LEAD HEALTH RISK ASSESSMENT
FOR RICO TOWNSITE SOILS

RICO, COLORADO

Submitted to
Colorado Department of
Public Health and Environment

Submitted by
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ACRONYMS AND ABBREVIATIONS

AF	absorption fraction
AR	Atlantic Richfield Company
ALM	adult lead methodology
bgs	below ground surface
BKSF	biokinetic slope factor
CDC	Centers for Disease Control and Prevention
CDPHE	Colorado Department of Public Health and Environment
CSM	conceptual site model
DL	detection limit
EF	exposure frequency
EPC	exposure point concentration
FDA	Food and Drug Administration
GSD	geometric standard deviation
HHRA	human health risk assessment
ICP	inductively coupled plasma
ICP-AES	inductively coupled plasma-atomic emission spectrometry
IEUBK	integrated exposure uptake biokinetic model
IR	intake rate
NHANES	National Health and Nutrition Evaluation Survey
OSWER	Office of Solid Waste & Emergency Management
P10	probability of blood level value > than 10
PbB	predicted blood lead levels
PbB_0	"baseline" blood lead level
PbS	soil lead concentration
QA/QC	quality assurance and quality control
RBA	relative bioavailability adjustment
RBCs	risk-based concentrations
RfD	reference dose
RME	reasonable maximum exposure
SAP	sampling and analysis plan
SOPs	standard operating procedures
TDS	total diet study
TRW	Technical Review Workgroup
UCLM	upper confidence limit on the mean
USEPA	U.S. Environmental Protection Agency
VCUP	Voluntary Cleanup Plan
XRF	x-ray fluorescence analysis

EXECUTIVE SUMMARY

This report presents the results of a human health risk assessment conducted to quantify potential human exposures to lead in soil and identify health-protective risk-based concentrations to guide soil remediation activities within the town of Rico, Colorado (the Townsite). This risk assessment is being conducted to support approval of a Voluntary Cleanup Plan (VCUP) submitted to the Colorado Department of Public Health and the Environment (CDPHE) for Townsite soils (SEH 2004).

The VCUP sampling investigation included Townsite soils within the town limits, as well as portions of residential planned unit development areas and other properties immediately contiguous to the east, south, and west of the current town limits (SEH 2005). Emphasis was given to residential, commercial, public, and open space (recreational) parcels in the existing developed portions of Townsite that were expected to have the highest concentrations of lead.

In general, soil samples were collected from the near-surface (0 to 2 inches below ground surface) to best represent potential human exposures. Within the developed areas (Zone 1), composite soil samples were collected from multiple areas within properties, including dirt driveways. Discrete (i.e., not composited) samples were also taken from play areas in residential lots. Samples from undeveloped areas (Zone 2) were collected as discrete samples. Additional samples were collected from source materials (i.e., discrete, identifiable mine waste deposits) in both Zone 1 and Zone 2, the Dolores River east overbank corridor, background soils and bedrock, and Town streets.

This risk assessment was performed because the State of Colorado does not have an applicable soil standard for lead. USEPA (2002b) has a screening level of 400 mg/kg for soil lead, but this value is not a cleanup level. Rather, exceeding a screening level suggests that a further evaluation of the potential risks posed by site contaminants is appropriate to determine the need for a response action (USEPA 2002b).

Health risks associated with lead exposures are assessed by determining the potential to exceed a concentration of lead in blood that is associated with increased potential for adverse health effects (CDC 1997, 2002; USEPA 1998). The Centers for Disease Control and Prevention (CDC) and USEPA have adopted 10 micrograms lead per deciliter of blood (μg/dL) as a risk management action level for children. Site-specific risk assessments are performed to determine the risk that exposures will result in blood lead concentrations at or above this level (USEPA 1994, 1998).

Lead is widespread in the environment, and exposure occurs from many different sources, including drinking water affected by lead pipes or solder or brass fittings, imported lead-glazed ceramics, lead-painted toys, occupational exposures and hobbies that use lead solder, and other sources. Thus, blood lead concentrations reflect integrated exposures from multiple sources, rather than just site-related exposures. Lead levels in the blood change relatively quickly in response to changes in exposures. Therefore, blood lead data for an exposed population reflect recent exposures.

Comprehensive studies of large communities can be used to assess the range of exposures to lead in soil if the studies are conducted during late summer when contact with soil is expected to be greatest. Concurrent sampling of soil, dust, drinking water and paint is needed to examine the relative contributions of all environmental sources. Questionnaires are also administered to characterize the study population and to identify other activities that could contribute to lead exposures. The limited blood lead data available for Rico (33 residents tested in April 2004 and 16 residents tested in June 2004) is considered to serve as a preliminary assessment. None of the residents tested had blood lead levels at or above the target blood lead level. The data suggests that blood lead levels of the residents may increase during the summer when soils are more accessible; however, due to the small sample size and lack of information on other potential sources of lead exposure for those sampled, no definitive conclusion can be drawn.

Comprehensive blood lead studies cannot be conducted in every community evaluated. Therefore, two toxicokinetic models have been developed for use in predicting potential blood lead levels in children and adults exposed to lead in soils and indoor dust. These models are recommended by USEPA as primary risk assessment tools for establishing risk-based remediation goals at residential and non-residential sites.

The child lead exposure model is called the *Integrated Exposure Uptake Biokinetic Model for Lead in Children* or IEUBK model. This model is used to estimate the probability that children will have blood lead levels exceeding the risk management action level of 10 µg/dL. The child lead exposure model was utilized in this risk assessment to evaluate residential property within the Townsite boundaries. The adult lead exposure model is called the *Adult Lead Methodology* or ALM model. This model is used to estimate the probability that the fetus of a pregnant woman will have a blood lead level exceeding the risk management action level of 10 µg/dL. Protection of the fetus is considered the most sensitive health endpoint for adults. The adult lead exposure model was used to evaluate commercial properties. Open space along the river corridor designated for recreational use was evaluated using both models.

Reliable site-specific estimates of exposure and risk using the child and adult lead exposure models depend on site-specific information for a number of key input parameters, including lead concentration in soil, dust and drinking water at the site, intake rates of each of these exposure media, and the rate and extent of lead absorption from each medium. Because not all of the lead entering the body through the gastrointestinal tract is actually absorbed into the systemic circulation, the models also incorporate differences in the bioavailability of lead from different exposure media (i.e., diet, drinking water and soil). This risk assessment incorporates the findings of site-specific studies of the bioavailability of lead in Rico soils.

Soil exposure point concentrations were calculated for each individual residential property, while for commercial/industrial and recreational properties a single soil concentration was calculated as an upper confidence limit on the mean (UCLM) concentration from the selected data set.

For both lead exposure models, a matrix of results was calculated by utilizing multiple values for certain parameters. Since the population of Rico is too small to derive site-specific inputs for all parameters, a combination of USEPA defaults and alternate values derived from similar communities was utilized. In the child exposure model (IEUBK model), alternate values in addition to the default values were used for soil ingestion rate, soil-dust relationship, and geometric standard deviation (which measures variability in blood lead levels). In the adult lead model (ALM model), both default and alternate values were selected for the soil ingestion rate, absorption fraction from water and diet, and geometric standard deviation. By running the models with different combinations of parameter values, the results can be presented as a range of outputs that represent the range of possible risks from exposure to Rico soils.

USEPA has a risk management goal that there be no greater than a 5% risk that blood lead levels in a child or in the fetus of a pregnant woman will exceed the target blood lead level of 10 µg/dL. In USEPA jargon, this probability is termed a "P10 of 5%". For the 355 residential properties evaluated using the child lead exposure model (IEUBK model) with a site-specific bioavailability estimate and default values for the rest of the input parameters, the number of properties exceeding a P10 of 5% prior to remediation is 228 (64.2%). Use of alternate values for soil ingestion, dust concentration estimates and geometric standard deviation that are expected to better predict conditions in Rico result in a range of from 13 (3.7%) to 231 (65.1%) properties exceeding the P10 value. Varying the soil ingestion rate had the greatest impact on the risk results. When USEPA defaults were selected for the soil ingestion rate, the number of properties exceeding a P10 of 5% was always greater than 50%, regardless of the other input parameters, but when selecting more likely soil ingestion values, fewer than 50% exceeded this risk level.

It should be noted that there are far fewer than 355 residences in Rico. There are only 220 water hook-ups to buildings in Town, including commercial and industrial buildings, indicating that many of the residential lots do not have houses on them. In addition, more than 40 of the properties tested are in the undeveloped area. The risk estimates presented essentially assume that all of these properties are developed and have young children in residence.

Based on the results of the sampling effort 35 of the residential properties with higher soil lead concentrations were remediated during 2004 and 2005. All of these properties cleaned in 2004 and 2005 were assumed to have a P10<5% post remediation. Using the site-specific bioavailability and other default assumptions, the number of properties with a P10>5% post remediation (January 2006) is 193 (54.4%). Using alternate assumptions the number exceeding the P10 ranges from 8 (2.3%) to 196 (55.2%) depending on parameter inputs.

Risk-based concentrations (RBCs) to serve as a guide for planning remediation for residential areas were determined using the IEUBK model for the base case (i.e., site-specific bioavailability and IEUBK default values for the rest of the input parameters), as well as for other combinations of parameter values more likely to represent conditions in Rico. Specifically, a dust concentration algorithm expected to more accurately represent the baseline dust concentrations for older housing such as that present in some areas of Rico was selected. Newer housing is expected to have even lower dust lead concentrations than those assumed. Lower soil ingestion rates were also used, including the rate found to best predict blood lead concentrations in Leadville, CO. A lower value for geometric standard deviation was also selected that was more consistent with geometric standard deviation values observed in other relatively homogeneous Rocky Mountain communities. For each of these cases, the soil concentration corresponding to the P10>5% was selected as the RBC. The RBC for the base case using the site-specific bioavailability value and default values for the other assumptions was 356 mg/kg. RBCs for alternate assumptions ranged from 794 to 3650 mg/kg.

Commercial/industrial properties were evaluated using scenarios for indoor workers and for seasonal outdoor workers. The ALM modeling results were generated based on an exposure point concentration of 1,496 mg/kg, which is the UCLM of concentrations for composite soil samples collected from 25 commercial/industrial properties. For the base case, the probability that fetal blood lead will exceed 10 μg/dL is 8.1%. All of the other combinations of alternative and default values result in less than a 5% probability of fetal blood lead exceeding10 μg/dL. Thus it is only with highly conservative default assumptions that exceedances of the target blood lead level is predicted.

The RBC for commercial/industrial areas based on the indoor worker scenario was determined to be 1,090 mg/kg for the base case. Use of geometric standard deviations more representative of Rocky Mountain communities yielded RBCs of 1,670 and 2,223 mg/kg for geometric standard deviations of 1.8 and 1.6, respectively. Use of alternate values for bioavailability and soil ingestion resulted in RBCs ranging from 2,725 to 13,998. The base case risk-based concentration is lower than the UCLM, and eleven sampled properties exceed this value. The upper end of this range is not exceeded at any sampled properties that are identified for commercial and industrial uses.

For outdoor workers the probability that a fetus will have a blood lead level greater than 10 μg/dL is 8.7% for the base case. All of the other combinations of alternative and default values result in less than a 5% probability of fetal blood lead exceeding 10 μg/dL. Thus it is only with highly conservative default assumptions that exceedances of the target blood lead level is predicted. It should be noted that these values are likely conservative when evaluating risk over a whole year. The averaging time in this scenario was determined to be 20 weeks, which is the time period when outdoor work is likeliest. The modeling results do not take into account a wash-out period that is likely to occur as outdoor worker exposure will decrease significantly, if not cease altogether, during the winter months.

The RBC for commercial/industrial workers for the outdoor worker scenario was 1,040 mg/kg for the base case. Use of geometric standard deviations more representative of Rocky Mountain communities yielded RBCs of 1,594 and 2,122 mg/kg for geometric standard deviations of 1.8 and 1.6, respectively. Use of alternate values for bioavailability and soil ingestion resulted in RBCs ranging from 2,601to 13,362. Due to the small size of most properties outdoor workers are likely to spend time at multiple commercial / industrial properties in a day or to only spend a fraction of time each week working outdoors, so these results are best compared to the UCLM soil concentration of 1496 mg/kg, rather than individual property soil concentrations.

The Dolores River corridor was assessed using recreational scenarios for both children and adults that assumed intermittent exposures during the 20 warmest weeks of the year. The dataset used samples collected from 35 locations in the Dolores River corridor (Table A-3). The mean lead concentration was 4,915 mg/kg, and the UCLM was 11,468 mg/kg. The concentrations ranged from 128 to 43,100. Only 4 samples exceeded the UCLM which was very high due to a small number of samples collected at locations suspected of containing mine waste, i.e., “hot spots”.

For adult visitors, the river corridor base case RBC of 4,578 mg/kg was exceeded at 11 individual river floodplain properties, while the other RBCs (ranging from 7,013 to 58,793 mg/kg) were exceeded at 4 to 5 properties. For child visitors, RBCs were identified using a USEPA intermittent exposure model that apportions exposures between the child’s residence and a secondary location such as the river corridor. This model requires that an overall risk-based target soil concentration first be identified and then various lower values are selected for the residential RBC and the model is run to identify the allowable RBCs for the secondary location.

This approach was used to derive risk-based soil concentrations for the river corridor by selecting four possible overall target RBC values from the range of results of the IEUBK modeling. It was then assumed that a child resident receives 14%, i.e., one-seventh, of the weekly exposure to soil and dust from river corridor soils for 20 weeks during the warmer season. This equates to approximately 30% of outdoor soil intake from the river corridor and the remaining 70% of soil intake from the home yard (based on USEPA’s assumption that more than 50% of soil and dust intake is due to intake of indoor dust).

For example, using an overall target RBC of 1400 mg/kg, and assuming a residential soil action level of 1200 mg/kg, the resulting RBC for the Dolores River corridor is 2,600 mg/kg. For an overall target RBC of 1,600 mg/kg and residential soil action level of 1200 mg/kg, the resulting river corridor RBC is 4,000 mg/kg. With an overall target RBC of 1,200 mg/kg and a residential action level of 1,000 mg/kg, the RBC at the Dolores River corridor is 2,400 mg/kg. The apportionment of the total residential RBC value between residential and river corridor soils can be varied to identify the combination that minimizes the area to be remediated.

Uncertainties in lead exposure estimates have been explored by use of a matrix approach to present results for the model default values and for alternate values that are likely to better represent exposures in other communities with characteristics similar to Rico. These analyses have found a wide range of predicted potential exposures. Additional assumptions not evaluated quantitatively may have contributed to predicting higher blood lead levels than are likely to occur, e.g., the dietary lead intakes used in the IEUBK model may overestimate current lead intakes from the diet. For the ALM, the biokinetic slope factor used was at the high end of the range of values calculated in various analyses.

Selection of sample locations biased toward high soil lead concentrations may also have contributed to overestimation of exposures. Sample locations in all three property types (residential, commercial/industrial, and recreational) were selected with emphasis placed on locations expected to have the highest soil lead concentrations. As such, the datasets are expected to be biased high, and results from this assessment may be overly conservative. In addition, 35 of the residential properties with generally the highest lead concentrations among all occupied residential properties have already been remediated.

Another source of uncertainty is the fact that populations living at higher altitudes have higher red blood cell levels. Because more than 95% of blood lead is typically found in red blood cells, high altitude populations may have higher blood lead levels relative to body burden than sea level populations. The blood lead level of concern of 10 μg/dL is based on populations at sea level and may be conservative for high altitude populations. Based on the Townsite's minimum elevation of 8,700 ft, the blood lead levels comparable to the target blood lead level of 10 μg/dL could range from 11.0 to 11.3 μg/dL for Rico residents. Although this factor has not been assessed quantitatively in this risk assessment, it provides an additional protective factor that should be considered when determining what RBCs should be selected.

It should be noted that the purpose of the human health risk assessment is to provide information concerning potential risks posed by contaminants at the site as necessary to help guide selection of particular response actions or remedies. The risk assessment results are not intended to specify how property-specific remediation goals will be met (e.g., the nature and extent of soil removal, if any, at a property where the risk-based action level is exceeded). If actions are determined to be necessary, the exact remediation approach should be addressed separately from the risk assessment.

1 INTRODUCTION

This report presents the results of a human health risk assessment (HHRA) conducted to quantify potential human exposures to lead in soil and identify health-protective risk-based concentrations (RBCs) to guide soil remediation activities within the town of Rico, Colorado (the Townsite). This HHRA is being conducted to support approval of a Voluntary Cleanup Plan (VCUP) submitted to the Colorado Department of Public Health and the Environment (CDPHE) for Townsite soils (SEH 2004). The Townsite was the location of a variety of mining and mineral processing activities for more than a century. These activities were driven by the presence at ground surface of a highly mineralized ore body. A by-product of both the ore bodies and the mining and mineral processing activities is the occurrence of elevated metal concentrations in Townsite soils. Of the metals, only lead is present in sufficient concentrations to present a potential health risk (SEH 2004).

