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Site-Wide Human Health Risk Assessment

Libby Asbestos Superfund Site
Libby, Montana

November 2015

CDM Smith

- FINAL-

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Tetra Tech EM Inc.

Site-Wide Human Health Risk Assessment
Libby Asbestos Superfund Site,
Libby, Montana

FINAL – November 2015

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Acronyms and Abbreviations

%	percent
>	greater than
≥	greater than or equal to
<	less than
µm	micrometers
95UCL	95% upper confidence limit
ABS	activity-based sampling
Ago	area of grid opening
ARP	Lincoln County Asbestos Resource Program
ASTM	American Society for Testing and Materials
ATS	American Thoracic Society
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	all-terrain vehicle
BE	best estimate
BNSF	Burlington Northern and Santa Fe
C	concentration
CB&I	CB&I Federal Services, LLC
cc^{-1}	per cubic centimeter of air
CDM Smith	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	conceptual site model
CTE	central tendency exposure
CUA	common-use area
DEQ	Montana Department of Environmental Quality
DPT	diffuse pleural thickening
ED	exposure duration
EDS	energy dispersive spectroscopy
EF	exposure frequency
EFA	effective area of the filter
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ESATR8	Environmental Services Assistance Team, EPA Region 8
ET	exposure time
F	f-factor
FBAS	fluidized bed asbestos segregator
f/cc	fibers per cubic centimeter of air
FS	feasibility study
GO	grid opening
GPS	global positioning system
Grace	W.R. Grace Company
H&S	health and safety
HDR	HDR Engineering, Inc.
HEI-AR	Health Effects Institute – Asbestos Research
HEPA	high-efficiency particulate air
HHRA	human health risk assessment

HI	hazard index
HQ	hazard quotient
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
ISO	International Organization of Standardization
IUR	inhalation unit risk
KBPID	Kootenai Business Park Industrial District
L	liters
LA	Libby amphibole asbestos
LPT	localized pleural thickening
LRC	Lower Rainy Creek
LUA	limited-use area
MCL	maximum contaminant level
MDNRC	Montana Department of Natural Resources and Conservation
MDT	Montana Department of Transportation
mL	milliliters
mm^2	square millimeters
MP	mile post
mph	miles per hour
MotoX	motorcross
Ms/g	million structures per gram
NAS	National Academy of Sciences
ND	non-detect
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NPL	National Priorities List
NTP	National Toxicology Program
NVLAP	National Voluntary Laboratory Accreditation Program
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PCM	phase contrast microscopy
PCME	phase contrast microscopy-equivalent
PLM	polarized light microscopy
PLM-Grav	polarized light microscopy-gravimetric
PLM-VE	polarized light microscopy using visual area estimation
QA	quality assurance
QC	quality control
RAGS	Risk Assessment Guidance for Superfund
RfC	reference concentration
RI	remedial investigation
RME	reasonable maximum exposure
ROD	record of decision
ROW	right-of-way
s	structures
s/cc	structures per cubic centimeter of air
s/cm^2	structures per square centimeter of area
s/g	structures per gram
SAB	Scientific Advisory Board

SAED	selective area electron diffraction
SAP	sampling and analysis plan
Site	Libby Asbestos Superfund Site
SOP	standard operating procedure
SQAPP	Supplemental Remedial Investigation Quality Assessment and Project Plan
SUA	specific-use area
TEM	transmission electron microscopy
TRW	Technical Review Workgroup
Tetra Tech	Tetra Tech EM Inc.
TWF	time-weighting factor
UB	upper-bound
UF	uncertainty factor
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
V	volume
VI	vermiculite insulation
VV	visible vermiculite
WHO	World Health Organization

EXECUTIVE SUMMARY

Introduction

Libby is a community in northwestern Montana that is located near a former vermiculite mine (**Figure ES-1**). The vermiculite mine near Libby began limited operations in the 1920s and was operated on a larger scale by the W.R. Grace Company (Grace) from approximately 1963 to 1990. Vermiculite from the mine contains varying concentrations of amphibole asbestos, referred to as "Libby amphibole asbestos" or LA. Epidemiological studies revealed that workers at the mine had an increased risk of developing asbestos-related lung disease (McDonald *et al.* 1986a, 1986b, 2004; Amandus and Wheeler 1987; Amandus *et al.* 1987a,b; Whitehouse 2004; Sullivan 2007). Additionally, radiographic abnormalities were observed in 17.8 percent (%) of the general population of Libby, including former workers, family members of workers, and other residents of Libby and Troy, Montana (Peipins *et al.* 2003; Whitehouse *et al.* 2008; Antao *et al.* 2012; Larson *et al.* 2010, 2012a, 2012b).

