions at the site for an extended period of time. While the survey area covered the entire county, data from site residents was included in the tabulation. Therefore, while these numbers may not exactly reflect conditions at the site, they are an indication of residential patterns within the area.

4.0 Nature and Extent of Contamination

This section presents, evaluates, and interprets results of the chemical analysis of samples collected during the RI. The health risks posed by the presence of the identified contaminants are discussed in the Baseline Human Health Risk Assessment report prepared by the Syracuse Research Corporation under a contract with the EPA (Ref. 62).

Analytical data for the surface soil samples from residential properties are compared to the EPA Region VI Human Health Medium-Specific Screening Levels (Ref. 64) to determine the nature and extent of contamination. The screening level for lead concentrations in soil at residential properties is 400 ppm.

4.1 Data Validation

As discussed in Section 2 of this report, samples collected during this investigation were analyzed in the field office using XRF technology. To verify the accuracy of field XRF equipment, approximately one of every 20 soil samples was submitted to the EPA Region 7 laboratory for confirmation analysis of lead concentrations. The confirmation samples were analyzed by the XRF instrument in the Omaha field office and the EPA Region 7 laboratory in Kansas City, Kansas. The EPA Region 7 laboratory validated the analytical data according to their standard operating procedures. No duplicate samples were collected for XRF analysis.

To evaluate these results, a linear regression was developed by comparing the field XRF result to the corresponding laboratory result. The site-specific QAPP prepared by Sverdrup Environmental, Inc. (Ref. 63, p. 34) required the coefficient of determination (R^2) between the XRF analysis and laboratory analysis to be equal to or greater than 0.49. The coefficient of determination provided a measure of the strength of the correlation. It is the percentage of the observed values of Y (XRF data) that is explained by the observed values of X (EPA laboratory data). Raw laboratory and XRF values were used for the calculations.

When the linear regression was performed on the XRF and laboratory data from this investigation, the resulting R^2 value was 0.5242. This value indicates that the field equipment was performing well and providing results that are comparable to laboratory results. A graph showing the relationship between XRF and laboratory data is presented in Figure 4-1.

The BVSPC QAPP (Ref. 60) specified that the Relative Percent Difference (RPD) between the XRF analysis and the laboratory result should be less than 80 percent. The RPD was determined for all confirmation samples analyzed between 2001 and 2007 and the data is presented in Table A-1 on the accompanying diskette contained in Appendix A of this RI Report. The RPD between the confirmation samples analyzed with the XRF and the laboratory met the overall 80 percent goal in 94.3 percent of the samples.

As discussed in Section 2 of this report, one soil sample per day was also sieved through a No. 60 sieve (0.25 mm) and analyzed with the XRF unit. This testing provided a correlation between the soil samples that were routinely analyzed (No. 10 mesh sieve) and the fine fraction of the soil obtained using a No. 60 mesh sieve. The fine fraction of soil was analyzed because it represents the soil fraction that is more likely ingested by children.

The XRF results from sieving the samples through a No. 60 mesh sieve and a No. 10 mesh sieve are presented in Table A-2. A linear regression was also developed by comparing the sample results from the soil sieved through the No. 60 sieve with the sampling results from soils that had been sieved through a No. 10 sieve. A graph showing the relationship between the samples sieved with a No. 60 sieve and a No. 10 sieve are presented in Figure 4-2. As indicated on Figure 4-2, the coefficient of determination for this data is 0.9306, indicating that there is a very strong correlation between the results from the two sieve sizes. The RPD of the samples analyzed using a No. 60 sieve and a No. 10 sieve was determined and compared to the RPD goal of 80 percent. The RPD between the samples analyzed using a No. 60 sieve and a No. 10 Sieve met the overall 80 percent goal in 98.6 percent of the samples.

4.2 Soil at Residential Properties

Between March 1999 and February 2009, surface soil samples were collected from 34,565 residential, EBL, and child care properties within the OLS and analyzed for lead. An additional 2,511 properties were sampled outside the focus area. Sampling of the properties at the site is ongoing and the number of samples collected is being continuously updated. The properties are located in the 13 Zip Code areas that cover the final Focus Area (68102, 68104, 68105, 68106, 68107, 68108, 68110, 68111, 68112, 68117, 68131, 68132, and 68147). The properties that were sampled were relatively evenly distributed throughout the expanded Focus Area in the site and represented lead concentrations in surface soil in all areas of the expanded Focus Area. At the time this RI Report was prepared, soil samples had not been collected from the western portion of the OLS defined as the Final Focus Area. The locations of sampled properties are shown in Figure 4-3.

Between March 1999 and July 2000, sampling was conducted by Jacobs Engineering (Jacobs), and since July 2000 all sampling has been performed by BVSPC. All data from the sampling performed by both firms is presented in Appendix A to this report. Due to differences in data format, two tables are included in Appendix A. Table A-3 includes the results of sampling performed by Jacobs, and Table A-4 includes the results of sampling performed by BVSPC. Because of the large amount of data, Tables A-3 and A-4 are included on a diskette in Appendix A.

Ten percent of the samples collected by Jacobs were split. One split was analyzed by an XRF in the Omaha field office and the sample was analyzed by PDP Laboratories. This laboratory analysis was performed for various metals. A summary of the results of the laboratory analyses on the samples collected by both Jacobs and BVSPC is presented in Table 4-1. These analyses indicated that several metals, in addition to lead, were found in the soils in Omaha. The risks associated with these other metals are discussed in the final BHHRA discussed in Section 6.0 of this Final RI report.