The purpose of this HHRA is to characterize the nature and magnitude of potential soil lead exposures by residents, workers, and visitors to the Townsite. More specifically, the HHRA focuses on the direct and indirect potential lead exposures derived from soils in current residential, commercial/industrial, and recreational Townsite areas, as well as certain areas of proposed future residential development within the Townsite. As part of the HHRA, health protective RBCs are developed to guide cleanup actions.

Overall, the results of this HHRA are intended to help inform state and local agencies and the public about the level of exposure that may be attributable to lead in Townsite soils, to guide the extent of cleanup at the site, and to provide a basis for determining the levels of lead that can remain in Townsite soils while still ensuring protection of public health.

The methods employed in this assessment to evaluate risks to humans are consistent with current guidelines provided by the U.S. Environmental Protection Agency (USEPA) for use at lead-contaminated sites (USEPA 2002b, 2003b), and are comparable with the methods used by USEPA Region 8 at similar sites (USEPA 2001, 2003c).

1.1 OVERVIEW OF RISK ASSESSMENT APPROACH

Applicable standards for lead in soil are not available from the State of Colorado. On the federal level, USEPA's (2002b) *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (hereafter called the "Soil Screening Guidance") identifies a generic (i.e., not site-specific) screening level of 400 mg/kg for lead in soil. According to the "Soil Screening Guidance," soil screening levels should not be considered national cleanup values; and concentrations in soil above the screening level do not automatically trigger a response action. Rather, exceeding a screening level suggests that a further evaluation of the potential risks posed by site contaminants is appropriate to determine the need for a response action (USEPA 2002b). The State of Colorado has no similar guidance for lead concentrations in soils.

Health risks associated with lead exposures are assessed by determining the potential to exceed a concentration of lead in blood that is associated with increased potential for adverse health effects (CDC 1997, 2002; USEPA 1998). The Centers for Disease Control and Prevention (CDC) and USEPA have adopted 10 micrograms lead per deciliter of blood (µg/dL) as a risk management action level for children. Agency management decisions seek to limit exposures that result in blood lead concentrations at or above this level by using site-specific risk assessments to reduce the likelihood that such exposure will occur (USEPA 1994, 1998).

Two models have been developed for use in predicting potential blood lead levels in children and adults exposed to lead in soils, and are recommended by USEPA as primary risk assessment tools for establishing risk-based remediation goals at residential and non-residential sites where exposure to soil lead is a concern. These models are the *Integrated Exposure Uptake Biokinetic* (IEUBK) *Model for Lead in Children* and the *Adult Lead Methodology* (ALM). The IEUBK model was utilized in this HHRA to evaluate residential properties identified within the Townsite boundaries, while the ALM model was used to commercial properties. Open space along the river corridor designated for recreational use was evaluated using both the ALM and the IEUBK model (via an intermittent exposure approach).

USEPA's Office of Solid Waste and Emergency Response (OSWER), uses the IEUBK model to predict the potential lead levels in children exposed to lead in the environment. The risk reduction goal described in the guidance and recommended by USEPA is intended to "…limit exposure to soil lead levels such that a typical (or hypothetical) child or group of similarly exposed children would have an estimated risk of no more than 5% of exceeding a 10 µg/dL blood lead level" (USEPA 1994, 1998).

For non-residential exposures to soil lead, USEPA's Technical Review Workgroup (TRW) for lead recommends use of the ALM (USEPA 2003c). The ALM model equations are designed to be protective of a "fetus of a worker who develops a body burden as a result of non-residential exposure to lead." According to the TRW, protection of the fetus is the most health-sensitive endpoint for adult workers. This makes remediation goals using the ALM sufficiently protective of male or female adult workers in a non-residential setting. Similar to the IEUBK model for residential exposure, the ALM model equations identify RBCs that equate to no more than a 5% probability that fetuses of women exposed to soil lead would exceed a blood lead of 10 µg/dL (USEPA 2003c).

Exposure to lead can occur by many different pathways and from many different sources, in addition to site soils. Both the IEUBK and ALM models incorporate inputs to address the contribution of multiple sources or baseline exposures to blood lead predictions.

1.2 LEAD TOXICITY AND EXPOSURE ASSESSMENT SUMMARY

The objective of a toxicity assessment is to evaluate available information concerning a chemical's potential to cause adverse health effects and to understand the extent to which such effects will occur in relation to different kinds and levels of exposure (i.e., dose-response relationship). Whether or not a toxic effect occurs upon exposure to a particular chemical may depend on the route of exposure (oral, inhalation, dermal), the duration of exposure (subchronic, chronic or lifetime), as well as the exposed individual's inherent susceptibility to the effect (e.g., a young child may be more susceptible to a neurotoxicant than an adult due to critical stages of neurodevelopment occurring in the early years of life).

The toxicity assessment process is usually divided into two parts: evaluating potential cancer effects and characterizing and quantifying the non-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. Toxicity assessments for lead have been conducted by the CDC (1997, 2002) and Agency for Toxic Substances and Disease Registry (ATSDR) (1999, 2005). USEPA has just released an updated assessment in the draft *Ambient Air Quality Criteria Document for Lead* (2005a). A brief summary of lead toxicity is provided below.

1.2.1 Lead as a Carcinogen

The USEPA (2005c) has determined that lead is a probable (or B2) human carcinogen based on sufficient evidence of carcinogenicity in animals. Specifically, bioassays in rats and mice reported statistically significant increases in renal tumors with dietary and subcutaneous exposure to several soluble lead salts. The animal assays provided reproducible results in several laboratories, in multiple rat strains, and with some evidence of multiple tumor sites. Short-term studies indicated that lead affects gene expression. Human evidence of lead carcinogenicity was found to be inadequate. Despite the B2 classification, USEPA has determined that noncancer effects of lead provide a more sensitive toxicity endpoint than cancer effects, and no toxicity values have been derived for cancer endpoints.

1.2.2 Noncancer Effects of Lead

Lead can affect almost every organ and system in the body if exposures are sufficiently elevated (ATSDR 1999, 2005). The most sensitive among these are the central nervous system, hematological and cardiovascular systems, and the kidney. It is important to note that many of lead's health effects may occur without overt signs of toxicity.

Lead has particularly significant effects in young children who are also likely to have the greatest exposure to environmental sources. Effects in children on the developing nervous system occur at very low absorbed doses and thresholds for these effects have generally not been identified. Deficits in social behavior, attention span and fine motor skills have been reported, as well as decreased reading and arithmetic skills. A decline of 1 to 5 IQ points has been associated with an increase in blood lead of 10 µg/dL (ATSDR 2005). The kinds of effects are the same at comparable absorbed doses whether lead is inhaled or ingested.

At high levels, lead may decrease reaction time; cause weakness in fingers, wrists, or ankles; and possibly affect the memory. High lead levels may cause anemia, a disorder of the blood. Lead can also damage the male reproductive system. The connection between these effects and exposure to low levels of lead is uncertain.

1.2.3 Target Blood Lead Levels

Health effects in humans associated with lead exposures are typically correlated with observed or predicted blood lead levels (PbB). As stated above, the CDC (2002) has identified a blood lead level of 10 µg/dL as the concentration above which further evaluation may be warranted for an individual child. The 10 µg/dL blood lead level was selected based on studies indicating that exposures resulting in blood lead levels at or above this concentration may present an increased health risk to children (CDC 1997, 2002; USEPA 1998).

Since the 2002 CDC evaluation, additional studies have been published examining the effects of low levels of lead on children's health. The CDC (2004) reviewed these studies and recently decided to retain the 10 µg/dL blood lead level of concern for three reasons:

- "No effective clinical interventions are known to lower blood lead levels for children with levels less than 10 µg/dL or to reduce the risks for adverse developmental effects.
- Children cannot be accurately classified as having blood lead levels above or below 10 µg/dL because of the inaccuracy inherent in laboratory testing.
- Finally, there is no evidence of a threshold below which adverse effects are not experienced. Thus, any decision to establish a new level of concern would be arbitrary and provide uncertain benefits."

1.2.4 Blood Lead as a Biomarker of Exposure and Risk

Lead levels in the blood change relatively quickly in response to changes in exposures. Therefore, blood lead data for an exposed population reflect recent exposures. Comprehensive studies of large communities can be used to assess the range of exposures to lead in soil if the studies are conducted during late summer when contact with soil is expected to be greatest. Concurrent sampling of soil, dust, drinking water and paint is needed to examine the relative contributions of all environmental sources.

Questionnaires are also administered to characterize the study population and to identify other activities that could contribute to lead exposures.

Comprehensive blood lead studies cannot be conducted in every community evaluated. Therefore, lead exposures and risks are typically assessed using toxicokinetic models that predict blood lead concentrations rather than calculating an estimated dose and comparing that dose to a dose that is not associated with any adverse effects, i.e., a reference dose (RfD), as is done in evaluating other chemicals. These models are recommended by USEPA as primary risk assessment tools for establishing risk-based remediation goals at residential and non-residential sites. The IEUBK model and ALM model are described in detail in Section 4.

1.2.5 Assessment of Preliminary Rico Blood Lead Survey

Blood lead testing of Rico Townsite residents, selected on a voluntary basis, was conducted in April and June of 2004. A total of 33 residents participated in April and 16 residents participated in June. Due to the need to maintain confidentiality of individual records, it is not known if any individual residents were sampled in both April and June. The limited blood lead data available for Rico provides important information, but is considered a preliminary assessment.

All blood lead levels were below the calculated target risk management level for the Townsite and CDC's and USEPA's blood lead level of concern (i.e., 10 μg/dL), ranging from below the detection limit (1 μg/dL) to 8.8 μg/dL (Table 1-1 and Appendix B). Blood lead levels were highest in the youngest age group, which is consistent with other populations. For all age categories, average blood lead levels were higher in June than in April. The consistency of this trend, while not conclusive, suggests that exposures to lead in soil and dust increase in the summer after snow melts and the soil dries. However, due to the small sample size and lack of information on other potential sources of lead exposure for those sampled, no definitive conclusion can be drawn. For both sampling dates, mean levels for women were slightly less than those for men in the adult age group, but this difference was not statistically significant.

1.2.6 Altitude and Blood Lead Levels

Hematocrit (the volume of red blood cells in the blood) and hemoglobin (iron containing pigment in red blood cells) levels in whole blood are affected by a variety of factors. Young children, people who are anemic, and pregnant women have lower hematocrits and decreased hemoglobin in their blood as compared with normal adults. Additionally, those residing at high elevations have higher hematocrits and increased hemoglobin in their blood to counteract lower oxygen levels in the air (UCDEH 1997). For example, an average child at sea level has a hematocrit of 35% while the value for that same child living at 10,300 ft above sea level (the elevation of Leadville, CO) is between 40 and 42% (UCDEH 1997).

The blood lead level of concern determined by the CDC and USEPA is 10 µg/dL and is based on studies conducted in sea level populations. Because the vast majority of lead (95% or more) in blood is bound to red blood cells, this blood lead level of concern may be overly conservative for populations with significantly higher red blood cell contents, such as those living at high elevations. Specifically, an individual who resides at a higher elevation will likely have more available binding sites for lead (UCDEH 1997) and a higher blood lead level than an identically exposed individual living at sea level.

A pharmacokinetic model developed by Dr. Ellen O'Flaherty indicated that this higher blood lead level is not associated with a corresponding increase in body burden (UCDEH 1997). Thus, risks associated with a blood lead level of 10 µg/dL in a lowlander population could correspond to a higher blood lead level in highlander populations. This model has not been accepted by USEPA, and includes several assumptions that require verification before this model could be accepted in considering alternate risk-based soil concentrations in site cleanups (Diamond 2006).

Hemoglobin and hematocrit levels tend to increase exponentially with elevation (Dirren et al. 1994). To derive an altitude correction for hemoglobin, they used hemoglobin data taken from Ecuadorian children aged 6 to 59 months with normal blood iron levels who lived at elevations ranging from 0 to 3365 m. The data were broken into 10 elevation groupings and mean hemoglobin and hematocrit levels for each were used for the exponential regression. Further, they compare their results for children to previously studied populations of adult males. This comparison demonstrated that the same correction factors apply to adults and to children.

The following equation was used to fit the data:

$$Hb = a \times e^{b \times ALT} + c$$

Where:

Hb = hemoglobin concentration (g/L)
ALT = altitude (m)
a, b, and c = constants calculated in the regression (see Table 1-1)

Rico, CO, is at an elevation of 8,700 ft (2,652 m) or more above sea level. Hemoglobin and hematocrit levels for 0 and 2,652 m were calculated using the equations from Dirren et al. (1994). Correction factors were then calculated by taking the ratio of the result at 2,652 m to the result at 0 m (see Table 1-2). Applying these correction factors to the CDC's 10 µg/dL blood level of concern would result in a range of 11.0 to 11.3 µg/dL as the comparable risk management level. As noted above, USEPA considers that these alternate values would require additional supporting research prior to application at a high elevation site.

1.3 REPORT ORGANIZATION

The remainder of this report is organized as follows:

- Section 2 describes the Townsite setting and soil investigations.
- Section 3 discusses exposure pathways and exposure point concentrations.
- Section 4 describes the lead exposure models and multiple input assumptions evaluated.
- Section 5 provides quantitative estimates of health risk and the derivation of RBCs for each exposure scenario evaluated. This section also describes uncertainties in the risk estimates.
- Section 6 includes the reference list.

2 BACKGROUND

This section presents background information relevant to characterizing potential health risks associated with Townsite soil lead exposures. An overview of the site setting, history, and origin of soil lead within the Townsite is provided along with a brief summary of prior soil lead investigations conducted in the Townsite area. This overview is followed by a more detailed discussion of the recent soil lead investigation conducted as part of the 2004 VCUP program and relied upon in this HHRA. The Final Data Report and Data Evaluation (SEH 2005) provides additional discussion of site mining background and geology, field sampling, and laboratory test methodology and results, and evaluation of the distribution and inferred origin of lead in the Townsite soils.

2.1 SITE SETTING AND HISTORY

The Townsite is located in the southwest part of the San Juan Mountains where very steep mountain slopes, and sloping tributary stream valleys abruptly descend upon the gently to moderately sloping, and relatively narrow, Dolores River valley (Figure 2-1). Many of the steep draws and gulches formed on the hillsides on both sides of the Dolores River and its Silver Creek tributary are snow avalanche chutes. Elevations in the Townsite area generally range from over 12,000 feet at the crest of surrounding mountain peaks to about 8,700 feet in the Dolores River valley (SEH 2004). The elevation along the main street in the Townsite is greater than 8,800 ft.

The projected 2004 population size of the Townsite is 216 permanent residents (USCB 2006b), with additional residents during the summer. Based on 2000 census data (USCB 2006a), the median age of Townsite residents is 35.4 years. Children under 5 years old make up 5.4% of the population (or approximately 12 children in a population of 216), 3.4% of the population is over 65, and 41% consists of women. The population can be described as homogeneous, since 92.7% is of a single race (White) and over 80% is between 18 and 65 years of age (USCB 2006a).

The Townsite's first mining claim was staked in 1869. A variety of mining-related activities have occurred within and nearby the Townsite since that date. Identification of the locations and nature of specific activities conducted during the area's key historical periods of mining operation is summarized in the June 2004 *Rico Townsite Soils VCUP (Voluntary Cleanup Plan) Application* (SEH 2004), previously submitted to the CDPHE, and Part II of the Final Data Report (SEH 2005).

The VCUP proposes to address the presence of lead in Townsite soil at concentrations that may pose a potential health risk to residents through a phased investigation and cleanup. Atlantic Richfield (AR) Company, Rico Renaissance, LLC, and Rico Properties, LLC support this application as co-applicants. The Town of Rico also participates as a VCUP co-applicant, providing access to its properties for VCUP activities, and facilitating and coordinating public participation and access to non-applicant properties within the Townsite as needed for data gathering and cleanup activities.

Two prior VCUP's were completed during the 1990s to address specific waste areas in or near Rico (described in SEH 2004). Tailings and waste rock from several areas were consolidated at the Columbia Tailings site, and remediation of the Grand View Smelter site occurred. The current VCUP application (SEH 2004) addresses Townsite soils in areas of current residential, commercial/industrial, and recreational uses, as well as some adjacent areas with planned future residential uses (Figure 2-2).

2.2 ORIGIN OF LEAD IN SOILS

Due to the highly mineralized nature of the natural soils in the area, the relative contributions of historic mine operations, redistribution of mine waste source material, or natural background to soil lead concentrations within the Townsite is not clear. Colluvium soils are characteristic of the North and South Rico residential areas. These soils reflect highly mineralized zones that have generally higher soil lead concentrations than soils in the east and west slope wash areas, where the predominance of talus soils is consistent with lower soil lead concentrations.