In October 2002, the Libby Asbestos Superfund Site (Site) was listed on the U.S. Environmental Protection Agency (EPA) National Priorities List (NPL). The Site includes homes and businesses that may have become contaminated with LA as a result of the vermiculite mining and processing conducted in and around Libby, as well as other areas that may have been affected by mining-related releases of LA. In addition to vermiculite mining and processing activities, LA contamination also occurred as a consequence of use of LA-contaminated vermiculite as building insulation in residential and commercial buildings and as soil amendments (e.g., gardens and flowerbeds), use of LA-contaminated building materials (e.g., mortar, chinking), and other uses.

The purpose of this document is to quantify potential human health risks from exposures to LA at the Site under current and future conditions. This risk assessment differs from other "typical" Superfund risk assessments in that extensive interior and exterior removal actions have been conducted at the Site for more than 10 years, prior to the completion of the risk assessment, to allow for the timely removal of LA contamination while awaiting the necessary exposure and toxicity data needed complete a quantitative assessment of human health risk. Results of this risk assessment are intended to help Site managers determine if past removal actions have been sufficient to mitigate risk, if additional remedial actions are necessary to address risks, and if so, which exposure scenarios would need to be addressed in future remedial actions.

Exposure Assessment

Conceptual Site Model

Historical mining, milling, and processing operations, use of vermiculite in building materials, transport of mining-related materials, tailings, and waste, and runoff from the mine site are known to have released LA to the environment. People may be exposed to LA by two exposure routes: inhalation and ingestion. Of these two exposure routes, inhalation exposure of LA is considered to be of greatest concern.

Asbestos fibers in source materials are typically not inherently hazardous, unless the asbestos is released from the source material into air where it can be inhaled (EPA 2008a). Asbestos fibers may become airborne in a number of ways. This may include natural forces, such as wind blowing over a contaminated soil, or human activities that disturb contaminated sources, such as soil or indoor dust. **Figure ES-2** presents the conceptual site model (CSM) that depicts how LA in source media can be transported in the environment to exposure media that humans may encounter at the Site. The two main types of exposure media are indoor air and outdoor air. **Table ES-1** summarizes the inhalation exposure scenarios and populations that will be evaluated in the human health risk assessment (HHRA).

Exposure Parameters

The risk assessment evaluates potential inhalation exposures for several exposure populations, including residents, recreational visitors, teachers/students, and several types of workers (indoor workers, local tradespeople, outdoor workers). Exposure estimates in the risk assessment do not seek to evaluate exposures for specific individuals. Rather, risk estimates are calculated for representative members of the exposure population, calculating risks based on both members of the population with "typical" levels of exposure and members of the population with "high-end" exposures. These two exposure estimates are referred to as central tendency exposure (CTE) and reasonable maximum exposure (RME), respectively.

For each exposure scenario evaluated in the risk assessment, information on estimated exposure time (ET, in hours per day), exposure frequency (EF, in days per year), and exposure duration (ED, in years) is used to derive a lifetime time-weighting factor (TWF) as follows:

$$TWF = (ET/24 \cdot EF/365 \cdot ED/70)$$

The value of the TWF ranges from zero to one, and describes the average fraction of a lifetime during which the specific exposure scenario occurs.

Exposure Point Concentrations

Predicting the LA levels in air based on measured LA levels in source media is extremely difficult. For this reason, EPA recommends an empiric approach for investigating asbestos-contaminated Superfund sites, where concentrations of asbestos in air from source disturbances are measured rather than predicted (EPA 2008a). This type of sampling is referred to as activity-based sampling (ABS).