Of the 37,076 properties sampled during the investigation, 8,552 properties had at least one non-foundation sample with a total lead concentration between 400 ppm and 800 ppm and 4,144 properties had at least one non-foundation sample with a total lead concentration greater than or equal to 800 ppm, which is the lead concentration that triggers a response under the Interim ROD.

Approximately 23 percent of the properties sampled contained lead concentrations between 400 ppm and 800 ppm. Approximately 11 percent of the properties sampled contained lead concentrations exceeding 800 ppm. Figure 4-2 presents the locations of properties that had soil lead concentrations less than 400 ppm, between 400 ppm and 800 ppm, and greater than 800 ppm.

4.3 Indoor Dust

4.3.1 2003 Investigation

Dust samples were collected from 159 properties within the site boundary during October and November 2003. At each property where interior dust samples were collected, three vacuum dust samples were collected from the floor and one wipe sample was collected from a window sill as discussed in Section 2. Wipe samples were not collected from the floors during this sampling activity. The lead loadings (mass per unit of area sampled) from the wipe samples and the lead concentrations in the samples collected using the vacuum are presented in Table 4-2.

There are no EPA criteria for defining acceptable lead concentrations in the dust. As indicated in Table 4-2, the average lead concentration for vacuum samples was 435 ppm and the median lead concentration for vacuum samples was 232 ppm. The highest lead concentration detected in a dust sample collected with a vacuum was 15,900 ppm.

The EPA regulations under the Toxic Substances and Control Act (TSCA) concerning lead concentrations in wipe samples are found in the Code of Federal Regulations (CFR) at 40 CFR 745.227(h)(3)(i). The regulation specifies that a dust-lead hazard is present in a residential dwelling when the weighted arithmetic mean lead loadings for all single surface or composite samples of floors and interior window sills are equal to or greater than 40 $\mu g/ft^2$ for floors and 250 $\mu g/ft^2$ for interior window sills, respectively. The data in Table 4-2 indicate that lead concentrations in 31 of the wipe samples collected from the window sills exceeded 250 $\mu g/ft^2$.

4.3.2 2007 Investigation

Dust samples were collected from 98 properties during November and December 2007. At each property where interior samples were collected, one composite dust sample was collected from the floors of three rooms using a vacuum. One composite wipe sample was collected from the window sill, window trough, and floor of the home. Each composite wipe sample consisted of individual wipes collected from similar surfaces in the living area and two bedrooms in the home. The lead loadings from the three composite wipe samples from each residence and the lead concentrations in the samples collected using the vacuum are presented in Table 4-3.

As indicated in Table 4-3, the lead concentrations in the vacuum samples ranged from 9.4 ppm to 3,810 ppm. The average lead concentration in the vacuum samples was 380 ppm and the median concentration was 232 ppm. The data in Table 4-3 indicate that lead concentrations in 25 of the wipe samples collected from the window sills were equal to or exceeded 250 $\mu g/ft^2$ and the lead concentrations in 5 of the wipe samples collected from the floors were equal to or exceeded 40 $\mu g/ft^2$.

4.4 Potable Water

Potable water samples were collected in November and December 2007 from each residence where indoor dust samples were collected. The samples were analyzed for lead and the analytical results are presented in Table 4-3. The analytical results were compared to the EPA MCL for lead (15 μg/L). As indicated in Table 4-3, the potable water from one property contained lead concentrations for the first flush sample and post flush sample of 48.8 μg/L and 634 μg/L, respectively. The potable water at the home was re-sampled in April 2008 and the lead concentrations were 10.2 μg/L and 4.7 μg/L, respectively. It is believed that the initial sampling results may have been due to sampling error and that there were no residences that contained lead concentrations exceeding the EPA MCL.

4.5 Lead Based Paint Assessments

BVSPC has performed LBP assessments at more than 2,894 properties since the beginning of 2006. LBP assessments are ongoing and the number of assessments is being continuously updated. The data from the LBP assessments are presented in Table A-5. Because of the large amount of available data, Table A-5 is presented on a diskette contained in Appendix A. The data from the LBP assessments indicated that there were 1,335 properties where deteriorating LBP, if it were to fall onto the ground surface within 6 feet of the foundation and be uniformly mixed with the top 1 inch of soil, would result in an increase in the lead concentration in the soil to more than 400 ppm.

4.6 Drip Zone Width Study

BVSPC conducted a drip zone width study to characterize the drip zone widths in the OLS Focus Area for a representative group of homes and determine if a single drip zone width applicable to all residences could be identified. The Drip Zone Width Report is presented in Appendix I of this RI Report. The raw data from the study is presented in Table 4-4.

The data indicate that, on average, soil lead concentrations drop below 400 ppm at approximately six feet from the exterior foundation wall, based on average lead concentrations in 6-inch intervals from the exterior foundation wall to 10 feet from the structures.

4.7 Lead Based Paint Recontamination Study

BVSPC conducted a LBP Recontamination Study in 2008 to determine the potential for elevated soil lead levels to develop in the drip zone area of homes due to deteriorating

LBP where surface soils and drip zones had been previously remediated. The LBP Recontamination Study Report is presented in Appendix L.

Twenty-five properties were sampled where soil remediation had been previously performed but paint stabilization had not been performed. In addition, 21 properties were sampled where both soil remediation and paint stabilization had been performed prior to sampling. The numbers of properties matching all of the criteria in the work plan were not sampled because the property owners were not interested or willing to participate in the study. Table 4-5 presents the properties sampled in each category during LBP Recontamination Study.