Previous investigations (Walsh 1995; ARCO 1996a; Titan 1996; USEPA 2004a) have identified the presence of higher soil lead concentrations within the main residential areas of North Rico, South Rico, and the Silver Creek Alluvium residential planned unit development, where colluvium soils predominate, and lower soil lead in proposed future residential zones along the east and west slope wash areas, where talus soils are present. Prior statistical comparisons between area-specific site and background soil lead values further support these relationships (SEH 2004). More detailed discussion of the origin of lead in Townsite soils is provided in the VCUP application (SEH 2004).

Part II of the Final Data Report presents detailed analysis of the distribution and inferred origin of soil lead based on the comprehensive sampling and laboratory analysis (SEH 2005). In this report, SEH (2005) concluded that "in addition to mining impacted areas, the surficial sediments and soils in the Rico Townsite area contain elevated lead concentrations from natural sources due to the presence of near surface bedrock mineralization and subsequent erosion and transport." A summary of the distribution and sources of lead in Townsite soils is provided below.

SEH (2005) states that the Rico Townsite "was developed primarily on natural surficial materials eroded from variably mineralized bedrock source materials" (SEH 2005). Previous studies conducted by Arco (1996) and CDPHE (1996), as well as SEH (2005) concluded that the mining waste materials could be distinguished from soils derived from erosion of bedrock materials. Natural soils and anthropogenic deposits each had a distinct statistical signature (SEH 2005). In general, mine waste materials in the Townsite are discrete and localized with the exception of mine waste used as road base for gravel roads.

Previous studies at the Townsite reported that lead concentrations in bedrock ranged from 13 to 39,700 mg/kg with a mean of 3,500 mg/kg, and that levels in undisturbed and disturbed colluvium averaged 1,400 and 1,790 mg/kg, respectively. The new sampling results are consistent with past study results with a median colluvium lead concentration of 1,420 mg/kg (SEH 2005). Lead levels in colluvium showed high concentrations at all depths with a slight trend toward increasing with increasing depth, supporting "the conclusion that the primary source of lead in this unit [colluvium] is naturally occurring (or background)" (SEH 2005). Previous studies found concentrations in alluvial fan deposits averaged less than 800 mg/kg. Median results from the more recent sampling are 829 and 501 mg/kg for the older fan deposits and more recent alluvial soils, respectively. SEH (2005) reports median lead levels in talus of 219 mg/kg, while results from the previous studies averaged 152 mg/kg. Based on the data from the 2004 sampling event and previous investigations, it can be concluded that background lead levels vary based on soil type and that background concentrations in excess of 1,200 mg/kg are likely to be found in colluvial soils.

2.3 SUMMARY OF SOIL LEAD INVESTIGATIONS

As delineated in the VCUP application (SEH 2004), five previous investigations (Walsh 1995; ARCO 1996a,b; Titan 1996; CDPHE 2003; USEPA 2004a) conducted in the study area vicinity included sampling and analysis of Townsite soils for lead. These prior studies were not designed to fully characterize the distribution of lead in the study area or to provide a basis on which remedial action decisions for lead in the Townsite could be made. Consequently, data from these studies are supplemented with sampling and analysis results generated as part of the current VCUP application to adequately characterize lead in soils in support of this HHRA.

An overview of the soil investigation activities conducted to support this HHRA is provided below. More detailed presentation of the investigation approach and findings are provided in the VCUP application (SEH 2004) and Part I Data Report (SEH 2005), respectively.

2.3.1 Description of the VCUP Townsite Investigation

The VCUP sampling investigation included Townsite soils within the town limits, as well as portions of the Silver Creek Alluvium development area and selected other properties immediately contiguous to the east, south and west of the current town limits. Emphasis was given to residential, commercial, public and open space (recreational) parcels in the existing developed portions of the Townsite that were expected to have the highest concentrations of lead, i.e., the dataset is expected to be biased high in terms of lead concentrations from the Townsite.

Field sampling and laboratory analysis was conducted in accordance with the process and procedures described in the VCUP application (SEH 2004). A sampling and analysis plan defined sampling zones and investigation boundaries, described the protocol for sampling locations and depths, and identified field methods and laboratory analytical parameters and procedures. Standard operating procedures (SOPs) were provided for sample collection and handling, field documentation, and laboratory analytical techniques. Quality assurance and quality control (QA/QC) procedures were also provided that specified project organization and responsibilities, sampling strategy, and analytical quality objectives. Field and sample handling QA/QC procedures were specified along with laboratory procedures and equipment QA/QC protocols. Internal and third-party data validation techniques and corrective action procedures were also specified.

Land use zones within the Townsite are shown in Figure 2-2. In addition, developed areas were distinguished from undeveloped areas in SEH (2004) as follows:

- Zone 1 residential, commercial, public, and open space (recreational) parcels in existing developed portions of the Town
- Zone 2 properties designated for future development.

It should be noted that some properties in Zone 2 have been developed since the initial classification.

Based on the review of land use information collected by Atlantic Richfield (Markle 2005, pers. comm.) and sampling location distribution maps (SEH 2005), individual properties were evaluated and categorized by land use category, and identified as residential (for the residential scenario, 355 properties), commercial/industrial or public buildings (for the indoor and outdoor worker scenarios, 25 properties), or as open space (for the recreational scenario, 34 properties). It should be noted that many of the residential properties are not currently developed. A Town representative has indicated that there are currently approximately 220 establishments with water hookups, providing an indication of the number of buildings that are currently in use as residences or businesses (Eric Heil, personal communication to Rosalind Schoof, December 14, 2005).

2.3.1.1. Types and Locations of Soil Lead Samples Collected

In general, soil samples were collected from the near-surface (0 to 2 inches below ground surface [bgs]) to best represent potential human exposures. Within Zone 1, yard soil samples consisted of a composite of five subsamples located randomly within a sampling area (e.g., back yard). Each sampling area was approximately 2,500 to 5,000 square feet in area. Driveway samples consisted of composites of two locations. One discrete surface soil grab sample was collected from small play areas on residential lots. Zone 2 samples were collected as discrete (i.e., not composited) samples.

All identifiable areas of mine waste or mining/ore processing source material within developed properties were sampled at the 0- to 2-inch depth. A minimum of two subsamples were composited into a single sample for analysis. Subsamples were collected at a rate of one subsample per 100 to 1,000 square feet.

Discrete depth samples were collected at various Townsite locations, including approximately one in every other block Zone 1 properties and one in every three Zone 2 properties. Depth samples were collected from 2 to 12 inches bgs and 12 to 18 inches bgs. Garden samples were collected over a depth of 0 to 12 inches to represent typical tilling depths.

More than 1,000 surface soil samples (0 to 2 inch soil depths), including surface samples, earthen driveway samples, garden samples, play area samples, mine waste samples, and source material samples, were collected from existing residential or commercial/industrial properties in developed areas.

A total of 61 samples were also collected over depth intervals of 2 to 12 inches and 12 to 18 inches at 32 locations in Zones 1 and 2. The results of these subsurface samples are not incorporated into exposure point concentrations evaluated in the HHRA, but they are characterized in SEH (2005).

Additional sample types collected included source materials (i.e., discrete, identifiable mine waste deposits) in both Zone 1 and Zone 2, the Dolores River east overbank corridor, background soils and bedrock, and Town streets. These samples were collected for the following purposes:

- Dolores River east overbank corridor—Sampling along the Dolores River at and between the historic Pro Patria mill/tailings site and the Columbia Tailings site was conducted to more fully characterize soil lead levels in this area where future open space/recreational land uses are planned.
- Background soil and rock—Background sampling and associated geologic mapping and mineral speciation analyses were conducted to identify soils at the site with naturally occurring versus mining-impacted elevated lead levels.
- Town streets—Surficial soils were sampled on unpaved Town streets. Each sample was a composite from two locations. Analytical results from this sample set were also used to assess the potential for recontamination of remediated yards/lots from dust and/or stormwater runon-runoff. These results are presented in the HHRA.

Samples collected along the proposed sewer line samples were collected at depth intervals of approximately 0 to 2 feet bgs and 2 to 4 feet bgs to represent typical excavation depths.

2.3.1.2. Description of Sample Categories

Samples were coded into 12 categories, as listed in Table 2-1. Sample identification as source material ("M") or mine waste ("W") was a field decision based on the judgment of the samplers. These materials were not always easy to identify, and there was some subjectivity in use of this designation. The identified materials may have been spread throughout the yard, mixed in, or located in distinct areas. Further discussion of the nature and distribution of mining-related materials at the Rico Townsite is provided in Part II (Data Evaluation) of the Final Data Report (SEH 2005). The fact that such material is not readily observed on the aerial photograph shows that these were not generally large, distinct piles. Thus, for the purposes of the risk assessment, samples designated "M" or "W" were included in the data sets used to evaluate lead in surface soils.

2.3.1.3. Analysis of Soil Lead Samples

Soil samples were prepared for laboratory analysis by passing the sample through a U.S. Standard No. 10 mesh sieve prior to analysis of lead according to laboratory-grade X-Ray fluorescence analysis (XRF) procedures (i.e., material > 2mm in diameter was excluded). In order to establish confidence in the accuracy of the XRF methodology, every tenth sieved sample analyzed for lead by XRF methods was split and submitted to HKM Laboratory of Butte, Montana, for total lead analysis by inductively coupled plasma-atomic emission spectrometry (ICP-AES) (SEH 2005). Procedures for both the XRF and ICP-AES analytical methods were included as part of the VCUP application (SEH 2004). The 10% confirmation rate was maintained for the duration of the investigation. Good agreement was observed between soil lead concentrations obtained through XRF and that from ICP-AES (SEH 2005), indicating that the XRF data could be relied upon for the HHRA.

2.3.1.4. Results Summary of Soil Lead Samples

Soil lead results, obtained using both XRF and ICP-AES methods, are summarized in Part I of the Final Data Report (SEH 2005) for the following location-based soil sample categories:

- Zone 1 Properties
- Zone 2 Properties
- Zone 2 Mine Waste/Source Areas
- Town of Rico Streets
- Dolores River East Overbank Area
- Town of Rico Sewer Lines.

Detailed evaluation of these data is provided in Part II (Data Evaluation) of the Final Data Report (SEH 2005). Specifically, Part II of the Final Data Report addresses:

(1) The spatial distribution of lead across the Townsite;

(2) Characterization of lead content for different mapped surficial geologic units, mine source materials, and fill materials;

(3) Variations in lead content with depth; and

(4) Sources of lead as identified from metal speciation data.

Statistical analyses used to support evaluation of these data are also provided in Part II of the Final Data Report.

3 EVALUATION OF POTENTIAL EXPOSURE MEDIA

The lead exposure models focus on exposures associated with incidental ingestion of lead in site soils or in indoor dust. Other routes of exposure and other exposure pathways contribute much less to incremental exposures associated with lead in site soils. Specific exposure pathways are described further below, followed by a description of the calculation of exposure point concentrations (EPCs) for soil.

3.1 EXPOSURE PATHWAYS

Exposure pathways for each scenario are illustrated in the conceptual site model (CSM) (Figure 3-1). The CSM graphically describes the ways in which residents, indoor workers, outdoor workers, and visitors within the study area may come in contact with soil lead. It also depicts the pathways by which lead in outdoor soil and dust may be transferred to other areas or media. Generally, lead in soil has relatively low mobility, which limits its transport to groundwater. Lead is not volatile, but may enter air in dust particles that are eroded from the open land and yard soil into air by wind or mechanical forces. The latter may include traffic on dirt roads. Lead in soil may contribute to indoor dust due to settling of airborne soil particles or by transport of soil into buildings on shoes or pets. Theoretically, lead could also be transferred from soil into home-grown garden vegetables.

Previous investigations of exposures to lead from soil at former mining and smelting sites in the Rocky Mountains have demonstrated that inhalation of resuspended soil particulates is an insignificant exposure pathway. These investigations have also shown that ingestion of homegrown vegetables does not contribute to increased exposure to lead in these communities, many of which have short growing seasons similar to that in Rico. For direct contact with lead in soil and dust, ingestion is the primary exposure route, with dermal absorption being insignificant (the dermal pathway is not included in USEPA lead exposure models). Consequently, the only site-specific exposure pathways quantified in this HHRA are ingestion of soil and dust.

3.2 CALCULATION OF EXPOSURE POINT CONCENTRATIONS

For the residential properties, EPCs for each individual residential property were calculated using the soil sampling results from the Townsite VCUP Investigation. For the commercial properties and for open space, single EPCs were calculated as the 95th percentile upper confidence limit on the mean (UCLM) from the selected data set. EPC values are summarized in Table 3-1. Sample selection and calculation of EPCs for these property categories is described below.

3.2.1 EPCs for Residential Property

Among those 355 properties identified for residential uses, the following types of samples were used to derive EPCs for residents at each property:

- Surface soil
- Earthen driveway
- Garden
- Play area
- Mine waste
- Source material.

The number of discrete and composite samples collected from each of the residential properties varied depending on property size, the presence of gardens and play areas, and other factors. All samples for an individual property were assumed to contribute equally to the exposures of resident children, and an exposure point concentration (EPC) for an individual property was generated by averaging the lead concentrations for all of the composite samples from that property. The EPCs for each property are listed in Appendix A, and the summary of the EPCs is presented in Table 3-1.

Some of the residential soil samples were collected from between adjacent properties where property boundaries were not clearly delineated. Lead concentrations for these samples were grouped based on their proximity, and reported as one composite concentration. Since residents living on both properties could be exposed to soil from the area sampled, it was determined that this type of composite sample would be included in calculating the EPC for both adjacent properties. The samples that were assigned to more than one property are identified in Appendix A.

Thirty-five residential properties were cleaned in 2004 and 2005 with completion of remediation by October, 2005. Since the EPCs for these properties were based on lead concentrations in soil prior to remediation, overall risk results are reported for both January 2004 (before or during remediation) and January 2006 (post remediation).

Developed residential properties were broken into six subareas for descriptive purposes. Figure 3-2 shows designated subareas, and Appendix A-1 lists the zones and subareas for each residential property. Table 3-2 reports the average and range of soil concentrations in these areas, along with values for non-developed potential future residential properties in Zone 2. Since 35 occupied residential properties with generally the highest soil lead concentrations were remediated, minimum, maximum, and average soil concentrations are reported both pre- and post-remediation. Subareas A and B had the highest soil lead levels with mean concentrations pre-remediation of 1,690 and 3,131 mg/kg, respectively.

Areas C, D, E, and F, as well as the undeveloped properties in Zone 2 had much lower soil lead concentrations with means ranging from 266 to 991 mg/kg.

3.2.2 EPCs for Commercial Property

Commercial/industrial properties were evaluated based on indoor and outdoor worker scenarios. Thirty properties in Rico have been identified as having commercial/industrial uses (Markle 2005, pers. comm.). These commercial/industrial properties were identified through site visits and review of historic records during the sampling process. Among the 30 properties, 25 were sampled, and composite soil samples were collected from each property. Lead concentrations in these properties ranged from 221 to 3,798 mg/kg, with a mean of 1,195. This range is smaller than the range observed for the other property types. Due to this finding, combined with the lower frequency and intensity of exposure expected for adults, a single EPC was calculated for use in assessing lead exposures from commercial properties.

For both worker scenarios, the EPC was generated using the following two-step process. First, for each individual commercial/industrial and public property within the study area, an average soil concentration was calculated from the composite soil samples collected from that property (Appendix A). The average soil lead concentration for each property was calculated using the same sample types as described above for residential properties. Second, a 95% UCLM was generated for these 25 properties. The statistical analysis and the 95% UCLM calculations were performed using the ProUCL (Version 3.0) software following the USEPA (2004c) guidance. Statistical analysis showed that the individual average concentrations from the 25 properties follow a gamma distribution at 5% significance level. Accordingly, the 95% approximate gamma UCL was used as the EPC for indoor workers.

3.2.3 EPCs for Dolores River Corridor Open Space

Samples were collected from 35 locations in the Dolores River corridor (Appendix A). A single EPC was calculated for the entire corridor because recreational visitors are expected to visit different areas at different times. In addition, the sampling locations were selected in a manner that was expected to bias the dataset toward higher concentrations. The 95% UCLM from this data set was calculated using the ProUCL (Version 3.0) software following the USEPA (2004c) guidance. Statistical analysis showed that the soil lead concentrations for the 47 samples follow a non-parametric (Chebyshev) distribution at a 5% significance level. The 95% approximate Chebyshev UCL was used as the EPC for recreational visitors.