To date, more than two dozen different ABS investigations have been conducted at the Site to evaluate potential exposures to LA from various disturbances of source media. These studies have included a wide range of activities, including, but not limited to, dusting and vacuuming inside residences, raking/mowing/digging in yard soil, riding all-terrain vehicles (ATVs), bicycling and driving on roads, and various worker activities. In total, more than 3,100 ABS air samples have been collected at the Site since 2001. In addition, more than 1,500 outdoor ambient air samples have been collected at the Site.

All ABS and ambient air samples have been analyzed by transmission electron microscopy (TEM). During the analysis, detailed information for each observed asbestos structure (e.g., asbestos type, structure type, length, width) is recorded. For the purposes of computing risk estimates, it is necessary to use the results from the TEM analysis to estimate what would have been detected had the sample been analyzed by phase contrast microscopy (PCM). This is because available toxicity information is based on workplace studies that used PCM as the primary method for analysis. For convenience, structures detected under TEM that meet the recording rules for PCM are referred to as PCM-equivalent (PCME) structures. TEM analysis results for air samples are expressed as PCME LA structures per cubic centimeter of air (s/cc).

In accordance with EPA asbestos risk assessment guidance (EPA 2008a), exposure point concentrations (EPCs) for each exposure scenario are calculated as the sample mean, evaluating non-detect samples at a concentration value of zero. In cases where air filters required the use of indirect preparation techniques prior to TEM analysis, the reported PCME LA air concentration was adjusted (decreased) by a factor of 2.5 to avoid potentially biasing calculated EPCs high due to the effect of indirect preparation.

Toxicity Assessment

The adverse effects of asbestos exposure in humans have been the subject of a large number of studies and publications. Exposure to asbestos may induce several types of both non-cancer and cancer effects. A detailed summary of the cancer and non-cancer effects of asbestos is provided in the Agency for Toxic Substances and Disease Registry (ATSDR) *Toxicological Profile for Asbestos* (ATSDR 2001) and in EPA's *Airborne Asbestos Health Assessment Update* (EPA 1986). A detailed summary of effects related specifically to LA is provided in the *Toxicological Review for Libby Amphibole Asbestos* (EPA 2014c).

Cancer Effects

Many epidemiological studies have reported increased mortality from cancer in workers exposed to asbestos, especially from lung cancer and mesothelioma (tumor of the thin membrane that covers and protects the internal organs of the body). In addition, a number of studies suggest asbestos exposure may increase risk of cancer of the larynx (commonly called the voice box) and ovarian cancer (IARC, 2012). Based on these findings, and supported by extensive data from animal studies, EPA has classified asbestos as a known human carcinogen.

Cancer risk from inhalation exposure is determined based on an inhalation unit risk (IUR) value, which is defined as the excess lifetime cancer risk estimated to result from continuous exposure to one asbestos fiber per cubic centimeter of air (1 f/cc). The LA-specific IUR, referred to as IUR_{LA}, is derived from a group of workers employed at the vermiculite mining and milling operation in and around Libby, referred to as the "Libby worker cohort". The IUR_{LA} is 0.17 (PCM f/cc)$^{-1}$ (EPA 2014c).

Non-Cancer Effects

Non-cancer effects from asbestos exposure include asbestosis (formation of scar tissue in the lung parenchyma) and several types of abnormalities in the pleura (the membrane surrounding the lungs), such as pleural effusions (excess fluid accumulation in the pleural space), pleural plaques (collagen deposits and calcification), and pleural thickening.

Non-cancer hazard from inhalation exposure is determined based on a reference concentration (RfC) value. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure that is likely to be without an appreciable risk of deleterious effects in humans (including sensitive subgroups) during a lifetime (EPA 2009e). The LA-specific RfC, referred to as RfC_{LA}, is derived from a group of workers employed at the O.M. Scott Plant in Marysville, Ohio. This plant utilized vermiculite that originated from the mine in Libby from 1959 to 1980 in their lawn care products. Localized pleural thickening was selected as the critical effect endpoint for the derivation of the RfC_{LA}. The RfC_{LA} is 0.00009 PCM f/cc (EPA 2014c).

Risk Characterization

Basic Equations

The basic equation used to estimate excess lifetime cancer risk from inhalation of LA is:

$$Risk = EPC \cdot TWF \cdot IUR_{LA}$$

where:

Risk = Lifetime excess risk of developing cancer (lung cancer or mesothelioma) as a consequence of LA exposure.