4.7.1 Properties Sampled Prior to Paint Stabilization

The lead concentrations in the soil samples collected from the 25 properties prior to paint stabilization are presented in Table 4-6A. The table presents the lead concentrations at 6-inch increments from the foundation. The table also presents the average lead concentrations within 6 feet of the foundation of the home (defined as the drip zone width at the OLS) and from 6 feet to 10 feet from the foundation of the home. Table 4-6B presents the average lead concentrations and the total number of soil samples collected, the average lead concentrations and the number of soil samples collected within 6 feet of the foundation, and the average lead concentrations and the number of soil samples collected from 6 to 10 feet from the foundation of the home. The completed field sheets for the sampled properties are presented in Appendix L.

The average lead concentrations for the 945 soil samples collected at the 25 pre-stabilization properties was 113 ppm. The average lead concentration for the 588 samples collected from these properties within 6 feet of the foundation was 148 ppm. The average lead concentration in the 357 samples collected at distances greater than 6 feet from the foundation wall at these properties was 51 ppm.

The majority of the soil samples with elevated lead concentrations were collected within 6 feet of the foundation of the home. The average lead concentration in the samples collected along a transect within 6 feet of the foundation exceeded 400 ppm in 4 of the 52 transects in this group. These 4 transects were located at 4 separate properties, and in no case did average concentrations exceed 400 ppm within 6 feet of the foundation at more than one transect at each property. The average lead concentrations in the soil samples collected from 6-10 feet from the foundation were less than 400 ppm at all of the properties.

A correlation was observed between the degree of LBP deterioration identified in the LBP assessments and soil lead levels found at pre-stabilization properties. The calendar year in which the soil remediation was performed did not appear to be a factor in whether the property contained average lead concentrations greater than 400 ppm in the samples collected within 6 feet of the foundation. Properties that were remediated in calendar years 2003, 2004, 2006, and 2007 all contained soil with average lead concentrations greater than 400 ppm.

The presence of paint chips was not a reliable indicator of elevated soil-lead concentrations. Paint chips were generally observed in the drip zone at properties where elevated lead concentrations were detected in individual samples and at all of the properties where the average lead concentration in the soil exceeded 400 ppm. However, there were also paint chips observed in the drip zones at several properties that did not have elevated lead concentrations in individual sample results. In addition, there were no paint chips observed at two properties that contained elevated lead concentrations in individual sample results.

Site drainage or the presence or absence of gutters on the home did not appear to be a factor as to whether there were elevated lead concentrations in the drip zone

4.7.2 *Properties Sampled Following Paint Stabilization*

The lead concentrations in the soil samples collected from the 21 properties where paint stabilization had been performed are presented in Table 4-6C. The table presents the lead concentrations at 6-inch increments from the foundation. The table also presents the average lead concentrations within 6 feet of the foundation of the home and from 6-10 feet from the foundation of the home. Table 4-6D presents the average lead concentrations and the total number of soil samples collected, the average lead concentrations and the number of soil samples collected within 6 feet of the foundation, and the average lead concentrations and the number of soil samples collected from 6 to 10 feet from the foundation of the home. The completed field sheets for the sampled properties are presented in Appendix L.

A total of 810 individual soil samples were collected at the 21 post-stabilization properties in this study. As shown in Table 4-6D, the average lead concentration for all samples collected from the 21 post-stabilization properties was 73 ppm. The average lead concentration for the 483 samples collected within 6 feet of the foundation from the post-stabilization properties was 95 ppm. The average lead concentration in the 327 samples collected 6-10 feet from the foundation wall at the post-stabilization properties was 41 ppm.

Of the 810 soil samples collected from post-stabilization properties, 21 samples (2.6%) had concentrations exceeding 400 ppm. The 21 soil samples that exceeded 400 ppm were all collected within 6 feet of the foundation. Soil lead concentrations in all samples collected from 6-10 feet of the foundation were less than 400 ppm.

The average lead concentrations were less than 400 ppm along all transects collected from post-stabilization properties, both in the 0-6 foot and 6-10 foot intervals.

4.8 Small Parks Investigation

During April to June 2006, BVSPC collected soil samples from 39 small parks with an area less than 10 acres. Soil samples from high child impact areas at four small parks (Christie heights Park, Columbus Park Community Center, Himebaugh Park, and Sherman Community Center) were previously collected by Sverdrup Environmental, Inc. and these parks were not resampled. Sketches were prepared for all of the BVSPC sampled parks and are presented in Appendix J.

The data from the small park investigation are presented in Table 4-7. The lead concentrations in one sample from 29th & Blondo Park (438 ppm) and three samples from Kellom Greenbelt Park (404 ppm, 477 ppm, and 554 ppm) exceeded 400 ppm. The locations where these samples were collected were not high child impact areas. However, the locations were resampled and the lead concentrations were below 400 ppm (293 ppm, 172 ppm, 156 ppm, and 266 ppm, respectively).

4.9 Large Parks Investigation

During July 2007, BVSPC collected soil samples from 15 large parks with an area greater than 10 acres. The results of the large park sampling investigation are presented in Tables 4-8 through 4-23. Lead concentrations were detected above the 400 ppm screening level in three parks. Three soil samples from Levi Carter Park contained lead concentrations of 400 ppm, 401 ppm, and 542 ppm, respectively. One soil sample from Miller Park had a lead concentration of 416 ppm and one soil sample from Spring Lake Park contained a lead concentration of 539 ppm.