4 LEAD EXPOSURE MODELS AND ASSUMPTIONS

As described in Section 1, lead exposures and health risks are evaluated based on observed or predicted blood lead levels. Lead is widespread in the environment, and exposure occurs from many different sources in addition to site soils. Thus, blood lead concentrations reflect integrated exposures from multiple sources, rather than just site-related exposures. Therefore, calculating the level of exposure and risk from lead in soil also requires assumptions about background exposures to lead in other media such as diet and drinking water. Intake estimates for lead from these sources are incorporated into toxicokinetic models that predict blood lead levels in exposed populations of children or adults.

As described previously, USEPA has modified two toxicokinetic models for use in assessing lead exposures in children and adults. These models are also used to generate risk-based remediation goals for soil. It is often difficult to obtain reliable estimates of key toxicokinetic parameters (e.g., absorption fraction (AF), distribution and clearance rates, etc.), because direct observations in humans are limited. The absorption, distribution, and clearance of lead in the human body are complicated processes, and mathematical models intended to simulate the actual processes are likely to be an oversimplification. Consequently, model calculations and predictions should not be thought of as being identical to actual risk. Because not all of the lead entering the body through the respiratory or gastrointestinal tracts is actually absorbed into the systemic circulation of the blood, the models also incorporate differences in the bioavailability of lead from different environmental media.

The IEUBK model is used to evaluate lead exposures in children at residential properties (USEPA 2002c). For non-residential properties (e.g., commercial, industrial, and recreational), USEPA recommends use of the ALM model (USEPA 2003c, USEPA 1996). The USEPA (2003a) guidance manual *Assessing Intermittent or Variable Exposures at Lead Sites* (hereafter called "Intermittent Exposure Guidance") provides methodology for estimating lead exposure in children when contamination is present both at a residence and at a second contaminated site. This methodology was used to estimate RBCs for child residents of Rico who visit the Dolores River corridor on an intermittent basis.

Reliable site specific estimates of exposure and risk using the IEUBK and ALM models depend on site-specific information for a number of key input parameters, including lead concentration in environmental media, intake rates (IR) of each medium, and the rate and extent of lead absorption from each medium. A number of the input parameters for the lead exposure models are associated with uncertainty. For example, exposure to soil and dust is difficult to quantify because human intake of these media is likely to be highly variable, and it is difficult to derive accurate measurements of actual intake rates. The USEPA guidance for these models provides for the substitution of default parameters with site-specific values derived from studies at the site. Comprehensive blood lead studies have been conducted at a substantial number of mining sites in the Rocky Mountain region. The results of these studies have then been used to identify site-specific inputs for the blood lead models (e.g., see Griffin 1999; URS 2003; UCDEH 1997; USEPA 1995; USEPA 2001; Weston 1996, 1997a).

Unfortunately, the population of Rico is too small to generate enough data to provide site-specific values for many parameters. Nevertheless, alternate values are available from many similar mountain mining communities. Since there is uncertainty associated with many critical input parameters, exposure modeling was conducted using both default and alternate inputs. Parameters found to differ significantly from the defaults include the geometric standard deviation ([GSD] used to generate a distribution of blood lead levels for the population), bioavailability of lead in soil, and soil ingestion rates. Site-specific bioavailability data was available for Rico. Alternate inputs for the geometric standard deviation and soil ingestion rates were selected based on the results of blood lead studies in communities with characteristics similar to Rico. Tables 4-1 (IEUBK) and 4-4 (ALM) list the value(s) for each parameter. By running the models with different combinations of parameter values, the results can be presented as a range of outputs. Additionally, the effect of individual parameters on the model is easily determined.

4.1 ASSESSING EXPOSURES OF CHILDREN: THE IEUBK MODEL

USEPA has a goal of limiting exposure to lead in soil such that “a typical (or hypothetical) child or group of similarly exposed children would have an estimated risk of no more than 5 percent of exceeding a 10 µg/dL blood lead level” (USEPA 1994, 1998). The 10 µg/dL blood lead level was selected based on studies indicating that exposures resulting in blood lead levels at or above this concentration may present an increased health risk to children (CDC 1997, 2002; USEPA 1998).

The IEUBK model may be used to predict the plausible range of blood lead levels in a population of young children exposed to a specified set of environmental lead levels. The model may also be used to derive site-specific cleanup levels by selecting a soil concentration associated with a 5% probability of a child or group of children having blood lead levels above 10 µg/dL.

Input values selected for the parameters in the IEUBK modeling for Rico are described below, and summarized in Table 4-1.

4.1.1 Lead Concentration in Soil and Dust

The IEUBK model is based on the assumption that children ingest lead from site surface soils directly and via indoor dust that contains lead from outdoor soil. The soil concentration used in the IEUBK model for the residential scenario for Rico is the average of lead concentrations of all the samples collected for each property evaluated.

No indoor dust samples were collected in Rico. When site-specific data are not available, the default assumption is that the indoor dust lead concentration is 70% of the concentration in outdoor soil for each property. However, studies that have been performed at a number of mining/smelting sites in Colorado and Utah indicate that the default assumption is not representative of these sites (USEPA 2003b). The relationship between lead in soil and dust at eight mining and/or smelting sites and one urban site with possible contamination from two smelting operations is shown in Table 4-2. Many of these sites included both smelting and mining-related lead releases similar to those historically experienced in Rico. Other similarities in exposure conditions exist between the Rico communities and other mountain communities studied. Thus, the relations observed in these other communities are likely to be reasonably predictive for Rico.

Due to the existence of other sources of lead in indoor dust, such as lead from paint, that are unrelated to soil lead, there is typically lead present in indoor dust even when soil lead concentrations are very low. Thus, regression equations relating dust concentrations to soil concentrations typically have a nonzero intercept. At higher soil lead concentrations this intercept has a smaller impact on the predicted indoor dust concentrations. Two alternate algorithms for estimating lead in dust based on the soil concentration were selected for this assessment. A directly proportional relation between soil and dust in Rico was selected that was expected to be predictive of the soil to dust relation at higher soil concentrations when the intercept has little influence:

$$C_{dust} = 0.30 \times C_{soil}$$

At soil lead concentrations above 1,000 mg/kg, this relation will predict higher indoor dust concentrations than are likely to be present in Rico. Because most of the residential soil concentrations are greater than 1,000 mg/kg, this will provide a conservative estimate for blood lead predictions. As a second alternate assumption, the relationship found at the Vasquez Boulevard/I-70 site in Denver, Colorado (USEPA 2001) was also selected:

$$C_{dust} = 0.34 \times C_{soil} + 150$$

This relation was a mid range values from those presented in Table 4-2. None of the communities listed in the table is a perfect match for Rico. The Vasquez Boulevard/I-70 site is a smelter site rather than a site predominantly affected by mining activities as is the case in Rico. Nevertheless, this relation is expected to provide a more accurate representation of dust concentrations in older homes in Rico. Newer housing is expected to have even lower dust lead concentrations than those assumed.

4.1.2 Age-Dependent Soil Intake

The IEUBK model is designed to use central tendency values of all input parameters. Default values for age-dependent soil ingestion rates are assumed to be 85 mg/day for 0–1 year, 135 mg/day for 1–4 years, 100 mg/day for 4–5 years, 90 mg/day for 5–6 years, and 80 mg/day for 6–7 years, which yields an average of 108 mg/day.

USEPA's default daily soil ingestion values for use in a reasonable maximum exposure (RME) scenario are 200 mg/day and 100 mg/day, for young children and adults, respectively. These ingestion rates are for combined ingestion of soil and indoor dust, and are based on short-term population surveys.

As noted in USEPA's *Exposure Factors Handbook* (1997), distributions derived from short-term population surveys will overestimate upper percentile values for long-term daily average values for the population. For soil ingestion, surveys based on 3–7 day observations in children have typically been used to derive mean and 95th percentile daily soil ingestion estimates, but the 95th percentiles represent the short-term distribution, rather than the distribution of long-term average daily soil ingestion across a population of children. This issue was recently addressed by Stanek and Calabrese (2000) and Stanek et al. (2001), who showed that 95th percentile estimates drop substantially when the distribution represents a longer time period (Table 4-3).

Stanek and Calabrese (2000) estimate one-year average 95th percentiles of 106 and 124 mg/day for the Anaconda and Amherst data sets, respectively, (with means of 31 and 57, respectively) for 1–4 year old children. Ninety day average 95th percentile intakes that may also be relevant for evaluating lead exposures are almost identical to the one-year averages. Based on this analysis, the default values in the IEUBK model are similar to 95th percentile values for 30–365 day exposure periods, and are not representative of central tendency values.

Considering the reported mean values of 31 and 57 mg/day from the two studies, the IEUBK model would be more accurate if the default soil ingestion rates were reduced by 50%. It should also be noted that snow cover at the Rico Townsite limits the contact with soils over a significant portion of the year. Dividing the default soil ingestion rates in half results in values of 68 mg/day being used for 1–4 year old children, more than double the mean soil ingestion rate reported in the Anaconda study and almost 20% greater than the mean from the Amherst study.

In the risk assessment for the Leadville, CO site (Weston 1997a), soil and dust ingestion rates were estimated using blood lead and soil lead concentration data. This study found much lower soil ingestion rates than USEPA defaults ("conceivably as low as 5–6 mg/day of each [soil and dust]"). Based on these estimates, soil ingestion rates of 5, 20, and 50 mg/day were used as inputs in their exposure model. The results from the runs that used 20 mg/day as the combined soil and dust ingestion rate provided estimates of blood lead levels closest to observed values.

For the IEUBK modeling in this study, three different soil ingestion rates were used: USEPA defaults (i.e., averaging 108 mg/day), half of USEPA defaults (i.e., averaging 54 mg/day), and the best fit value from the Leadville risk assessment (i.e., 20 mg/day) (see Table 4-1).

4.1.3 Dietary Lead Intake

Dietary intake of lead fell sharply in the U.S. during the 1980s, and has continued to fall at a slower pace during the past 10 years. Consequently, USEPA (2005b) has updated the default dietary lead intake values for the IEUBK model. These values are lower than those used recently by USEPA Region 8 (USEPA 2001), but are not as low as the values used in an earlier USEPA Region 8 evaluation (Griffin 1997). The earlier USEPA Region 8 values were based on a critical analysis of updated market-basket studies by the Food and Drug Administration (FDA) (Bolger et al. 1996; Gunderson 1995). The updated USEPA defaults were used in this risk assessment. These values are likely to slightly overestimate current dietary intakes.

4.1.4 Geometric Standard Deviation

GSD is a measure of relative inter-individual variability in blood lead concentrations of a child of a specific age, or children from a hypothetical population whose lead exposures are known. It is used to generate a distribution of blood lead levels from the central tendency estimate generated by the other model inputs. The GSD parameter in the IEUBK model encompasses biological and behavioral differences, measurement variability for repeat sampling, variability as a result of sampling locations and analytical variability. A range of GSD from 1.2 to 1.6 has been presented and discussed by USEPA Region 8 (USEPA 2001) for application in lead modeling and risk assessment. Studies conducted at many sites have shown that the GSD value is often lower than the IEUBK default value of 1.6, and the modeled risks to children from lead could be substantially overestimated if the default GSD value is used (USEPA 2001). It is appropriate to evaluate the broader range of GSDs as described by Griffin et al. (1999). A GSD of 1.4 has been used to evaluate lead exposures at the Murray and Sandy smelter sites in Utah (Weston 1997b; USEPA 1995). Based on USEPA's findings in these studies, GSD values of 1.4, 1.5, and 1.6 are used as the input GSDs for IEUBK modeling at the Rico Townsite.

4.1.5 Relative Bioavailability of Lead from Rico Soils

The absorption fraction assumed for lead ingested from soil is particularly important because the fraction of ingested lead that is absorbed or bioavailable is variable and depends on the origin and physical-chemical properties of the soil lead. For example, lead in soil and mining-related wastes may exist, at least in part, as minerals that have low water solubility or may exist inside particles of inert matrix such as rock or slag (USEPA 2004b). These factors tend to influence, usually by decreasing, the bioavailability of lead when ingested. Weathering of site soil, soil pH, and other soil components are also factors that can affect bioavailability (Ruby 2004). Thus, the use of site-specific bioavailability and mineralogy information about lead in soil can be used to improve the accuracy of exposure and risk assessments of a site (USEPA 2004b).

The measure of the degree to which a chemical is absorbed into the body is expressed as *bioavailability*. *Absolute bioavailability* is the fraction of the dose of a chemical that is absorbed and enters the body after being ingested (Hrudey et al. 1996). In assessing risks from exposure to lead, the USEPA estimates that the absolute bioavailability of lead from water or diet averages 50% in children and 20% in adults (USEPA 2002b,2003c). In other words, one-half of the lead ingested from water or diet is absorbed by very young children, and only one-fifth of the lead ingested from these sources is absorbed by adults.

When lead is ingested from other sources such as soil, absorption may be increased or decreased compared to the lead absorption from water or diet. *Relative bioavailability* is a measure of the difference in absorption between different forms of a chemical or between different dosing vehicles (e.g., lead in water, food, or soil).

In the absence of site-specific data, the absolute bioavailability of lead from soil and dust ingested by young children is estimated by USEPA to average 30% (USEPA 2002c). Thus, when comparing the bioavailability for soil lead (0.3 or 30%) with the bioavailability of lead in drinking water (0.5 or 50%), the relative bioavailability of soil lead versus drinking water lead is 60% (i.e., 0.3/0.5) (USEPA 2002c).

When the relative bioavailability of lead in soil from a particular site is determined to be different than USEPA's 60% relative bioavailability assumption, exposures to lead in that soil may be lower or higher than exposures estimated using the default assumptions (USEPA 2004b). Site-specific relative bioavailability data can be used to adjust the default bioavailability assumptions in the exposure models and derive risk estimates that are more aligned with site conditions.

The relative oral bioavailability of lead was evaluated in two sets of soil samples collected from the Townsite. The mineral forms of the soil lead and the degree to which the soil lead is likely to dissolve in the gastrointestinal tract were studied. A detailed report of the results of these studies is provided in Integral (2005), and a summary follows.

The first set of soil (10 samples) was collected by URS on behalf of USEPA in 2003 (referred to herein as the USEPA data set). A second set of soil (18 samples) was collected in 2004 by SEH on behalf of Atlantic Richfield (AR) (referred to herein as the AR data set). The locations of the soil samples are shown in Figure 1, Integral (2005). All 28 samples were evaluated using an in vitro extraction test to measure the fraction of lead that could become liberated in the human gastrointestinal tract (i.e., the bioaccessible fraction) and thus be available for absorption. Electron microprobe analysis of the lead-bearing mineral phases was also conducted to quantify the distribution of lead among mineral phases in the soil.

For the USEPA data set of 10 samples, the average lead bioaccessibility was 64%, with a range from 53 to 73% (collected from a 6–12 inch depth). For the AR data set of 18 samples (collected from a 0–2 inch depth), the average lead bioaccessibility was 68, with a range of 46 to 84%. The average value of the two data sets (i.e., 66%) is slightly above USEPA's default value of 60% relative bioavailability. The AR data set average bioaccessibility of 68% was selected for use in the site-specific risk assessment. This means that the absolute bioavailability input for the IEUBK model was 0.34.

The dominant lead-bearing phases in Rico soils are iron and manganese oxides, phases generally associated with low bioaccessibility. These oxidized materials are consistent with lead derived from natural weathering, but could also be from processed materials that were oxidized during handling or treatment. Despite their low relative solubility, these mineral forms were found in small particles, averaging less than 40 microns in diameter. This small particle size may have contributed to the unexpectedly high bioaccessibility of lead in these samples. Galena-bound lead was present above 15% relative mass or frequency of occurrence in 35% of the samples (i.e., 10 out of 28), indicating the presence of un-weathered lead ore. Lead in slag particles had a relative mass or frequency of occurrence above 15% in 18% of the soil samples (i.e., 5 of the 28 samples). Because slag is released from smelters, these particles provide a direct indication of the impact of historical smelting activities (see additional discussion of inferred soil lead origins in Part II of the Final Data Report [SEH 2005]).

4.2 ASSESSING EXPOSURES OF ADULTS: THE ALM MODEL

As noted above, USEPA (2003c) recommends use of the ALM model for assessing non-residential (i.e., commercial/industrial) exposures to soil lead. The ALM model equations are designed to be protective of a "fetus of a worker who develops a body burden as a result of non-residential exposure to lead." According to USEPA (2003c), protection of the fetus is the most health-sensitive endpoint for adults, making cleanup goals derived via the ALM sufficiently protective of male or female adults in a non-residential setting. Similar to the IEUBK model for residential exposure, the ALM model equations target cleanup goals that equate to no more than a 5% probability that fetuses exposed to lead would exceed a blood lead level of 10 μg/dL (USEPA 2003c).