EPC = Exposure point concentration of LA in air (PCME LA s/cc). The EPC is an estimate of the long-term average concentration of LA in inhaled air for the specific activity being assessed.

TWF = Time-weighting factor for the specific activity being assessed.

IUR_{LA} = LA-specific inhalation unit risk $(0.17 \text{ PCM s/cc})^{-1}$

The basic equation used for characterizing non-cancer hazards from inhalation exposures to LA is as follows:

$$HQ = EPC \cdot TWF / RfC_{LA}$$

where:

HQ = Hazard quotient for non-cancer effects from LA exposure

EPC = Exposure point concentration of LA in air (PCME LA s/cc)

TWF = Time-weighting factor

RfC_{LA} = LA-specific reference concentration (0.00009 PCM s/cc)

Risk Interpretation

In general, EPA considers cumulative excess cancer risks[1] that are less than 1E-06 to be negligible, and risks greater than 1E-04 to be sufficiently large that some form of remedial action is desirable. Excess cancer risks that range between 1E-04 and 1E-06 are generally considered to be acceptable, although this is evaluated on a case-by-case basis, and EPA may determine that risks lower than 1E-04 are not sufficiently protective and warrant remedial action.

For non-cancer, if the cumulative HQ (referred to as the hazard index [HI]) is less than or equal to 1, then remedial action is generally not warranted. If the HI exceeds 1, there is some possibility that non-cancer effects may occur, although an HI greater than 1 does not indicate an effect will definitely occur. However, the larger the HI value, the more likely it is that an adverse effect may occur.

[1] Note that excess cancer risk can be expressed in several formats. A cancer risk expressed in a scientific notation format as 1E-06 is equivalent to 1 in 1,000,000 (one in a million) or 1×10^{-6}. Similarly, a cancer risk of 1E-04 is equivalent to 1 in 10,000 (one in ten thousand) or 1×10^{-4}.

Scenario-Specific Risk Characterization

Risks from Exposures to Ambient Air

In the past (circa 1970s), ambient air concentrations as high as 1.5 PCM f/cc were measured in downtown Libby when the mine was in operation. Beginning in 2006, there have been several long-term outdoor ambient air monitoring studies conducted in Libby, Troy, and at the mine site. These data show that average ambient air concentrations in the Libby community and in Troy are less than 0.00001 PCME LA s/cc under current conditions. Current ambient air concentrations at the Site are greatly improved relative to historical conditions and are consistent with asbestos levels that have been measured in ambient air in Eureka and Helena, Montana, as well as across the country (SRC, Inc. 2013a).

Data from the recent ambient air monitoring studies at the Site were used to calculate EPCs for use in evaluating potential exposures to LA in ambient air. All individuals at the Site have the potential to be exposed to LA in ambient air. However, for simplicity, risk estimates from exposures to ambient air were calculated for each exposure area based on the maximally-exposed receptor (e.g., residential exposure scenario in Libby). RME cancer risks are less than or equal to 1E-06 and non-cancer HQs are less than 0.1 for all Site exposure locations; CTE cancer risks and non-cancer HQs are even lower. These results indicate that exposures to LA in ambient air are not likely to be of concern to individuals at the Site and are not likely to contribute significantly to cumulative risks.

Risks from Exposures During Soil/Duff Disturbances

Overview

Potential exposures to LA during disturbances of soil/duff can occur for a wide range of receptor types and exposure scenarios. More than 80 different types of exposures during soil/duff disturbances were evaluated, encompassing multiple disturbance activities, exposure populations, exposure locations, and LA concentrations. In reviewing the risk estimates for exposures during soil/duff disturbance activities, there are a number of general conclusions that can be drawn:

- Estimated cancer risks and non-cancer HQs span more than four orders of magnitude depending upon the exposure scenario.
- For a given exposure scenario, non-cancer HQs can exceed 1 even when cancer risks are less than 1E-04, which indicates that non-cancer exposure is a more sensitive metric of potential concern. (For LA, a non-cancer HQ of 1 is approximately equivalent to a cancer risk of 1E-05.)
- There were only a few soil/duff disturbance exposure scenarios where risks from the exposure scenario alone had the potential to be above a level of concern based on RME, including residential and outdoor worker exposures during disturbances of yard soils with detected LA at properties in Libby and Troy, outdoor worker exposures during disturbances of subsurface soils with LA contamination at properties in Libby and Troy, and rockhound exposures in the disturbed area of the mine.
- Quantitative risks were not calculated for potential exposures to workers exposed to residual LA in subsurface soils in the former Screening Plant and Export Plant areas; however, these exposure scenarios could result in potentially unacceptable exposures and risks because LA concentrations greater than 1% are present in subsurface soil beneath the cover fill in some areas.

- Exposure to LA in outdoor air during yard soil disturbances has the potential to be an important exposure scenario. Even when only trace levels of LA are present in the soil, this exposure scenario, when considered alone, could yield non-cancer HQs greater than 1, depending upon the spatial extent of the LA in soil and the frequency and intensity that these soils are disturbed.

Extrapolation to Properties without ABS

As noted above, exposure to LA in outdoor air during yard soil disturbances has the potential to be an important exposure scenario. There are more than 5,000 residential/commercial properties in Libby and Troy. Because it is not feasible to evaluate risks by conducting outdoor ABS at every property, it is necessary to use the measured ABS data from the properties where ABS has been performed to draw risk conclusions about properties where ABS has not been performed. This is accomplished by assuming that properties without ABS data, but having the same LA soil level and similar disturbance activities, will have similar outdoor air concentrations as properties with ABS data.

Table ES-2 presents estimated RME cancer risks and non-cancer HQs from exposures to LA during soil disturbances for a range of LA soil levels at residential properties in Libby and Troy. In interpreting these risk estimates, it is important to understand that these calculations are intended to represent a given LA soil concentration. However, a specified exposure area for a property may have varying LA soil concentrations with differing spatial extents. The evaluation of risk at a property is based on the average exposure across the entire exposure area. Thus, for exposure areas that encompass varying soil concentrations, it is necessary to derive a spatially-weighted average risk estimate for the entire exposure area. **Figure ES-3** presents a simplified example of this approach.

Background LA Concentrations in Soil

EPA has conducted several investigations at the Site to characterize LA in soil from areas that are thought to be representative of "background" conditions, meaning that the soils are not expected to be affected by anthropogenic releases from vermiculite mining and processing activities. LA structures have been consistently detected in background soils within the Kootenai Valley. However, potential exposures and risks from LA in background soil are likely to be low.

Risks from Exposures to Indoor Air

There are a wide range of different activities that could occur inside buildings (residences, businesses, schools, etc.) at the Site that could result in exposures to LA. There have been several indoor ABS investigations to evaluate LA concentrations in air during various indoor disturbance scenarios, including indoor exposures inside residences, schools, and commercial and industrial buildings in Libby and Troy. In general, ABS air samples were collected under two representative conditions – active and passive behaviors. Active behaviors include indoor activities in which a person is moving about the building and potentially disturbing indoor sources; such activities have included walking from room to room, sitting down on upholstered chairs, sweeping, and vacuuming. Passive behaviors are minimally energetic actions, such as sitting and reading a book, watching television, and working at a desk, that will have low tendency to disturb any indoor source materials. In addition, air samples were also collected to evaluate potential exposures to local tradespeople (e.g., carpenter, electrician, plumber) from high intensity disturbances of vermiculite insulation (VI) or other asbestos-containing building materials.

With the exception of indoor exposures at properties under "pre-removal" conditions and during tradesperson activities (discussed below), estimated RME cancer risks were less than 1E-04 and non-cancer HQs were less than 1 for all indoor exposure scenarios.

Estimated RME non-cancer HQs were greater than 1 for both residential exposures and indoor worker exposures to LA inside "pre-removal" properties (these are properties where an interior removal has been deemed necessary, but a removal had not been completed at the time of the ABS). Activities associated with active disturbance behaviors contributed most to total exposures. Non-cancer HQs were less than 1 for properties where an interior removal has been completed ("post-removal") and for properties where an interior removal was deemed not to be necessary ("no removal required"). These results demonstrate that interior investigations and removals have been effective at identifying and mitigating sources of LA inside properties.