4.10 Presence of Arsenic

The 2004 RI Report (Ref. 50) presented an analysis of the arsenic data collected at that time to determine if the arsenic concentrations detected at the site were related to the lead concentrations at the site. When the 2004 RI Report was prepared, arsenic had been detected in approximately 17 percent of the soil samples analyzed by laboratory methods. Analyses performed by the XRF detected arsenic at almost the same frequency.

EPA's NERL and the University of Colorado's LEGS analyzed the data collected from the site to determine if the occasional detection of arsenic was related to the lead that is widely found in soil at the site. The reports are presented in Appendix D of this report. Arsenic at concentrations below 25 ppm is more difficult to characterize.

The NERL analyzed the site data and prepared a report titled, "*Arsenic and Lead Contamination in Soils - Omaha Nebraska*" that described the analyses performed on the data and the conclusions that were based on this analysis. The report concluded that soil samples with arsenic above 25 ppm are not correlated with lead contamination. The report concluded that arsenic concentrations greater than 25 ppm occasionally found in residential soils were not related to lead contamination that is found in most residential yards. A 25 ppm concentration is significant because it was the approximate arsenic detection level for the Niton XRF.

To support their first report, the NERL prepared a second report titled, "*Spatial Distribution of Lead and Arsenic Contamination - Omaha Nebraska*" supplementing its earlier report with geo-spatial analyses of the lead and arsenic data. This report concluded that the arsenic data did not have the same geo-spatial pattern as the lead data. This further supported the NERL's conclusion that arsenic that was found at levels above 25 ppm was not related to atmospheric deposition originating from the area of downtown Omaha.

The LEGS also analyzed the data from the site. In addition, EPA sent LEGS three soil samples from residential properties that had high arsenic concentrations. The LEGS analysis of the soil data from the site revealed that arsenic and lead concentrations did not correlate with each other, indicating that the two metals were from different sources. The LEGS analysis of three residential soil samples with high arsenic concentrations showed that the arsenic was in a relatively pure form that is usually associated with the rotenticides arsenic trioxide and lead arsenate. The LEGS concluded that high arsenic concentrations occasionally found in residential soil was not from atmospheric deposition from an industrial source.

Both NERL and LEGS independently concluded that high arsenic concentrations were not caused by atmospheric deposition from a source or sources originating from the downtown Omaha area.

5.0 Contaminant Fate and Transport

Early investigations at the Omaha Lead Site found evidence of high lead concentrations in surface soils along the corridors of the prevailing wind currents which pass through downtown Omaha. At the same time, two industrial properties on the east side of downtown Omaha were being investigated as the sources of the contamination. The conclusions of these investigations demonstrated that the contamination was deposited from air currents originating at the east edge of downtown, along the Missouri River, and traveling outward, primarily to the north, south and west (Ref. 39 and 46). These potential sources are no longer operating and no other potential sources of lead contamination that could have widespread influence have been identified.

The 2004 RI, as well as previous investigations conducted at the site, investigated potential migration of lead contamination from surface to subsurface soils. Investigations of soil chemistry and lead concentrations in subsurface soils at the site have indicated that the lead contamination at the site is concentrated in the top 12 inches of soil. The 2002 apportionment study conducted by the University of Colorado LEGS (Appendix D) states that "The near neutral (6-8.5 pH) acidity of the local soils stimulate very low metal mobility, generally concentrating metals in the surface horizons by preventing their downward distribution over time." (Ref. 46, pg. 8)

During the SI for the Omaha Lead Site, subsurface soil samples were collected at 511 properties where surface soil samples were collected at the same location. The subsurface soil samples were collected from the 0 to 8-inch, 8 to 16-inch, and 16 to 24-inch ranges. The number of samples in which lead was detected decreased at each downward depth interval. The average, maximum, and median lead concentrations also decreased as depth increased, indicating little to no migration downward from surface soils. These results led EPA to discontinue depth sampling at the end of the SI. Table 5-1 provides a summary of the depth sampling.

Figure 5-1 presents the properties with lead concentrations in the non-foundation soil samples above and below 400 ppm at 1-mile intervals from the former ASARCO facility. Figure 5-2 presents the percentage of sampled properties with lead concentrations in the non-foundation soil samples above 400 ppm at 1-mile intervals from the former ASARCO facility.

Additional migration of contaminants on the site may occur through wind and surface water erosion and human activity.

6.0 Baseline Human Health Risk Assessment

6.1 Introduction

The BHHRA for the OLS was prepared by the Syracuse Research Corporation and is presented as Appendix M to this final RI Report (Ref. 62). The purpose of the BHHRA is to characterize the risks to area residents, both now and in the future, from site-related contaminants present in environmental media, assuming that no steps are taken to remediate the environment or to reduce human contact with contaminated environmental media. The results of the final assessment are intended to help inform risk managers and the public about potential human risks attributable to site-related contaminants and to help determine where there is a need for action at the site.

6.2 Site Characterization

In the past, two lead smelters operated in the eastern part of the OLS. Historical smelting, refining, and recycling activities that occurred at these smelters resulted in the release of lead and other smelter-related metals into air in the form of particulate matter. These particulates in the air were transported by wind and deposited onto soil in the vicinity of the site. Humans may be exposed to lead and other smelter-related metals in soil by a number of pathways, and adverse health effects may occur if concentrations and exposure levels are high enough.