The ALM model uses a technical approach described by Bowers et al. (1994), which predicts the blood lead level in an adult with a site-related lead exposure by summing the "baseline" blood lead level (PbB_0) (that which would occur in the absence of any site-related exposures) with the increment in blood lead that is expected as a result of increased exposure due to contact with a lead-contaminated site medium. The latter is estimated by multiplying the average daily absorbed dose of lead from site-related exposure by a "biokinetic slope factor" (BKSF). Thus, the basic equation for exposure to lead in soil is:

$$PbB = PbB_0 + BKSF \times [PbS \times IR_s \times AF_s \times EF_s/365]$$

Where:

PbB = Geometric mean blood lead concentration (µg/dL) in women of child-bearing age that are exposed at the site

PbB_0 = "Background" geometric mean blood lead concentration (µg/dL) in women of child-bearing age in the absence of exposures to the site

BKSF = Biokinetic slope factor (µg/dL blood lead increase per µg/day lead absorbed)

PbS = Soil lead concentration (µg/g)

IR_s = Intake rate of soil (g/day)

AF_s = Absolute gastrointestinal absorption fraction for lead in soil (dimensionless). The value of AF_s is given by:

$$AF_s = AF(food) \times RBA(soil)$$

EF_s = Exposure frequency for contact with site soils (days per year)

RBA = Relative bioavailability adjustment

Once the geometric mean blood lead value is calculated, the full distribution of likely blood lead values in the population of exposed people can then be estimated by assuming the distribution is lognormal with a specified individual geometric standard deviation (GSD_i). The 95th percentile of the predicted distribution is given by the following equation from Aitchison and Brown (1957):

$$95^{th} \text{ percentile} = GM \times GSD_i^{\,1.645}$$

Where:

GM = Geometric mean

GSD_i = Individual geometric standard deviation

Input values selected for each of these parameters are described below and summarized in Table 4-4.

4.2.1 Biokinetic Slope Factor

The biokinetic slope factor (BKSF) has units of µg Pb/dL blood per µg Pb absorbed /day. This factor is used to predict the blood lead concentration based on the estimated lead uptake (in µg/day). The original Bowers model, which the USEPA ALM model was based on, was developed using a BKSF of 0.375 µg/dL per µg/day (Bowers and Cohen 1998). The Bowers adult lead model has been demonstrated to predict blood lead levels accurately using the lower BKSF; however, USEPA (2003c) rounded this to a value of 0.4 µg/dL per µg/day that used as the default BKSF in the ALM model. A more recent analysis of BKSF suggests values ranging from 0.3 to 0.4 (Maddaloni et al. 2005). The default value of 0.4 is used in this risk assessment and no alternate values were quantitatively evaluated.

4.2.2 Geometric Standard Deviation

In the ALM, the individual GSD is the measure of inter-individual variability that is used to generate a distribution of blood lead levels from the central tendency estimate. The GSD is intended to be a measure of the variability in blood lead levels in a population exposed to the same nonresidential lead levels (USEPA 2003c). The values of GSD vary based on the relative homogeneity of a population, with the lowest values expected in populations with similar socioeconomic and ethnic characteristics living within a relatively small geographic area. Thus, the community of Rico would be expected to have a relatively low GSD.

The default value for GSD in the ALM model is 2.1. This value is based on a combined analysis of blood lead levels in adults from two phases of a survey of individuals expected to be representative of the entire United States (referred to by its acronym NHANES III or National Health and Nutrition Evaluation Survey). Initially USEPA used a default GSD based on the first phase of this study conducted from 1988 to 1991 (USEPA 1996). Phase 2 was conducted from 1992 to 1994. Combining the results of Phases 1 and 2 yields lower baseline blood lead levels, but increased GSDs (USEPA 2002a, 2003c).

There are several reasons why using GSDs derived by combining results of the two phases of the NHANES study may overpredict variability in adult blood lead levels. First, combining data from the two different phases of NHANES III obscures the continuing decline in blood lead levels, and may amplify the variation (i.e., GSD). This is not a simple issue because the study design is very complex, and there is apparently disagreement among the researchers over the implications of dividing the data. Second, the detection limit (DL) for blood lead levels in the study was 1 µg/dL. As blood lead levels continue to decline, the proportion of nondetects in the population has increased dramatically (now almost 25% of the phase 2 data, USEPA 2002a). The GSD values have been found to be very sensitive to the value assigned to the nondetects. USEPA (2003c) found that GSD increases from 1.7 to 2.1 to 2.7 if the nondetects are set equal to the DL, or half the DL or one quarter of the DL, respectively). This suggests that the GSD cannot be reliably estimated for this dataset. The extreme uncertainty of the GSDs from this dataset is a major source of uncertainty in the adult lead model.

USEPA acknowledged that a GSD of 1.8 was calculated recently among adult women in Leadville, Colorado (USEPA 2003c), and use of a GSD of 1.8 is supported by Bowers and Cohen (1998). USEPA further pointed out that low GSD (1.6–1.8) is consistent with an analysis of blood concentration measured in populations in mining communities (USEPA 1992) in the U.S. and Canada. As described above, the lowest values of GSD are expected among homogeneous populations like the one found in the Townsite. Thus, both 1.8 and 1.6 were used as alternate estimates of GSD.

4.2.3 Baseline Blood Level

The baseline blood lead concentration is intended to represent the best estimate of a reasonable central value of blood concentration in women of child-bearing age that are not exposed to lead-contaminated soil or dust at the study area (AGEISS 1996). The ALM default value for homogeneous populations is 1.5 µg/dL. For adults in the Western Region of the U.S., the Phase 2 NHANES III survey geometric mean baseline blood lead value is 1.36 µg/dL (Bowers and Cohen 1998). The default value is likely to be conservative; however, this is another parameter that is sensitive to the value assigned to nondetects. Baseline blood lead values will increase slightly if nondetects are set equal to the detection limit rather than to one half the detection limit.

4.2.4 Soil Ingestion Rate

The ALM default value of 50 mg/day (0.05 g/day) is recommended for use for all occupational sources and is used for both indoor and outdoor workers. This value is also used for the adult recreational visitor scenario. The default value is derived from a 1990 study by Calabrese et al. (1990). A subsequent study (Stanek et al. 1997) suggested an average soil ingestion value of 10 mg/day (0.01 g/day). A value of 20 mg/day (0.02 g/day) has been recommended for use in the adult lead model based on comparison of model predictions with the validated model of O'Flaherty (Bowers and Cohen, 1998), and this is used as an alternate value.

4.2.5 Bioavailability and Absorption Fraction

Based on the ALM model guidance (USEPA 2003c), USEPA assumes that the absorption factor for soluble lead in water or diet is 0.2 (20%). However, a validated lead pharmacokinetic model developed by O'Flaherty (1993) used an adult lead absorption value of 0.08 (8%) for water and diet. A recent review suggests that both of these values are plausible (Maddaloni et al. 2005). Therefore, 0.08 was used as an alternate value to the default value of 0.2.

Applying the site-specific relative bioavailability of 0.68 to the default water and diet absorption fraction, yields a soil and dust absorption fraction of 0.136 (13.6%). Applying the site-specific relative bioavailability value to the alternate water and diet absorption value (0.08) yields an alternate soil lead absorption factor of 0.054 (5.4%).

4.2.6 Exposure Frequency

The default ALM exposure frequency for workers is 219 days/year (USEPA 2003c). This value is based on 1991 data from the Bureau of Labor Statistics and was applied to the indoor worker scenario. The exposure frequency for the outdoor worker was assumed to be 88 days/year based on the assumption that a worker would work outside 4.4 days/week for 20 weeks out of the year. This assumption reflects the fact that soil in Rico is snow-covered or frozen for more than half of the year. Unlike the indoor worker, the assumed averaging time for the outdoor worker is assumed to be the 20-week period (or 140 days) rather than a full year.

4.3 ASSESSING EXPOSURE TO RECREATIONAL VISITORS

Residents living in the Townsite have access to the Dolores River corridor where recreational activities may take place. Recreational activities are assumed to occur 20 weeks out of the year (late spring, summer, and early fall). This professional judgment reflects the site-specific conditions in Rico, including high elevation with long snow cover season and low surface water temperatures. Due to these conditions, recreational visits that are likely to include contact with soil will occur primarily during late spring, summer, and early fall.

4.3.1 Child Exposures

The IEUBK model provides estimates of exposure for a single location. USEPA's (2003a) *Intermittent Exposure Guidance* provides guidance for incorporating a secondary location with lead contamination into the model if exposures are expected to occur at least once a week for at least 3 months. The recommended approach is to weight representative soil concentrations for each location based on the relative time spent at each location. This will yield a predicted blood lead level based on the combined exposures using the following equation:

$$PbS_w = (PbS_{res} \times f_{res}) + (PbS_{rc} \times f_{rc})$$

Where,
PbS_w = weighted soil lead concentration (mg/kg)
PbS_{res} = residential soil lead concentration (mg/kg)
f_{res} = fraction of soil exposure at residence (unitless)
PbS_{rc} = soil lead concentration at the river corridor (mg/kg)
f_{rc} = fraction of soil exposure at the river corridor (unitless)

Children visiting the river corridor during the summer months are assumed to receive 1/7 of their total soil and dust exposure from the Dolores River corridor and 6/7 from their residence. This equates to approximately 30% of outdoor soil intake from the river corridor and the remaining 70% of soil intake from the home yard (based on USEPA's assumption that more than 50% of soil and dust intake is due to intake of indoor dust). For seasonal exposures, the guidance recommends that time-weighted exposure inputs not be annualized and instead recommends using the exposure time as the averaging time.

Risk-based target soil concentrations can be apportioned among the two locations based on the fractions of weekly soil and dust intake predicted for each site. The current version of the model does not automatically back-calculate location-specific risk-based concentrations. Instead, location-specific risk-based concentrations can be determined via an iterative approach, in which multiple model runs are conducted using the overall risk-based target soil concentration and various values for the residential risk-based concentration to identify the risk-based concentrations for the secondary location. This approach was used to derive risk based soil concentrations for the river corridor were calculated by selecting four possible target RBC values from the range of results of the IEUBK modeling.

4.3.2 Adult Exposures

Adult recreational exposures to the Dolores River corridor were assessed using the ALM model. Input parameters were the same as the outdoor worker scenarios except exposure frequency was assumed to be 20 days/year. This value was determined based on the assumption that an individual would visit the Dolores River corridor for recreational activities that involve contact with soil one time per week, 20 weeks per year.

5 RISK CHARACTERIZATION

This section presents risk evaluations and RBCs for the residential and commercial /industrial properties, and the Dolores River corridor.

5.1 RESIDENTIAL PROPERTIES

The expected blood lead distribution for children (age 0–84 months) was calculated for each property using the latest version of the IEUBK available at the time (win v1.0 build 261). The model runs were conducted in batch mode. Based on the USEPA (2005b) guidance, the 50-month age group was used in batch mode runs. This age result approximates the 6- to 84-month average that is calculated in single run mode. Although there are some slight differences in this approach, USEPA has concluded that the differences in the results are so small that they are not expected to affect site decisions.

5.1.1 Risk Results Summary

The IEUBK modeling results for children are characterized in terms of the probability of a random child exceeding a blood lead value of 10 μg/dL (this is referred to as "P10"). Table 5-1 lists the number and percent of properties with a P10 greater than 5% for each input parameter combination. Table 5-1 reports two categories of risk results: January 2004 prior to remediation of any yards, and January 2006 after remediation of 35 properties.

Using the site-specific bioavailability estimate and IEUBK default values for the rest of the input parameters, the number of properties exceeding a P10 of 5% prior to remediation is 228 (64.2%). Use of alternate values for soil ingestion, GSD and dust concentration estimates that are expected to better predict conditions in Rico results in a range of from 13 (3.7%) to 231 (65.1%) properties exceeding the P10 value. Varying the soil ingestion rate had the greatest impact on the risk results. When USEPA defaults were selected for the soil ingestion rate, the number of properties exceeding a P10 of 5% was always greater 50%, regardless of the other input parameters, but when selecting more likely values, fewer than 50% exceeded this risk level.

It should be noted that there are far fewer than 355 residences in Rico. There are only 220 water hook-ups to buildings in Town, including commercial and industrial buildings, indicating that many of the residential lots do not have houses on them. In addition, more than 40 of the properties tested are in the undeveloped area. The risk estimates presented essentially assume that all of these properties are developed and have young children in residence.

As noted in Section 3, based on the results of the sampling effort 35 of the occupied residential properties with generally the highest soil lead concentrations were remediated during 2004 and 2005. All 35 properties cleaned in 2004 and 2005 were assumed to have a P10<5% post remediation. The number of properties with a P10 greater than 5% post remediation (January 2006) are reported in Table 5-1 and range from 8 (2.3%) to 196 (55.2%) depending on parameter inputs.

5.1.2 Risk-Based Concentrations for Residential Areas

RBCs for residential areas were determined using the IEUBK model for the base case (i.e., site-specific bioavailability and IEUBK default values for the rest of the input parameters), as well as for other combinations of parameter values more likely to represent conditions in Rico (see highlighted cells in Table 5-1). Specifically, the dust concentration algorithm from the Vasquez Boulevard/I70 site near Denver was selected because it more accurately represents the baseline dust concentrations for older housing such as that present in some areas of Rico. Newer housing is expected to have even lower dust lead concentrations than those assumed. Lower soil ingestion rates were also used, including the rate found to best predict blood lead concentrations in Leadville, CO. A lower value for GSD was also selected that was more consistent with GSD values observed in other relatively homogeneous Rocky Mountain communities. For each of these cases, the soil concentration corresponding to 5% probability of a random child within the study area exceeding a blood lead value of10 µg/dL (which is the health-based goal for children) was selected as the RBC. The selected RBCs for the residential area are reported in Table 5-2. The RBC for the base case using the site-specific bioavailability value and default values for the other assumptions was 356 mg/kg. RBCs for alternate assumptions ranged from 794 to 3650 mg/kg.

5.2 COMMERICAL/INDUSTRIAL PROPERTIES

Commercial/industrial properties were evaluated using scenarios for indoor workers and for seasonal outdoor workers. The range of concentrations at the 25 commercial/ industrial properties was from 221 to 3,798 mg/kg, with a mean of 1,195 (Table A-2). Three properties had concentrations equal to or greater than 2,000 mg/kg. An EPC of 1,496 mg/kg, which is the UCLM of concentrations for the composite soil samples, was used for assessing exposures to both indoor and outdoor workers.

5.2.1 Indoor Worker Scenario

As discussed previously, exposure to soil lead for adult indoor workers was estimated using the USEPA ALM model with default values and with alternate values for some parameters.

5.2.1.1. Risk Results Summary

The results are expressed as the probability that fetal blood lead will be greater than the target lead value of 10 µg/dL, assuming a lognormal distribution. Table 5-3 lists the results for the base case (i.e., site-specific bioavailability and ALM default values for other input parameters), as well as for other combinations of parameter values expected to better represent conditions in Rico.

For the base case, the probability that fetal blood lead will exceed 10 μg/dL is 8.1%. All of the other combinations of alternative and default values result in less than a 5% probability of fetal blood lead exceeding10 μg/dL. Thus it is only with highly conservative default assumptions that exceedances of the target blood lead level is predicted.

5.2.1.2. Risk-Based Concentrations for Commercial/Industrial Areas—Indoor Workers

Many properties were identified for commercial and industrial uses within Zone 1 inside of Rico Townsite (see Section 2 for details). The risk-based action level for remediation for these commercial/industrial areas was determined using the methodology specified in the USEPA (2003c) guidance and ALM model. Based on the guidance, the soil lead concentration at which the probability of blood lead concentration exceeding 10 μg/dL in fetuses of women exposed to soil lead is no greater than 5% is selected as the RBC. The RBC for commercial/industrial areas was determined to be 1,090 mg/kg for the base case (see Table 5-4). Use of GSDs more representative of Rocky Mountain communities yielded RBCs of 1,670 and 2,223 mg/kg for GSDs of 1.8 and 1.6, respectively. Use of alternate values for bioavailability and soil ingestion resulted in RBCs ranging from 2,725 to 13,998. The base case risk-based concentration is lower than the UCLM, and eleven sampled properties exceed this value. The upper end of this range is not exceeded at any sampled properties that are identified for commercial and industrial uses.

5.2.2 Outdoor Worker Scenario

Exposure to soil lead for adult outdoor workers was also estimated using the USEPA ALM model.

5.2.2.1. Risk Results Summary

The same dataset was used for the outdoor worker scenario, i.e., it was assumed that workers were only working at the commercial/industrial properties. Although outdoor workers might also work in the residential areas, the results of the IEUBK model for exposures of young children in these areas should be sufficiently protective for adult workers. As with the indoor worker, the results are expressed as the probability that fetal blood lead will be greater than the target lead value of 10 μg/dL assuming a lognormal distribution. The probability that a fetus of an outdoor worker has a blood lead level greater than 10 μg/dL is 8.7% for the base case (Table 5-5). All of the other combinations of alternative and default values result in less than a 5% probability of fetal blood lead exceeding10 μg/dL. Thus it is only with highly conservative default assumptions that exceedances of the target blood lead level is predicted.