Exposures of local tradespeople to LA while working inside buildings have the potential to result in RME cancer risks greater than or equal to 1E-04 and non-cancer HQs greater than 1 for all the activities investigated, which included active disturbances of VI (e.g., wall demolition, attic detailing, cleaning living space areas with visible VI). These results indicate that local tradesperson exposures have the potential to be significant and result in risks above a level of concern if appropriate personal protective measures are not employed to mitigate exposures during active disturbances of indoor source materials. There is the potential for tradesperson exposures to occur, even for properties that have had an interior removal or where no interior removal has been deemed necessary, if source materials have been left in place (e.g., VI contained within walls).

Risks from Exposures during Disturbances of Wood-Related Materials

Extensive data have been collected in the forested area near the mine site (CDM Smith 2015a) and in the forested area near the current Site NPL boundary (CDM Smith 2013g). These data show that LA structures are present on the outer bark surface of trees at the Site. If LA-containing trees or wood-related materials (e.g., woodchips, mulch) are disturbed, people may be exposed to LA that is released to air from the wood. If LA-containing trees are used as a source of firewood (e.g., in a residential woodstove), studies have shown that LA fibers can become concentrated in the resulting ash (Ward *et al.* 2009; EPA 2012c), which itself can become a source of potential LA exposure.

A number of ABS studies have been performed at the Site to provide measured data on LA concentrations in air during a variety of disturbances of wood-related materials, including ABS studies during residential wood harvesting activities, commercial logging activities, wood chipping activities, forest maintenance activities, woodchip/mulch disturbance activities, and woodstove ash disturbance activities. With the exception of activities related to commercial logging and the removal of ash from a woodstove (discussed below), estimated RME cancer risks were less than 1E-04 and non-cancer HQs were less than 1 for all wood-related exposure scenarios.

When commercial logging activities were conducted in an area located near the mine with higher concentrations of LA in tree bark and duff, estimated RME cancer risks for all commercial logging activities were less than 1E-04, but non-cancer HQs were greater than or equal to 1 during timber skidding and site restoration activities. However, when commercial logging activities were conducted in an area further from the mine, where concentrations of LA in tree bark and duff were lower, estimated RME cancer risks were less than 1E-04 and non-cancer HQs were less than 1 for all commercial logging activities.

Estimated RME non-cancer HQs for activities associated with the removal of ash from a woodstove differed depending on the source of the firewood that was burned. The estimated HQ was greater than 1 when firewood was collected from a location near the mine (where tree bark LA levels are highest), but HQs were less than 1 when firewood was collected from a location intermediate or far from the mine. RME cancer risks from exposure to LA in woodstove ash were less than 1E-04 regardless of the wood source. These risk estimates demonstrate that exposures to LA in woodstove ash may be an important contributor to cumulative exposures, if the ash is derived from a wood source in close proximity to the mine.

Risks from Exposures during Fire-Related Activities

ABS studies have been performed at the Site to provide measured data on LA concentrations in air during fire-related activities to provide information on potential exposures to fire fighters during an understory burn and to forest workers during a slash pile burn. Estimated RME cancer risks were less than 1E-04, but non-cancer HQs were greater than or equal to 1 for several fire-related exposure scenarios. The RME non-cancer HQs were greater than 1 during slash pile building activities and were greater than or equal to 1 during mop-up activities for the understory burn (when mop-up activities were conducted by hand) for both “wet” and “dry” mop-up scenarios. These risk estimates demonstrate that fire-related exposures have the potential to be significant near the mine if appropriate personal protective measures are not employed to mitigate exposures.

Cumulative Risk Characterization

Basic Approach

The calculation of cumulative risks is complicated by the fact that the exposure pattern of each individual at the Site may be unique. However, EPA does not typically perform risk calculations for specific individuals, but rather for generic classes of receptor populations with common exposure patterns. Thus, the goal of the cumulative risk assessment is to illustrate how risk depends on different types of disturbance activities, LA levels in the source media, and exposure locations.