One measure of human exposure to lead is the concentration of lead in the blood, generally expressed in units of micrograms of lead per deciliter of blood (µg/dL). Concentration values above 10 µg/dL are generally considered to be elevated and of potential health concern. The DCHD has been monitoring lead levels in the blood of children living in Douglas County for a number of years. The percentage of children with elevated blood leads (> 10 µg/dL) in the area of the site has been consistently higher when compared with State and national data. This indicates that children living in the area of the site are being exposed to lead in the environment at levels that exceed other locations, and which may be of potential health concern to some children.

6.3 Site Conceptual Model

Figure 6-1 presents a general conceptual model of how smelter-related contaminants that have been released to the environment at the OLS might result in exposure of humans. The environmental medium of chief concern is surface soil that has been impacted by the wet or dry deposition of metal-containing airborne particulates released from the smelters. The human population of chief concern is residents in the area of the site, now or in the future, including both children and adults. Residents might be exposed to smelter-related contaminants in site soils by a number of different pathways, including ingestion, inhalation, and dermal contact with contaminated soil or dust, and ingestion of home-grown produce that may have taken up contaminants from the soil. However, not all of these are likely to be of equal concern for all contaminants. Section 6.4 describes the exposure pathways that are of chief concern for lead, and Section 6.5 describes the exposure pathways that are of chief concern for other (non-lead) contaminants.

Chemicals of Potential Concern (COPCs) are chemicals which exist in the environment at concentration levels that might be of potential health concern to humans and which are or might be derived, at least in part, from site-related sources. The chief COPC at this site is lead. However, several other chemicals were identified that might also be of potential concern to humans, including the following:

- Aluminum
- Antimony
- Arsenic
- Cadmium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Manganese
- Mercury
- Thallium
- Vanadium
- Zinc

6.4 Evaluation of Risks from Lead

6.4.1 *Exposure Assessment*

The population of chief concern for lead exposure is young children (age 0-84 months). This is because young children tend to have higher intakes of lead than adults, tend to absorb more lead than adults, and are inherently more sensitive to lead than adults. If environmental exposures to lead in a residential area are acceptable for young children, exposures are usually also acceptable for older children and adults, including pregnant women.

Young children can be exposed to lead from a variety of sources. At the OLS, the environmental medium of chief concern is outdoor soil that became contaminated with lead released from historic smelter operations. Exposure to smelter-contaminated soil may occur through ingestion of soil or dust, or through inhalation. Dermal absorption of lead from soil or dust is considered to be very minor, as is uptake of lead from soil into home-grown produce.

In addition to these exposures to smelter-related releases of lead, children may also be exposed to lead from other sources as well. This includes lead from leaded paint, as well as lead in drinking water and food from grocery stores. Because risk from lead depends on exposure from all of these sources, these exposure pathways are also included in the risk evaluation for lead.

6.4.2 Toxicity Assessment

6.4.2.1 Non-Cancer Effects

Excess exposure to lead can result in a wide variety of adverse effects in children. However, the most important effect is on the nervous system. The effects of chronic low-level exposure on the nervous system include decreased performance in various types of tests of intelligence, attention span, hand-eye coordination, etc. The overall weight of the available evidence provides clear evidence of nervous system effects in young children occurring at blood lead levels in the range of 5-10 µg/dL, possibly lower. Such effects on the nervous system are long-lasting and may be permanent.

6.4.2.2 Cancer Effects

Studies in animals indicate that chronic oral exposure to very high doses of lead salts may cause an increased frequency of tumors of the kidney. However, there is only limited evidence suggesting that lead may be carcinogenic in humans, and the non-carcinogenic effects on the nervous system are usually considered to be the most important and sensitive endpoints of lead toxicity.

6.4.2.3 Current Guidelines for Protecting Children from Lead

The EPA identified 10 µg/dL as the concentration level at which effects begin to occur that warrant avoidance. For convenience, the probability that an observed blood lead value will exceed 10 µg/dL is referred to as P10. The EPA has established a health-based goal there should be no more than a 5% chance that a child will have a blood lead value above 10 µg/dL. That is, if P10 is ≤ 5%, risks from lead are considered acceptable.

6.4.3 Overview of the IEUBK Model

The EPA has developed a mathematical model for evaluating lead risks to residential children. This model is referred to as the IEUBK model. This model requires as input data on the levels of lead in all potentially contaminated environmental media (soil, dust, water, air, diet) at a specific location, and on the amount of these media taken in (by ingestion or inhalation) by a child living at that location. Given these inputs, the model calculates an estimate of the distribution of blood lead values that might occur in a population of children exposed to the specified conditions, including the value of P10.

6.4.4 Inputs to the IEUBK Model

For most IEUBK model exposure parameters, the default values recommended by current EPA guidance were used. Data from the site were used to estimate:

- The average concentration of lead in outdoor surface soil at each property
- The average concentration of lead in indoor dust at each property
- The average concentration of lead in air (site-wide)
- The average concentration of lead in drinking water (site-wide)
- The relative bioavailability (absorbability) of lead in soil and dust

These data were then used to calculate the value of P10 at each property inside the final focus area that has not already been remediated by EPA.