It should be noted that these values are likely conservative when evaluating risk over a whole year. The averaging time in this scenario was determined to be 20 weeks, which is the time period when outdoor work is likeliest. The modeling results do not take into account a wash-out period that is likely to occur as outdoor worker exposure will decrease significantly, if not cease altogether, during the winter months. The effect of this seasonal variation in blood lead levels on health effects is a source of uncertainty.

5.2.2.2. Risk-Based Concentrations for Commercial/Industrial Areas – Outdoor Workers

Risk-based action levels for soil were calculated as described for the indoor worker and are reported in Table 5-6. The RBC for the base case was 1040 mg/kg. Use of GSDs more representative of Rocky Mountain communities yielded RBCs of 1,594 and 2,122 mg/kg for GSDs of 1.8 and 1.6, respectively. Use of alternate values for bioavailability and soil ingestion resulted in RBCs ranging from 2,601 to 13,362. Due to the small size of most properties, outdoor workers are likely to spend time at multiple commercial/industrial properties or to only spend a fraction of time each week working outdoors, so these results are best compared to the UCLM soil concentration of 1496 mg/kg, rather than individual property soil concentrations. The base case risk-based concentration is lower than the UCLM, but all the other combinations of assumptions yielded RBCs greater than the UCLM.

5.3 DOLORES RIVER CORRIDOR

The Dolores River corridor was assessed using recreational scenarios for both children and adults. The dataset used samples collected from 35 locations in the Dolores River corridor (Table A-3). The mean lead concentration was 4,915 mg/kg, and the UCLM was 11,468 mg/kg. The concentrations ranged from 128 to 43,100. Only 4 samples exceeded the UCLM which was very high due to a small number of samples collected at locations suspected of containing mine waste.

5.3.1 Child Recreational Visitor

As described in Section 4.3.1, USEPA's Intermittent Exposure Guidance (2003a), was used to calculate RBCs for child visitors to the Dolores River corridor. An iterative approach was followed, in which multiple model runs were conducted using the overall risk-based target soil concentration (RBC) and various values for the residential RBC to identify the RBCs for the secondary location. This approach was used to derive risk-based soil concentrations for the river corridor by selecting four possible target RBC values from the range of results of the IEUBK modeling. It was assumed that a child resident receives one-seventh of the weekly exposure to soil and dust from river corridor soils for 20 weeks during the warmer season (i.e., over 30% of their outdoor soil intake).

Results are shown in Table 5-7. For example, using an overall target RBC of 1400 mg/kg, and assuming a residential soil action level of 1200 mg/kg, the resulting RBC for the

Dolores River corridor is 2,600 mg/kg. For an overall target RBC of 1,600 mg/kg and residential soil action level of 1200 mg/kg, the resulting river corridor RBC is 4,000 mg/kg. With an overall target RBC of 1,200 mg/kg and a residential action level of 1,000 mg/kg, the RBC at the Dolores River corridor is 2,400 mg/kg. The apportionment of the total residential RBC value between residential and river corridor soils can be varied to identify the combination that minimizes the total area to be remediated.

5.3.2 Adult Recreational Visitor

As described in Section 4.2 and 4.3.2, exposure and risk to lead for adult recreational visitors were estimated using the USEPA ALM model. The UCLM soil concentration of 11,468 mg/kg, which is from samples collected from 35 locations in the Dolores River corridor, was used.

5.3.2.1. Risk Results Summary

The ALM modeling results for recreational visitors are summarized in Table 5-8.

As with the indoor and outdoor workers, the results are expressed as the probability that fetal blood lead will be greater than the target lead value of 10 μg/dL assuming a lognormal distribution. For the base case, the probability that fetal blood lead is greater than 10 μg/dL is 20.0%. Using alternate values of GSD of 1.8 and 1.6, the probability of exceeding 10 μg/dL is 14.4 and 9.2%, respectively. All other combinations of assumptions yielded probabilities of 5% or less.

5.3.2.2. Risk-Based Concentrations for Recreational Areas

The RBC for the adult recreational visitor scenario was determined using the same methods described for commercial/industrial properties in Section 5.2.1.2. The resulting RBC for the base case was 4,578 mg/kg. Use of GSDs more representative of Rocky Mountain communities yielded RBCs of 7,013 and 9,338 mg/kg for GSDs of 1.8 and 1.6, respectively. Use of alternate values for bioavailability and soil ingestion resulted in RBCs ranging from 11,444 to 58,793 mg/kg. The base case RBC was exceeded at 11 individual properties, while the other RBCs were exceeded at 4 to 5 properties. However, the RBC may more appropriately be compared to the 95th percentile UCLM for the entire corridor if adult recreational visitors are likely to visit multiple areas within the river corridor. If that is the case, the 95th percentile UCLM of 11,468 mg/kg is more representative for the potential exposure than are concentrations for individual properties.

5.4 UNCERTAINTIES AND CONCLUSIONS

Uncertainties in lead exposure estimates have been explored by use of a matrix approach to present results for the model default values and for alternate values that are likely to better represent exposures in other communities with characteristics similar to Rico. These analyses have found a wide range of predicted potential exposures. Additional assumptions not evaluated quantitatively may have contributed to predicting higher blood lead levels than are likely to occur, e.g., the dietary lead intakes used in the IEUBK model may overestimate current lead intakes from the diet. For the ALM, the biokinetic slope factor used was at the high end of the range of values calculated in various analyses.

Selection of sample locations biased toward high soil lead concentrations may also have contributed to overestimation of exposures. Sample locations in all three property types (residential, commercial/industrial, and recreational) were selected with emphasis placed on locations expected to have the highest soil lead concentrations. As such, the datasets are expected to be biased high, and results from this assessment may be overly conservative. In addition, 35 of the residential properties with the highest lead concentrations have already been remediated.

As described in Section 1.2.4, populations living at higher altitudes have higher red blood cell levels, and thus higher blood lead levels. The blood lead level of concern of 10 μg/dL is based on populations at sea level and may be conservative for high altitude populations. Based on the Townsite's minimum elevation of 8,700 ft, the blood lead levels comparable to the target blood lead level of 10 μg/dL could range from 11.0 to 11.3 μg/dL for Rico residents (see Section 1.2.4). Although this factor has not been assessed quantitatively in this risk assessment, it provides an additional protective factor that should be considered when determining what RBCs should be selected.

It should be noted that the purpose of the human health risk assessment is to provide information concerning potential risks posed by contaminants at the site as necessary to help guide selection of particular response actions or remedies. The risk assessment results are not intended to specify how property-specific remediation goals will be met (e.g., the nature and extent of soil removal, if any, at a property where the risk-based action level is exceeded). If actions are determined to be necessary, the exact remediation approach should be addressed separately from the risk assessment.

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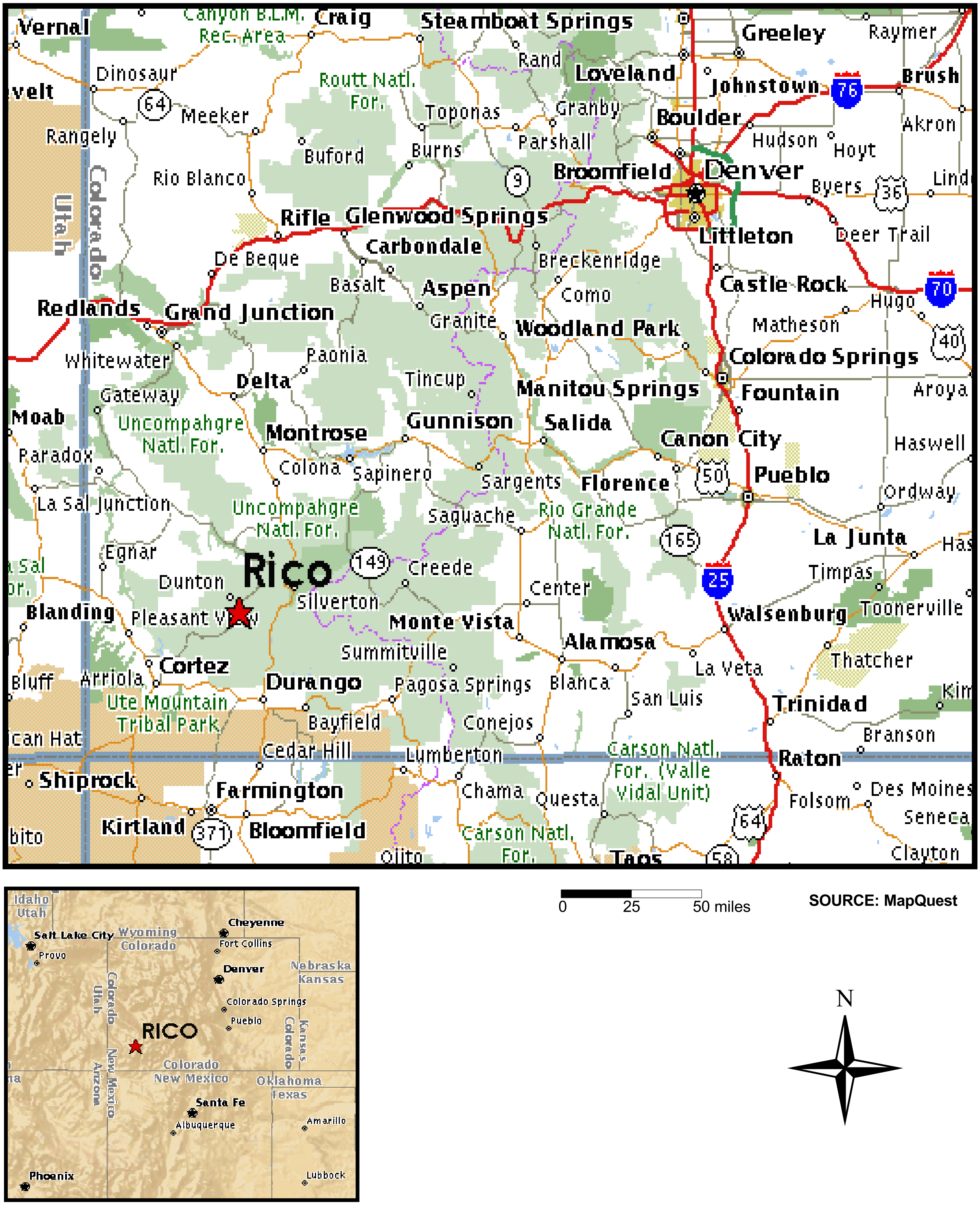
FIGURES AND TABLES



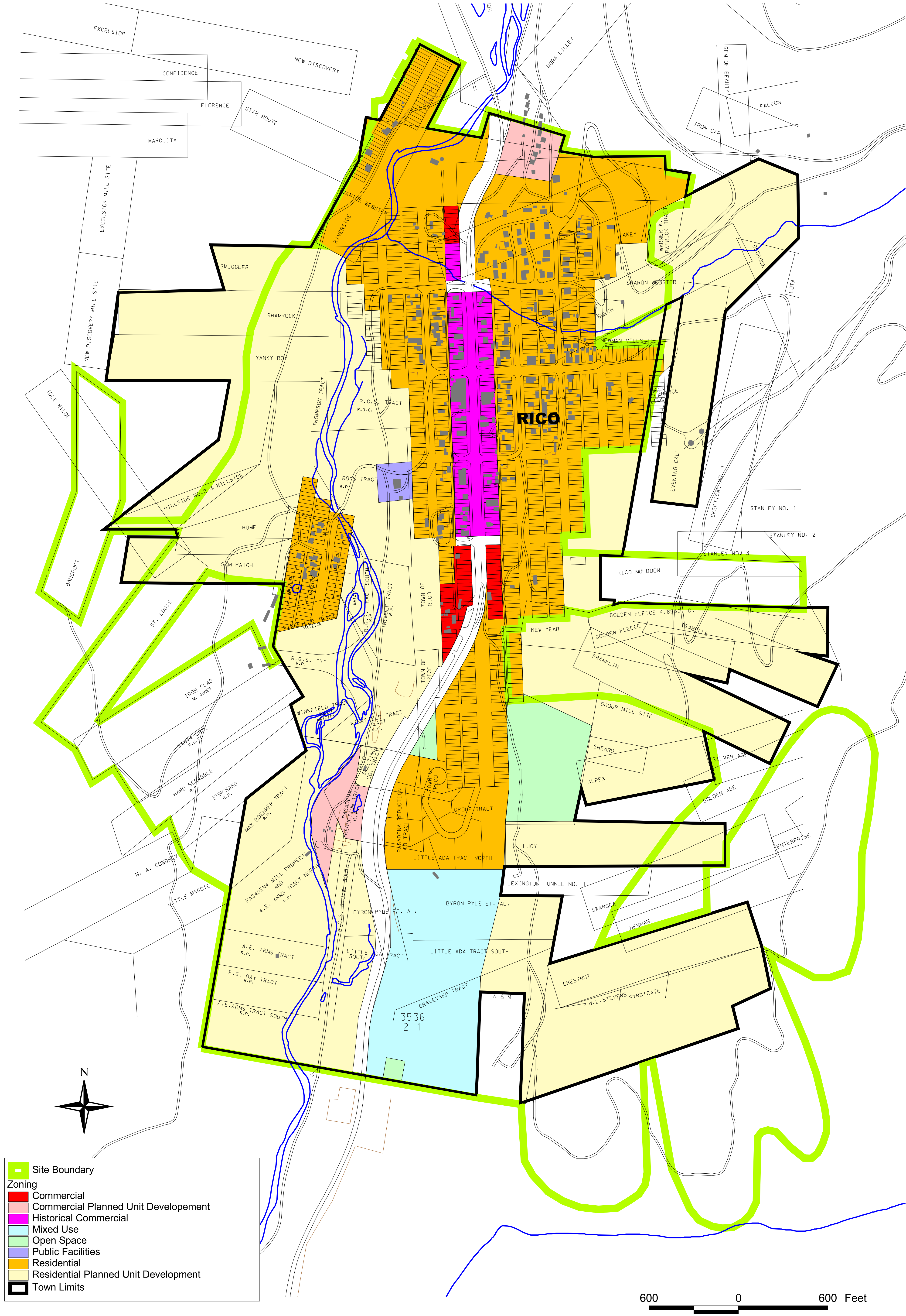
SOURCE: MapQuest

SEH

Lead Health Risk Assessment
Rico Townsite Soils

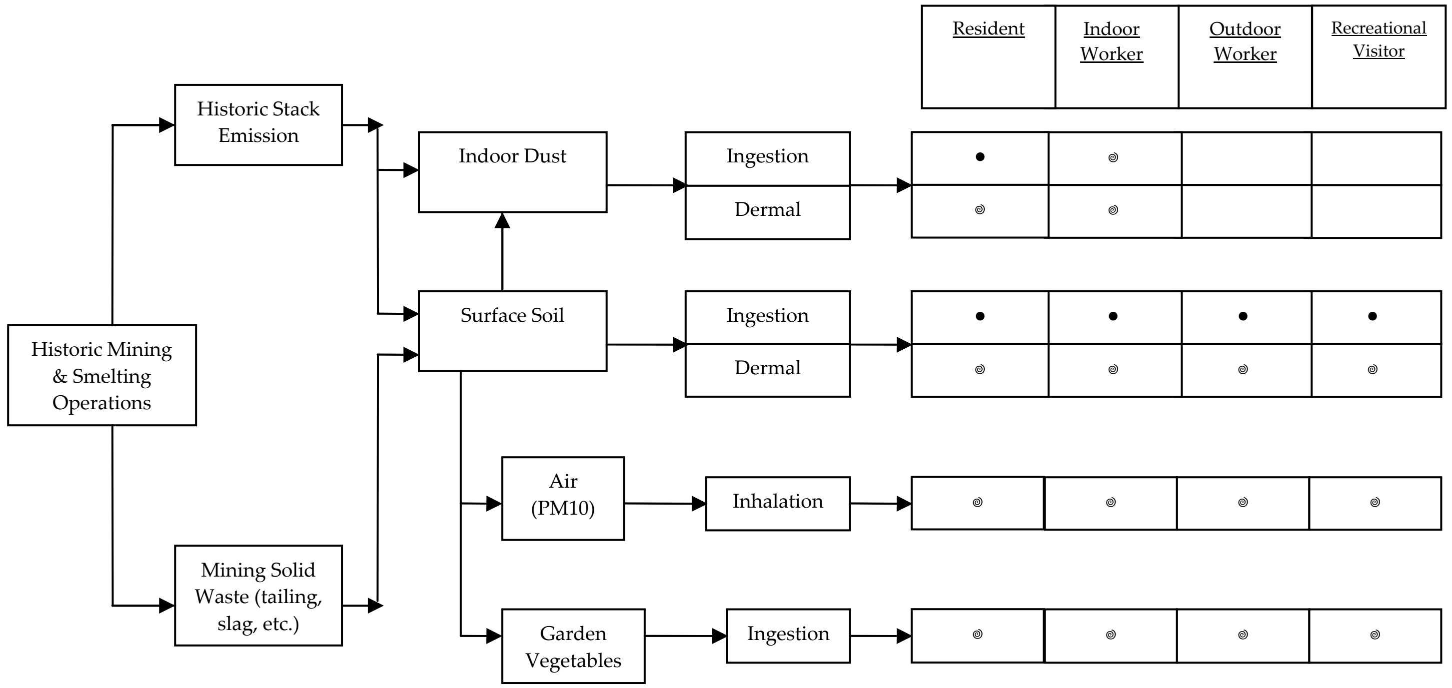
Figure 2-1
Rico Townsite
Location Map

PROJ NO.	C109 ARCO
DATE	6/06/05



Source: Town of Rico Official Zoning Map (Foley Associates, Inc.)

SEH	Lead Health Risk Assessment Rico Townsite Soils	Figure 2-2 Town of Rico Zoning Map	PROJ NO. C109 ARCO DATE 6/06/05



		Resident	Indoor Worker	Outdoor Worker	Recreational Visitor
Indoor Dust	Ingestion	●	◎		
	Dermal	◎	◎		
Surface Soil	Ingestion	●	●	●	●
	Dermal	◎	◎	◎	◎
Air (PM10)	Inhalation	◎	◎	◎	◎
Garden Vegetables	Ingestion	◎	◎	◎	◎

Legend:

☐	Pathway is not complete; no evaluation required.
◎	Pathway is or might be complete, but is determined to be minor; for qualitative evaluation.
●	Pathway is or might be complete and might be significant, and sufficient data are available for quantitative evaluation.

Figure 3-1. Conceptual Site Model for Human Exposure to Soil Lead.

Table 1-1. Rico, Colorado 2004 Blood Lead Data.[a]

Age (Years)	Sample Date	Gender (N)	Mean PbB (µg/dL)
0-6	4/20/2004	Male (7)	2.9
		Female (3)	1.6
		Both	2.5
	6/29/2004	Male (1)	7.6
		Female (2)	7.3
		Both	7.4
6-18	4/20/2004	Male (1)	<1
		Female (2)	<1
		Both	<1
	6/29/2004	Male (0)	-
		Female (1)	4.1
		Both	4.1
>18	4/20/2004	Male (9)	2.0
		Female (12)	1.7
		Both	1.8
	6/29/2004	Male (5)	4.1
		Female (8)	3.3
		Both	3.5

[a] All means were calculated assuming samples below the detection limit were equal to the detection limit and excluding samples coded as QNS (or inadequate). Additionally, a result of 4.3 µg/dL was excluded from the calculations of the age group means because no age was reported.

Table 1-2. Regression Constants from Dirren et al. (1994) and Correction Factors for Townsite.

Regression	a	b	c	Correction Factor for Rico, CO
Hemoglobin–child	3.44	0.000633	116.9	1.12
Hemoglobin–adult	6.83	0.000445	153.2	1.1
Hemoglobin–child (based on adult data)	6.83	0.000445	113.3	1.13
Hematocrit–child	0.449	0.000859	35.6	1.11

Table 2-1. Sample Categories and Codes.

Sample Code[a]	**GPS Code**	**Sample Category**
S	SO	Surface Sample
D	DR	Dolores River
E	ED	Earthen Driveway
G	GA	Garden Sample
P	PA	Play Area Sample
W	MW	Mine Waste Sample
T	ST	Town Street Sample
B	BK	Background Sample
L	SL	Sewer Line Trench Sample
A	AG	Gaseous Air Sample
M	SM	Source Material
O	OT	Other

[a] It should be noted that during the sampling process, some of the samples were labeled as “flower” and “vegetables.” These names refer to the type of garden, not the matrix. The matrix in both instances was soil.

Table 3-1. Summary of Soil Exposure Point Concentrations.

Property Category	Number of Properties	Mean (mg/kg)	Maximum (mg/kg)	Minimum (mg/kg)	EPC (mg/kg)
Residential Properties	355	1231	25590	24	Variable[a]
Commercial/Industrial Properties	25[c]	1195	3798	221	1496[b]
Dolores River Corridor	34[d]	4915	43100	105	11468[b]

Notes:

EPC = Exposure point concentration.

[a] Mean value for each property.

[b] 95th percentile upper confidence limit on the mean.

[c] 74 soil samples were taken from these 25 properties.

[d] 39 soil samples were included from these 34 properties.

Table 3-2. Residential Properties by Subareas A through F.

	Pre-Remediation				Post-Remediation[a]			
Subarea	**Min**	**Max**	**Mean**	**N**	**Min**	**Max**	**Mean**	**N**
A	79	20073	1690	140	79	20073	1488	112
B	493	25590	3131	36	493	9096	1847	31
C	55	2567	379	88	*	*	*	*
D	68	2653	991	22	68	2653	861	20
E	103	1618	266	17	*	*	*	*
F	82	3206	537	16	*	*	*	*
Zone 2[b]	24	7450	547	35	*	*	*	*

Notes:

* No cleaned properties.

[a] Results for remediated properties not included.

[b] Properties in Zone 2, not included in a subarea.

Table 4-1. Summary of Input Parameters for Lead (Pb) Modeling Using USEPA's IEUBK Model.

A. Soil/Dust Inputs

C_{soil} = Average of Composite Samples Collected from Specific Parcel/Property

C_{dust} Estimates:

1. USEPA default: $C_{dust} = 0.70 \times C_{soil}$
2. Combined Algorithm: $C_{dust} = 0.30 \times C_{soil}$
3. VB I-70 RA: $C_{dust} = 0.34 \times C_{soil} + 150$

B. Constant Inputs

Parameter	Unit	Proposed Input Values
Outdoor air concentration	µg/m^3	0.1
Indoor air concentration	µg/m^3	30% of outdoor
Drinking water concentration	µg/L	4.0
Absorption Fractions:		
Air		32%
Diet		50%
Water		50%
Soil/Dust		34%
Fraction soil		45%
GSD$_i$		1.4; 1.5; 1.6

C. Age Dependent Inputs—Air, Diet and Water

	Air		Diet	Water
Age	Time Outdoors (hour)	Vent. Rate (µg/m3)	Dietary Intake (µg/day)	Intake (L/day)
0-1	1.0	2.0	3.16	0.20
1-2	2.0	3.0	2.60	0.50
2-3	3.0	5.0	2.87	0.52
3-4	4.0	5.0	2.74	0.53
4-5	4.0	5.0	2.61	0.55
5-6	4.0	7.0	2.74	0.58
6-7	4.0	7.0	2.99	0.59

D. Age Dependent Inputs—Soil Ingestion Rate (mg/kg)

Age	Model Default	1/2 Model Default	Leadville RA
0-1	85	43	20
1-2	135	68	20
2-3	135	68	20
3-4	135	68	20
4-5	100	50	20
5-6	90	45	20
6-7	80	40	20

Table 4-2. Relationships for Lead in Soil and Dust at Mining and Smelting Sites.

Site	Observed Soil-Dust Relationship for Lead	Reference
Murray, UT	$C_{dust} = 0.19\ C_{soil} + 174$	USEPA 2003b
Midvale, UT	$C_{dust} = 0.18\ C_{soil} + 290$	USEPA 2003b
Sandy, UT	$C_{dust} = 0.15\ C_{soil} + 77$	USEPA 2003b
Bingham Creek, UT	$C_{dust} = 0.43\ C_{soil} + 90$	USEPA 2003b
Tooele, UT (IS&R)	$C_{dust} = 0.20\ C_{soil} + 91$	USEPA 2003b
Denver, CO (VB I-70)	$C_{dust} = 0.34\ C_{soil} + 150$	USEPA 2001
Leadville, CO	$C_{dust} = 0.25\ C_{soil} + 500$	Weston 1997a
Walkerville, MT	$C_{dust} = 0.20\ C_{soil} + 344$	URS 2003

Table 4-3. Estimates of True Average 95th Percentile Soil Ingestion for Children over Various Averaging Times.

	95th Percentile Soil Ingestion Per Day (mg)	
Time Period (days)	Anaconda[a]	Amherst[b]
1	141	210
7	133	177
30	112	135
90	108	127
365	106	124

Notes:

Data from Stanek and Calabrese (2000).

[a] Study of 64 children aged 1-4 years residing in Anaconda, MT, mean soil ingestion = 31 mg/day.

[b] Study of 64 children aged 1-4 years residing in Amherst, MA, mean soil ingestion = 57 mg/day.

Table 4-4. Input Parameters for the ALM Model.

Variable	Unit	Definition	Indoor Workers		Outdoor Workers		Recreational Visitors	
			Model Default	**Alternate Values**	**Model Default**	**Alternate Values**	**Model Default**	**Alternate Values**
$PbB_{fetal, 0.95}$	μg/dL	95th percentile PbB in fetus (for RBC calculations)	10	-	10	-	10	-
$R_{fetal/maternal}$	unitless	Fetal/maternal PbB ratio	0.9	-	0.9	-	0.9	-
BKSF	μg/dL per μg/day	Biokinetic Slope Factor	0.4	-	0.4	-	0.4	-
GSD_i	unitless	Geometric standard deviation PbB	2.1	1.8/1.6	2.1	1.8/1.6	2.1	1.8/1.6
PbB_0	μg/dL	Baseline blood Pb concentration	1.5	-	1.5	-	1.5	-
IR_S	g/day	Soil ingestion rate (including soil-derived indoor dust)	0.05	0.02	0.05	0.02	0.05	0.02
$AF_{W,D}$	unitless	Absorption fraction for water and diet	0.2	0.08	0.2	0.08	0.2	0.08
$AF_{S,D}$	unitless	Absorption fraction for soil and dust	0.136[a]	0.054	0.136[a]	0.054	0.136[a]	0.054
$EF_{S, D}$	days/yr	Exposure frequency (same for soil and dust)	219	-	88	-	20[b]	-
$AT_{S, D}$	days/yr	Averaging time (same for soil and dust)	365	-	140	-	140	-

[a] Absorption fraction based on a site-specific bioavailability of 0.68.

[b] Site-specific estimate.

Table 5-1. IEUBK Estimated Risk to Children from Lead Exposure.

Concentration in Dust	**Average Soil Ingestion Rate (mg/day)**																	
	20						**68**						**108**					
	Interindividual Geometric Standard Deviation																	
	1.4		**1.5**		**1.6**		**1.4**		**1.5**		**1.6**		**1.4**		**1.5**		**1.6**	
	Jan. 2004[a]	**Jan. 2006**[b]	**Jan. 2004**	**Jan. 2006**	**Jan. 2004**	**Jan. 2006**	**Jan. 2004**	**Jan. 2006**	**Jan. 2004**	**Jan. 2006**	**Jan. 2004**	**Jan. 2006**	**Jan. 2004**	**Jan. 2006**	**Jan. 2004**	**Jan. 2006**	**Jan. 2004**	**Jan. 2006**
-																		
0.3*Csoil	13 (3.7%)	8 (2.3%)	15 (4.2%)	9 (2.5%)	23 (6.5%)	14 (3.9%)	102 (28.7%)	71 (20.0%)	109 (30.7%)	77 (21.7%)	124 (34.9%)	91 (25.6%)	185 (52.1%)	150 (42.3%)	193 (54.4%)	158 (44.5%)	202 (56.9%)	167 (47.0%)
0.7*Csoil	24 (6.8%)	15 (4.2%)	31 (8.7%)	21 (5.9%)	43 (12.1%)	28 (7.9%)	125 (35.2%)	92 (25.9%)	152 (42.8%)	117 (33.0%)	177 (49.9%)	142 (40.0%)	207 (58.3%)	172 (48.5%)	219 (61.7%)	184 (51.8%)	228 (64.2%)[c]	193 (54.4%)
0.34*Csoil+150	14 (3.9%)	8 (2.3%)	20 (5.6%)	11 (3.1%)	27 (7.6%)	18 (5.1%)	109 (30.7%)	77 (21.7%)	127 (35.8%)	94 (26.5%)	153 (43.1%)	118 (33.2%)	202 (56.9%)	167 (47.0%)	219 (61.7%)	184 (51.8%)	231 (65.1%)	196 (55.2%)

Notes:

Shaded cells represent parameter combinations used to calculate RBCs (Table 5-2).

[a] Risk predictions based on soil concentrations prior to remediation.

[b] Risk predictions based on the assumption that properties cleaned in 2004 and 2005 would not exceed a P10 of 5%.

[c] Base case (site-specific bioavailability and default values for other input parameters).

Table 5-2. Selected Soil Lead Risk-Based Concentrations for Children (mg/kg).

Parameter Combinations	**RBC (mg/kg)**
Cdust = 0.7*Csoil, Soil IR = 108 mg/day, GSDi = 1.6	356[a]
Cdust = 0.34*Csoil+150, Soil IR = 68 mg/day, GSDi = 1.6	794
Cdust = 0.34*Csoil+150, Soil IR = 68 mg/day, GSDi = 1.4	1102
Cdust = 0.3*Csoil, Soil IR = 68 mg/day, GSDi = 1.4	1276
Cdust = 0.34*Csoil+150, Soil IR = 20 mg/day, GSDi = 1.6	2710
Cdust = 0.34*Csoil+150, Soil IR = 20 mg/day, GSDi = 1.4	3650

[a] Base case (site-specific bioavailability and default values for other input parameters).

Table 5-3. ALM Results for Indoor Worker: Probability of Fetal Blood Lead >10 µg/dL.

	Soil Ingestion Rate (g/day)					
	0.05			**0.02**		
	Geometric Standard Deviation					
Absorption Fraction: Food & Water / Soil & Dust	**2.1**	**1.8**	**1.6**	**2.1**	**1.8**	**1.6**
0.2 / 0.136	8.1%[a]	3.9%	1.4%	2.2%	0.5%	0.1%
0.08 / 0.054	2.1%	0.5%	0.1%	0.8%	0.1%	0.0%

[a] Base case (site-specific bioavailability and default values for other input parameters).

Table 5-4. Soil Lead Risk-Based Concentrations for Indoor Worker (mg/kg).

	Soil Ingestion Rate (g/day)					
	0.05			**0.02**		
	Geometric Standard Deviation					
Absorption Fraction: Food & Water / Soil & Dust	**2.1**	**1.8**	**1.6**	**2.1**	**1.8**	**1.6**
0.2 / 0.136	1090[a]	1670	2223	2725	4174	5558
0.08 / 0.054	2745	4205	5599	6862	10513	13998

[a] Base case (site-specific bioavailability and default values for other input parameters).

Table 5-5. ALM Results for Outdoor Worker: Probability of Fetal Blood Lead > 10 µg/dL.

	Soil Ingestion Rate (g/day)					
	0.05			**0.02**		
	Geometric Standard Deviation					
Absorption Fraction: Food & Water / Soil & Dust	**2.1**	**1.8**	**1.6**	**2.1**	**1.8**	**1.6**
0.2 / 0.136	8.7%[a]	4.3%	1.6%	2.3%	0.6%	0.1%
0.08 / 0.054	2.3%	0.6%	0.1%	0.9%	0.1%	0.0%

[a] Base case (site-specific bioavailability and exposure frequency, and default values for other input parameters).

Table 5-6. Soil Lead Risk-Based Concentrations for Outdoor Worker (mg/kg).

	Soil Ingestion Rate (g/day)					
	0.05			**0.02**		
	Geometric Standard Deviation					
Absorption Fraction: Food & Water / Soil & Dust	**2.1**	**1.8**	**1.6**	**2.1**	**1.8**	**1.6**
0.2 / 0.136	1040[a] and exposure frequency,	1594	2122	2601	3985	5306
0.08 / 0.054	2620	4014	5345	6550	10036	13362

[a] Base case (site-specific bioavailability and exposure frequency, and default values for other input parameters).

Table 5-7. Risk Based Concentrations for the River Corridor Based on Intermittent Exposure.

Total RBC mg/kg	Selected Residential Soil Action Level mg/kg	Fraction of the Week at RC	River Corridor RBC mg/kg
1000	800	0.14	2200
1200	1000	0.14	2400
1400	1200	0.14	2600
1600	1200	0.14	4000

Table 5-8. ALM Results for Recreational Visitor: Probability of Fetal Blood Lead >10 µg/dL.