6.4.5 Results

The results of the lead risk evaluation include the following key points:

- Of the 28,478 properties evaluated, a total of 19,445 homes (68%) are predicted to have P10 values at or below the health-based goal of 5%, and 9,033 properties (32%) have values that exceed the goal.
- Of these 9,033 properties, 3,177 have P10 values between 5% and 10%, 3,051 properties have P10 values between 10% and 20%, and 2,805 properties have P10 values greater than 20%.
- The location of properties with P10 values greater than the health-based goal of 5% were widespread across the OLS final focus area and were frequently found within all zip codes, with the exception of 68117 (which only had 2 properties).

These results indicate that a number of homes or parcels within the final focus area have soil lead levels that are of potential health concern to children who may reside there, now or in the future.

6.4.6 Uncertainties in the Evaluation of Risks from Lead

It is important to recognize that the exposure and risk calculations for lead presented in this section are subject to uncertainty that arises from a number of different sources. This includes:

- uncertainty in measured lead concentrations in soil
- uncertainty in estimated lead concentrations in indoor dust
- uncertainty in lead absorption from soil and dust
- uncertainty in the IEUBK model calculations and predictions

It is important to recognize that, because of these uncertainties, risk predictions for lead may not be highly accurate for every property, and risk managers and the public should take these uncertainties into account when interpreting the risk conclusions for lead at this site.

6.5 Evaluation of Risks from Non-Lead Contaminants

Although lead was the primary contaminant released to the environment from the historic operation of the smelters in the OLS, other metal and metalloid contaminants may also have been released. The purpose of this section is to provide an evaluation of the risks to area residents from these chemicals.

6.5.1 Exposure Assessment

The risk assessment focused on potential health risks to residents (both children and adults) from incidental ingestion of surface soil and indoor dust, as well as dermal contact with soil and indoor dust (when data permitted). Other pathways were judged to be sufficiently minor that quantitative evaluation was not warranted.

6.5.2 Quantification of Human Exposure

Exposure of residents (adults and children) to non-lead chemicals of potential concern in site soils and dusts was evaluated on a property-by-property basis. Exposure was calculated in accord with standard equations recommended by EPA. In brief, the amount of chemical ingested or absorbed per day from each medium was calculated from information on the concentration of the chemical in the medium and the amount of medium that is ingested or contacted. Because there are usually differences between individuals in the level of exposure due to differences in intake rates, body weights, exposure frequencies, and exposure durations, calculations were performed for individuals that are "average" or are otherwise near the central portion of the range, and on intakes that are near the upper end of the range (e.g., the 95th percentile). These two exposure estimates are referred to as Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME), respectively. Values of CTE and RME parameters for soil and dust were in accord with standard default values recommended by EPA for evaluation of residents. Because only limited data were available on the concentration of non-lead COPCs in residential yards, each yard was evaluated using the highest detected concentration of each chemical. This approach is expected to tend to overestimate actual exposure levels.

6.5.3 Toxicity Assessment

A toxicity assessment is usually divided into two parts: the first characterizes and quantifies the non-cancer effects of the chemical, while the second addresses the cancer effects of the chemical. This two-part approach is employed because there are typically major differences in the time-course of action and the shape of the dose-response curve for cancer and non-cancer effects.

Non-cancer effects of an ingested chemical are usually described in terms of a Reference Dose (RfD). An RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

For cancer effects of ingested chemicals, toxicity is usually expressed in terms of the Slope Factor (SF), which has dimensions of risk of cancer per unit dose. At this site, arsenic is the only chemical of potential concern that is known to cause cancer effects when ingested.

Toxicity values (RfD and SF values) for each non-lead COPC evaluated in this assessment were selected from EPA's database or other sources in accordance with EPA guidance. In the absence of site-specific data, the RBA for all non-lead chemicals in all media was assumed to be 1.0. This is expected to be a conservative assumption, tending to overestimate the true degree of absorption and risk.

6.5.4 Risk Characterization

6.5.4.1 Non-Cancer

The potential for non-cancer effects is evaluated by comparing the estimated daily intake of the chemical over a specific time period with the RfD for that chemical derived for a similar exposure period. This comparison results in a non-cancer Hazard Quotient (HQ), as follows:

HQ = DI / RfD

where:

HQ = Hazard Quotient
DI = Daily Intake (mg/kg-day)
RfD = Reference Dose (mg/kg-day)

If the HQ for a chemical is equal to or less than one (1E+00), it is believed that there is no appreciable risk that non-cancer health effects will occur. If an HQ exceeds 1E+00, there is some possibility that non-cancer effects may occur, although an HQ above 1E+00 does not indicate an effect will definitely occur. This is because of the margin of safety inherent in the derivation of all RfD values. However, the larger the HQ value, the more likely it is that an adverse effect may occur.

If an individual is exposed to more than one chemical, a screening-level estimate of the total non-cancer risk is derived simply by summing the HQ values for that individual. This total is referred to as the Hazard Index (HI). If the HI value is less than 1E+00, non-cancer risks are not expected from any chemical, alone or in combination with others. If the screening level HI exceeds 1E+00, it may be appropriate to perform a follow-on evaluation in which HQ values are added only if they affect the same target tissue or organ system (e.g., the liver). This is because chemicals which do not cause toxicity in the same tissues are not likely to cause additive effects.

6.5.4.2 Cancer

The excess risk of cancer from exposure to a chemical is described in terms of the probability that an exposed individual will develop cancer because of that exposure by age 70 which is considered a lifetime. For each chemical of concern, this value is calculated from the daily intake of the chemical from the site, averaged over a lifetime (DI_L), and the SF for the chemical, as follows:

$$\text{Excess Cancer Risk} = 1 - \exp(-DI_L * SF)$$

Excess cancer risks are summed across all chemicals of concern and all exposure pathways that contribute to exposure of an individual in a given population.