	Soil Ingestion Rate (g/day)					
	0.05			**0.02**		
	Geometric Standard Deviation					
Absorption Fraction: Food & Water / Soil & Dust	**2.1**	**1.8**	**1.6**	**2.1**	**1.8**	**1.6**
0.2 / 0.136	20%[a]	14.4%	9.2%	5.0%	1.9%	0.5%
0.08 / 0.054	5.0%	1.9%	0.5%	1.5%	0.3%	0.0%

[a] Base case (site-specific bioavailability and exposure frequency, and default values for other input parameters).

Table 5-9. Soil Lead Risk-Based Concentrations for Recreational Visitor (mg/kg).

	Soil Ingestion Rate (g/day)					
	0.05			**0.02**		
	Geometric Standard Deviation					
Absorption Fraction: Food & Water / Soil & Dust	**2.1**	**1.8**	**1.6**	**2.1**	**1.8**	**1.6**
0.2 / 0.136	4,578[a]	7013	9338	11444	17533	23344
0.08 / 0.054	11529	17663	23517	28822	44156	58793

[a] Base case (site-specific bioavailability and exposure frequency, and default values for other input parameters).

APPENDIX A

MEAN SOIL LEAD CONCENTRATIONS BY PROPERTY

LIST OF TABLES

Table A-1. Residential Property EPCs.

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
02	1511	1	F	
03	3206	2	F	
05	269	1	F	
06	469	1	F	
07	308	1	F	
09	195	1	F	
10	233	1	F	
11	206	1	F	
12	121	1	F	
13	394	1	F	
15	211	1	F	
16	427	1	F	
17	377	1	F	
18	448	1	F	
19	2448	1	A	
21	1760	1	A	
23	5800	1	A	
24	2372	1	A	
25	2804	1	A	
27	2520	1	A	
28	1681	1	A	
29	1590	1	A	
30	1447	1	A	
31	1308	1	A	
32	3770	1	A	9/7/2005
33	1290	1	A	
34	1998	1	A	9/14/2005
35	329	1	A	
37	1128	1	A	
38	2200	1	A	
39	2796	1	A	
40	1094	1	A	
41	862	1	A	
42	1893	1	A	
44	1457	1	A	
45	2969	1	A	
47	1948	1	A	
48	1457	1	A	
49	1728	1	A	
50	14250	1	A	
51	6725	1	A	
52	1300	1	A	
53	2300	1	A	

Table A-1. Residential Property EPCs (continued).

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
54	911	1	A	
56	1515	1	A	10/10/2005
57	974	1	A	
58	1053	1	A	10/3/2005
59	1910	1	A	10/7/2005
60	8480	1	A	10/3/2005
61	604	1	A	
62	896	1	A	
63	1588	1	A	9/1/2005
64	637	1	A	
65	726	1	A	
66	412	1	A	
67	941	1	A	
68	1138	1	A	
69	978	1	A	
70	844	1	A	
71	1663	1	A	
72	1897	1	A	10/6/2005
73	1430	1	A	10/6/2005
74	2460	1	A	10/6/2005
75	2427	1	A	10/5/2005
76	1464	1	A	10/5/2005
77	1110	1	A	
78	1620	1	A	10/5/2005
79	7695	1	A	8/15/2005
80	3173	1	A	8/26/2005
81	1345	1	A	9/21/2005
82	1765	1	A	9/21/2005
83	3343	1	A	8/12/2005
84	3340	1	A	8/29/2005
85	730	1	A	
86	1917	1	A	
87	4008	1	A	10/12/2005
88	1470	1	A	
89	1325	1	A	
91	568	1	A	
92	537	1	A	
93	634	1	A	
94	2501	1	A	10/12/2005
97	120	1	E	
98	158	1	E	
99	195	1	E	
100	195	1	E	
101	168	1	E	

Table A-1. Residential Property EPCs (continued).

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
102	185	1	E	
103	103	1	E	
104	150	1	E	
106	231	1	E	
108	149	1	E	
109	143	1	E	
110	322	1	E	
111	1618	1	E	
112	141	1	E	
116	130	1	E	
117	148	1	E	
119	311	1	D	
120	2653	1	D	
121	1327	1	D	
122	377	1	E	
123	959	1	D	
127	1046	1	B	
128	837	1	D	
129	1840	1	B	
130	140	1	D	
131	932	1	B	
133	2208	1	D	8/8/2005
134	826	1	D	
135	835	1	D	
136	1785	1	D	
137	68	1	D	
138	737	1	D	
139	227	1	D	
140	894	1	D	
141	1238	1	A	
142	473	1	A	
143	2232	1	A	
144	700	1	A	
145	672	1	A	
146	1237	1	A	8/25/2005
147	1595	1	A	
148	1344	1	A	9/12/2005
149	1495	1	A	
151	1243	1	A	
152	1489	1	A	
153	914	1	A	9/12/2005
154	737	1	A	
156	1930	1	A	8/19/2005
157	2306	1	A	8/31/2005

Table A-1. Residential Property EPCs (continued).

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
158	1860	1	A	8/18/2005
159	392	1	A	
161	905	1	A	
162	3273	1	A	
163	1647	1	A	8/15/2005
165	1085	1	A	
166	1405	1	A	
167	1295	1	A	
168	1320	1	A	
169	2025	1	A	
170	1363	1	A	
171	337	1	A	
172	729	1	A	
173	3410	1	A	
176	814	1	A	
177	735	1	A	
178	455	1	A	
179	811	1	B	
181	839	1	B	
182	817	1	B	
183	747	1	B	
184	1010	1	B	
185	1882	1	B	
186	1300	1	B	
189	928	1	B	
192	2750	1	B	
193	493	1	B	
197	1531	1	B	
198	733	1	D	
199	2380	1	D	8/8/2005
200	5702	1	B	
201	1557	1	B	8/9/2005
202	5427	1	B	
203	3065	1	B	
204	2176	1	B	
206	1633	1	D	
207	9096	1	B	
209	2215	1	D	
210	25590	1	B	8/3/2005
211	25590	1	B	8/3/2005
212	874	1	B	7/26/2005
213	1837	1	B	7/26/2005
214	1444	1	B	
215	684	1	B	

Table A-1. Residential Property EPCs (continued).

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
218	128	1	A	
219	185	1	A	
220	999	1	A	
221	79	1	A	
222	20073	1	A	
224	248	1	A	
227	161	1	A	
228	857	1	A	
229	248	1	A	
230	752	1	A	
232	1005	1	A	
233	522	1	A	
234	302	1	A	
235	1346	1	A	
237	178	1	A	
238	1121	1	A	
239	329	1	A	
240	763	1	A	
242	688	1	A	
243	576	1	A	
246	492	1	A	
247	450	1	A	
248	727	1	A	
249	579	1	A	
250	735	1	A	
251	736	1	A	
252	1015	1	A	
253	938	1	A	
255	790	1	A	
256	938	1	A	
257	756	1	A	
258	1570	1	A	
259	1290	1	A	
266	687	1	A	
267	785	1	A	
269	331	1	A	
270	721	1	A	
271	274	1	A	
272	1551	1	A	
280	853	1	B	
281	707	1	B	
282	1755	1	B	
283	1743	1	B	
284	582	1	B	

Table A-1. Residential Property EPCs (continued).

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
285	541	1	B	
286	790	1	B	
287	915	1	B	
289	1863	1	B	
291	3003	1	B	
292	1084	2		
293	230	2		
294	114	1	C	
295	126	1	C	
296	156	1	C	
297	168	1	C	
298	169	1	C	
299	177	1	C	
300	170	1	C	
301	199	1	C	
302	169	1	C	
303	691	1	C	
304	419	1	C	
306	180	1	C	
307	365	1	C	
308	141	1	C	
309	118	1	C	
311	120	1	C	
313	2567	1	C	
314	341	1	C	
315	814	1	C	
318	317	1	C	
320	408	1	C	
321	404	1	C	
322	426	1	C	
324	475	1	C	
325	735	1	C	
328	660	1	C	
329	977	1	C	
330	1081	1	C	
331	668	1	C	
334	832	1	C	
336	248	1	C	
337	144	1	C	
339	145	1	C	
340	237	1	C	
341	252	1	C	
342	191	1	C	
343	182	1	C	

Table A-1. Residential Property EPCs (continued).

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
344	228	1	C	
345	399	1	C	
347	372	1	C	
348	496	1	C	
349	229	1	C	
350	312	1	C	
352	360	1	C	
353	308	1	C	
355	291	1	C	
357	526	1	C	
358	1045	1	C	
360	857	1	C	
361	726	1	C	
362	879	1	C	
363	617	1	C	
364	1673	1	C	
365	731	1	C	
366	178	1	C	
367	108	1	C	
368	87	1	C	
369	107	1	C	
370	174	1	C	
371	876	1	C	
372	350	1	C	
373	291	1	C	
374	725	1	C	
377	148	1	C	
379	163	1	C	
382	173	1	C	
383	55	1	C	
385	121	1	C	
386	127	1	C	
387	164	1	C	
388	104	1	C	
389	166	1	C	
391	83	1	C	
392	93	1	C	
393	135	1	C	
394	255	1	C	
395	222	1	C	
396	154	1	C	
397	241	1	C	
398	160	1	C	
399	125	1	C	

Table A-1. Residential Property EPCs (continued).

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
400	303	1	C	
401	418	1	C	
402	479	1	C	
403	65	1	C	
404	330	1	C	
405	509	1	C	
410	86	2		
412	170	2		
420	108	2		
429	207	2		
432	132	2		
434	58	2	C	
437	89	2	D	
440	152	2		
442	106	2		
444	726	2		
447	1669	2		
449	101	2		
456	144	2		
460	60	2		
461	67	2		
469	479	2		
470	260	2	D	
472	221	2	D	
476	473	2	D	
477	7450	2		
478	82	2	F	
483	460	2		
484	230	2		
485	185	2		
487	271	2		
488	69	2		
489	132	2		
493	2915	2		
495	135	2	F	
499	24	2		
501	46	2		
502	56	2		
503	99	2		
504	104	2		
509	836	2	A	
510	238	2		
511	427	2		
518	543	2		

Table A-1. Residential Property EPCs (continued).

Property ID	Input Pb Concentration (mg/kg)	Zone	Subarea ID	Remediation Completion Time
520	204	2		
522	46	2		
524	115	2		
700	125	1		
Average	1231			

Table A-2. Data Used to Derive Commercial Property EPC.

Property ID	Input Pb Concentration (mg/kg)	Remediation Completion Time
160	812	
164	1330	
174	1808	
175	1275	
187	818	
188	1860	
190	756	
196	1893	
241	858	
260	1174	
262	1185	
263	1118	
273	2930	
274	2000	
277	987	
278	383	
279	646	
288	689	
290	982	
323	663	
326	654	
327	221	
333	3798	
335	439	
359	588	
Average:	1195	
95% UCLM	1496	

Table A-3. Data Used to Derive Dolores River EPC.

Property ID	SampleID	Pb Concentration (mg/kg)
001	0011D1	5840
002	0021D1	1840
003	0031D1	32400
004	0041D1	159
005	0051D2	351
006	0061D1	747
007	0071D1	648
008	0081D2	164
008	0081D3	179
009	0091D1	128
010	0101D1	1750
031	0311D1*	2770
032	0321D1*	677
033	0331D1*	559
034	0341D3	43100
011	0111D1	940
011	0111D2	7910
012	0121D1	2490
013	0131D1	3140
014	0141D1*	6410
015	0151D1	6400
016	0161D1	5340
017	0171D1	30100
018	0181D1	356
019	0191D1	2230
020	0201D1	11600
021	0211D1	1360
022	0221D1	6870
023	0231D1	105
024	0241D1	158
025	0251D1	1940
026	0261D1	218
027	0271D1*	6270
028	0281D1*	319.5
029	0291D1*	2720
030	0301D1*	1290
005	0051D1	257
005	0051D3	1590
008	0081D1	354
Average:		4915
95% UCLM		11468

* Average of sample and duplicate sample.

Table A-4. Soil Samples Used for Calculating EPCs for Adjacent Properties.

Soil Sample ID	Pb Concentration (mg/kg)	Original Property ID	Shared Property ID
0391S1	1530	039	041
0392S1	859	039	041
0521S1	1180	052	141
0541S1	1400	054	063
0561S1	1670	056	065
0701S1	923	070	054
0731E1	227	073	072
0731S1	2100	073	072
0762S1	3650	076	075
0871S1	1290	087	086
0872S1	5370	087	086
0941G2	173	094	093
0991S1	129	099	098
0992S1	410	099	098
0993S1	111	099	098
0994S1	181	099	098
1001E1	27.9	100	099
1001G2	21.4	100	099
1001S1	180	100	099
1002S1	214	100	099
1003S1	258	100	099
1004S1	466	100	099
1011S1	145	101	109
1031E1	93.6	103	112
1081E1	204	108	112
1081S1	124	108	112
1282W1	880	128	131
1341S1	646	134	135
1662S1	1530	166	167
1683S1	950	168	170
2101M1	35200	210	207
2101S1	6050	210	207
2101M1	35200	210	211
2101S1	6050	210	211
2102M1	11700	210	211
2111M1	1060	211	210
2111S1	3040	211	210
2112M1	179	211	210
2112S1	1380	211	210
2113M1	85100	211	210
2114M1	86600	211	210
2381S1	1630	238	240
2422S1	678	242	241
2433S1	569	243	246

Table A-4. Soil Samples Used for Calculating EPCs for Adjacent Properties (continued).

Soil Sample ID	Pb Concentration (mg/kg)	Original Property ID	Shared Property ID
2434S1	414	243	246
2781S1	711	278	277
2931S1	264	293	292
2932S1	196	293	292
2962S1	193	296	295
2963S1	135	296	295
2974S1	217	297	296
2984S1	169	298	300
2984S1	169	298	302
3412S1	265	341	336
3792S1	227	379	382
3961S1	128	396	397
4024S1	321	402	404
4021S1	626	402	405
4022S1	595	402	405
4023S1	373	402	405
7001S1	80.7	700	109
7002S1	98.7	700	109
7003S1	180	700	109
7004S1	140	700	109

APPENDIX B

BLOOD LEAD DATA FROM RICO, COLORADO

Sample Date	**Sex**	**Age (Years)**	**PbB (µg/dL)**
June–Age 0-6			
6/29/2004	F	0-6	8.8
6/29/2004	F	0-6	5.7
6/29/2004	M	0-6	7.6
Mean			**7.4**
June–Age >6-18			
6/29/2004	F	6-18	**4.1**
June–Age >18			
6/29/2004	F	>18	1.3
6/29/2004	F	>18	1.6
6/29/2004	F	>18	1.9
6/29/2004	F	>18	3.0
6/29/2004	F	>18	3.6
6/29/2004	F	>18	3.8
6/29/2004	F	>18	4.2
6/29/2004	F	>18	6.8
6/29/2004	M	>18	3.1
6/29/2004	M	>18	3.8
6/29/2004	M	>18	4.3
6/29/2004	M	>18	5.0
6/29/2004	M	>18	QNS
Mean			**3.5**
April–Age 0-6			
4/20/2004	M	0-6	QNS
4/20/2004	F	0-6	<1
4/20/2004	F	0-6	1.8
4/20/2004	F	0-6	2.1
4/20/2004	M	0-6	<1
4/20/2004	M	0-6	1.5
4/20/2004	M	0-6	2.1
4/20/2004	M	0-6	2.6
4/20/2004	M	0-6	3.8
4/20/2004	M	0-6	6.4
Mean			**2.5**
April–Age >6-18			
4/20/2004	F	6-18	<1
4/20/2004	F	6-18	<1
4/20/2004	M	6-18	<1
Mean			**<1**
April–Age >18			
4/20/2004	F	>18	1.0
4/20/2004	F	>18	<1
4/20/2004	F	>18	<1
4/20/2004	F	>18	3.1
4/20/2004	F	>18	4.3

Sample Date	Sex	Age (Years)	PbB (µg/dL)
4/20/2004	F	>18	<1
4/20/2004	F	>18	3.1
4/20/2004	F	>18	<1
4/20/2004	F	>18	1.8
4/20/2004	F	>18	1.2
4/20/2004	F	>18	<1
4/20/2004	F	>18	1.4
4/20/2004	M	>18	2.6
4/20/2004	M	>18	2.3
4/20/2004	M	>18	4.1
4/20/2004	M	>18	<1
4/20/2004	M	>18	<1
4/20/2004	M	>18	1.0
4/20/2004	M	>18	<1
4/20/2004	M	>18	2.9
4/20/2004	M	>18	1.7
Mean			**1.8**
4/20/2004	M	unknown	4.3
Overall Mean			**2.7**

Notes:

All means were calculated assuming samples below the detection limit were equal to the detection limit and excluding samples coded as QNS (or inadequate).