The level of total cancer risk that is of concern is a matter of personal, community, and regulatory judgment. In general, the EPA considers excess cancer risks that are below about 1E-06 to be so small as to be negligible, and risks above 1E-04 to be sufficiently large that some sort of remediation is desirable. Excess cancer risks that range between 1E-04 and 1E-06 are generally considered to be acceptable, although this is evaluated on a case by case basis, and EPA may determine that risks lower than 1E-04 are not sufficiently protective and warrant remedial action.

6.5.5 Results

6.5.5.1 Non-Cancer Risks

The estimated non-cancer risks from most COPCs in surface soils for residential CTE and RME scenarios, including both children (age 0-6 years) and adults (age 7-30 years), are below a level of potential concern ($HQ \leq 1$) for both child and adult residents. An exception is arsenic, which results in an $HQ > 1$ at about 10 percent of the properties. In addition, there are a small number of properties (< 1 percent of the total) where antimony, mercury and/or thallium yield HQ values above 1. Summation of non-cancer HQ values for chemicals that act on the same target tissue does not result in a substantial increase in non-cancer risk at most properties.

6.5.5.2 Cancer Risks

The only COPC at this site that is carcinogenic by the oral or dermal route is arsenic. As seen, estimated cancer risks to CTE residents are within EPA's target risk range (1E-06 to 1E-04) at all properties. Estimated risks to RME residents are also within EPA's target risk range at most properties, although risks exceed 1E-04 at 141 locations (5% of the properties with data). The excess individual lifetime cancer risks at these 141 properties range from 1E-04 to 1E-03.

6.5.5.3 Summary of Risks from Non-Lead COPCs

Based on the evaluations described above, the frequency of properties with chemical-specific HQ values or organ-specific HI values above 1E+00 is very low except for arsenic. At some properties, the concentrations of arsenic are sufficient that, if the soil is ingested by child and/or adult residents over a long period of time, the risk of both cancer and adverse non-cancer effects would be higher than normally considered acceptable by USEPA.

6.5.6 Uncertainties

Quantitative evaluation of the risks to humans from environmental contamination is frequently limited by uncertainty regarding a number of key data items, including concentration levels in the environment, the true level of human contact with contaminated media, and the true dose-response curves for non-cancer and cancer effects in humans. This uncertainty is usually addressed by making assumptions or estimates for uncertain parameters based on whatever limited data are available. In general, the assumptions are intentionally conservative, such that risk calculations based on the assumptions are more likely to overestimate than underestimate actual human exposure and risk. It is important for risk managers and the public to keep this in mind when interpreting the results of a risk assessment.

7.0 Summary and Conclusions

7.1 Summary

The following sections summarize conclusions regarding the nature and extent of contamination at the OLS.

7.1.1 Soil at Residential Properties

Between March 1999 and February 2009, surface soil samples were collected from 37,076 residential, EBL, and child care properties within the Omaha Lead Site and analyzed for lead. The properties were relatively evenly distributed throughout the expanded Focus Area in the site and represent lead concentrations in surface soil in all areas of the site. At the time this RI Report was prepared, soil samples had not been collected from the northern or western portion of the OLS defined as the Final Focus Area.

Of the 37,076 properties sampled in the investigation, 8,552 properties had at least one non-foundation sample with a total lead concentration between 400 ppm and 800 ppm and 4,144 properties had at least one non-foundation sample with a total lead concentration greater than or equal to 800 ppm, which is the lead concentration that triggers a response under the Interim ROD. Approximately 23 percent of the properties sampled contained lead concentrations between 400 ppm and 800 ppm and approximately 11 percent of the properties sampled contained lead concentrations exceeding 800 ppm.

BVSPC conducted a drip zone width study to characterize the drip zone widths in the OLS Focus Area for a representative group of homes and determine if a single drip zone width applicable to all residences could be identified. The data indicate that soil lead concentrations drop below 400 ppm at approximately six feet from the exterior foundation wall, based on average lead concentrations in 6-inch intervals from the exterior foundation wall to 10-feet from the structures.

7.1.2 Interior Dust Sampling

7.1.2.1 2003 Investigation

Dust samples were collected from 159 properties within the site during October and November 2003. At each property where interior samples were collected, three vacuum dust samples were collected from the floor and one wipe sample was collected from a window sill.

There are no EPA criteria for defining acceptable lead concentrations in the dust. The average lead concentration in the vacuum samples was 435 ppm and the median lead concentration in the vacuum samples was 232 ppm. The highest lead concentration detected in a dust sample collected with a vacuum was 15,900 ppm.

The EPA regulations under TSCA concerning lead concentrations in wipe samples are found in the Code of Federal Regulations at 40 CFR 745.227(h)(3)(i). The regulation specifies that a dust-lead hazard is present in a residential dwelling when the weighted arithmetic mean lead loadings for all single surface or composite samples of floors and interior window sills are equal to or greater than 40 $\mu g/ft^2$ for floors and 250 $\mu g/ft^2$ for interior window sills, respectively. Lead concentrations in 31 of the wipe samples collected from the window sills exceeded 250 $\mu g/ft^2$.

7.1.2.2 2007 Investigation

Dust samples were collected from 98 properties during November and December 2007. At each property where interior samples were collected, one composite dust sample was collected from the floors of three rooms. One composite wipe sample was collected from the window sill, window trough, and floor of the home. Each composite wipe sample consisted of individual wipes collected from similar surfaces in the living area and two bedrooms in the home.

The lead concentrations in the vacuum samples ranged from 9.4 ppm to 3,810 ppm. The average lead concentration in the vacuum samples was 380 ppm and the median concentration was 232 ppm. The lead concentrations in 25 of the wipe samples collected from the window sills were equal to or exceeded 250 $\mu g/ft^2$ and the lead concentrations in 5 of the wipe samples collected from the floors were equal to or exceeded 40 $\mu g/ft^2$.

7.1.3 Potable Water

Potable water samples were collected in November and December 2007 from each residence where indoor dust samples were collected. The samples were analyzed for lead and the analytical results were compared to the EPA MCL for lead (15 µg/L). The potable water from one property contained lead concentrations for the first flush sample and post flush sample of 48.8 µg/L and 634 µg/L, respectively. The potable water at the home was re-sampled in April 2008 and the lead concentrations were 10.2 µg/L and 4.7 µg/L, respectively. There were no residences where the potable water samples contained lead concentrations exceeding the EPA MCL.

7.1.4 Lead Based Paint Assessments

BVSPC has performed LBP assessments at more than 2,894 properties since the beginning of 2006. LBP assessments are ongoing and the number of assessments is being continuously updated. The data from the LBP assessments indicated that there were 1,335 properties where deteriorating LBP, if it were to fall onto the ground surface within six feet of the foundation and be uniformly mixed with the top one inch of soil, would result in an increase in the lead concentration in the soil to more than 400 ppm.

7.1.5 LBP Recontamination Study

Soil samples were measured at one group of 25 properties prior to LBP stabilization and another group of 21 properties following completion of LBP stabilization. The overall average lead concentration of all samples collected at pre-stabilization properties was 113 ppm, compared to an overall average concentration of all post-stabilization samples of 73 ppm. All pre-stabilization drip zone samples averaged 148 ppm, compared to a post-stabilization drip zone sample average of 95 ppm. Samples collected from 6-10 feet from the foundation averaged 51 ppm at pre-stabilization properties and 41 ppm at post-stabilization properties.

Soil samples collected within 6 feet of the foundation at pre-stabilization properties exceeded 400 ppm at 11 of 25 properties in 49 of 588 (8.3%) individual soil samples. Soil samples collected at a distance of 6-10 feet from the foundation at pre-stabilization properties exceeded 400 ppm at two properties in 2 of 357 (0.6%) individual soil samples.

Following LBP stabilization and HEPA vacuuming of exposed surface soils, the incidence and magnitude of elevated soil lead levels was greatly reduced. Soil samples collected within 6 feet of the foundation at post-stabilization properties exceeded 400 ppm at 10 of 21 properties in 21 of 483 (4.3%) individual soil samples. Following LBP stabilization, none of the 327 samples collected from 6-10 feet from the foundation exceeded 400 ppm

Average soil lead concentrations along transects generally remained below 400 ppm, except in four instances at pre-stabilization properties when a single transect average exceeded 400 ppm. In each case, the average soil lead concentration along the accompanying transect at the same property remained less than 400 ppm. The average soil lead concentration within 6 feet of the foundation at all post-stabilization properties was less than 400 ppm. Average soil lead levels at distances from 6-10 feet of the foundation was less than 400 ppm at all pre-stabilization and post-stabilization properties.

The data indicate that the majority of the elevated lead concentrations were confined to the area within 6 feet of the foundation of the home. The individual sample results along each transect were highly variable. None of the transects showed a consistent pattern of individual sample results exceeding 400 ppm. The data also indicate that soil lead concentrations were lower and less frequent at properties sampled following paint stabilization and HEPA vacuuming of exposed soils to remove visible paint chips.

Correlation was observed between the degree of LBP deterioration and soil lead concentrations at pre-stabilization properties. Elevated soil lead concentrations were the highest and most consistent at properties with a high degree of LBP deterioration. This same correlation was not observed at post-stabilization properties following HEPA vacuuming of exposed surface soils.

7.1.6 Small Parks

During April to June 2006, BVSPC collected soil samples from 39 small parks with an area less than 10 acres. Soil samples from high child impact areas at four small parks (Christie heights Park, Columbus Park Community Center, Himebaugh Park, and Sherman Community Center) were previously collected by Sverdrup Environmental, Inc., and these parks were not resampled.

The lead concentrations in one sample from 29th & Blondo Park (438 ppm) and three samples from Kellom Greenbelt Park (404 ppm, 477 ppm, and 554 ppm) exceeded 400 ppm. The locations where these samples were collected were not high child impact areas. However, the locations were resampled and the lead concentrations were below 400 ppm (293 ppm, 172 ppm, 156 ppm, and 266 ppm, respectively).

7.1.7 Large Parks

During July 2007, BVSPC collected soil samples from 15 large parks containing an area greater than 10 acres. Lead concentrations were detected above the 400 ppm screening level in three parks. Three soil samples from Levi Carter Park contained lead concentrations of 400 ppm, 401 ppm, and 542 ppm, respectively. One soil sample from Miller Park had a lead concentration of 416 ppm and one soil sample from Spring Lake Park contained a lead concentration of 539 ppm.

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Figures

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Omaha Lead Site
Final Remedial Investigation Report

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Omaha, Nebraska

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EPA Contract No.: EP-S7-05-06
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