Cumulative risk from asbestos is expressed as the sum of all the cancer risks or non-cancer HQs from various types of asbestos exposure scenarios. Exposure-specific TWF values for use in the cumulative assessment were selected by specifying the fraction of the lifetime spent engaging in each exposure scenario, taking care to ensure that the cumulative TWF is equal to 1.0. This approach is illustrated in **Figure ES-4**.

Cumulative Risk Examples

There are essentially an infinite number of possible exposure scenario combinations that could be evaluated in the cumulative risk assessment for the Site. The choice of which combinations to evaluate is a matter of judgment. For the purposes of this risk assessment, several alternate cumulative exposure scenario combinations were evaluated, representing a wide range of potential cumulative risks. These examples help to identify which exposure scenarios that tend to have the largest contribution to cumulative risk.

Figure ES-5 presents a graphical illustration of the cumulative assessment for one example receptor scenario. In this figure, the upper panel illustrates the fraction of time that each exposure scenario contributes to the total lifetime (i.e., a 70-year lifetime). The lower panel illustrates the contribution of each exposure scenario to the cumulative HI. The table below the figures provides a tabular presentation of the information shown in the two figures. (Note: This figure only presents cumulative HIs as the non-cancer endpoint appears to be the more sensitive metric of potential risk.)

In reviewing the cumulative exposure scenarios, several general observations can be made:

- Cumulative HI estimates were less than 1 when exposures occurred at properties and locations with lower levels of LA. However, cumulative HI estimates were greater than 1 when exposures occurred at properties and locations with higher levels of LA.

- Exposure scenarios that contributed the most time to the total lifetime exposure do not necessarily contribute most to the cumulative HI. In some cases, exposure scenarios that contribute little to the total lifetime exposure time can contribute significantly to the cumulative HI. For example, in **Figure ES-5**, exposures to LA in outdoor air during disturbances of yard soil (exposure scenario "D") contributes about 3% to the total lifetime exposure time, but about 14% to the cumulative HI.

- When cumulative exposure includes exposure scenarios that actively disturb LA-contaminated source materials (e.g., hiking along lower Rainy Creek near the mine, riding ATVs in the disturbed areas of the mine, disturbing yard soils with detected LA, performing timber skidding operations near the mine site, or disturbing VI during tradesperson activities), these pathways are important risk drivers for cumulative HI estimates.

- It is possible to reduce cumulative exposures and risks, without altering activity behavior patterns, by lowering LA levels in source media where disturbance activities are performed (e.g., removing yard soil with LA) (see **Figure ES-6**) and/or by changing the locations where the activities are performed (e.g., collecting firewood or performing logging in areas further from the mine site) (see **Figure ES-7**).

- As illustrated in **Figure ES-8**, it is not necessary to address every single exposure scenario to significantly lower cumulative risk. Addressing exposures for a small subset of the potential exposure scenarios, focusing on risk drivers, will have the greatest impact in lowering cumulative exposures and risks.

- It is possible for individual exposure scenario HQs to be less than 1, but the cumulative HI across all exposure scenarios to be greater than 1. Thus, risk managers should consider both cumulative risks and individual exposure scenario risks to identify potential risk drivers to guide decisions on future remedial levels and/or institutional controls.

Uncertainty Assessment

As with all HHRAs, uncertainties exist due to limitations in the exposure and toxicity assessments and our ability to accurately determine cumulative exposure and risk from multiple sources over a lifetime. This risk assessment has used the best available science to evaluate potential human health exposures and risks from LA at the Site; however, there are number of sources of uncertainty that affect the risk estimates that must be considered when making risk management decisions. The most important of these uncertainties are listed below.

- Uncertainty in true long-term average LA concentrations in air

- Uncertainty in the EPC due to non-detects

- Uncertainty due to air filter preparation methods

- Uncertainty due to analytical methods

- Uncertainty due to field collection methods
- Uncertainty in human exposure patterns
- Uncertainty in toxicity values used in risk characterization
- Uncertainty in the cumulative risk estimates

Because of these uncertainties, the cancer risks and non-cancer HQs for individual exposure scenarios are uncertain, and consequently all estimates of cumulative cancer risks and non-cancer HI values presented in this HHRA are also uncertain, and should be considered to be approximate. Actual risks may be either higher or lower than estimated.

EXECUTIVE SUMMARY TABLES AND FIGURES

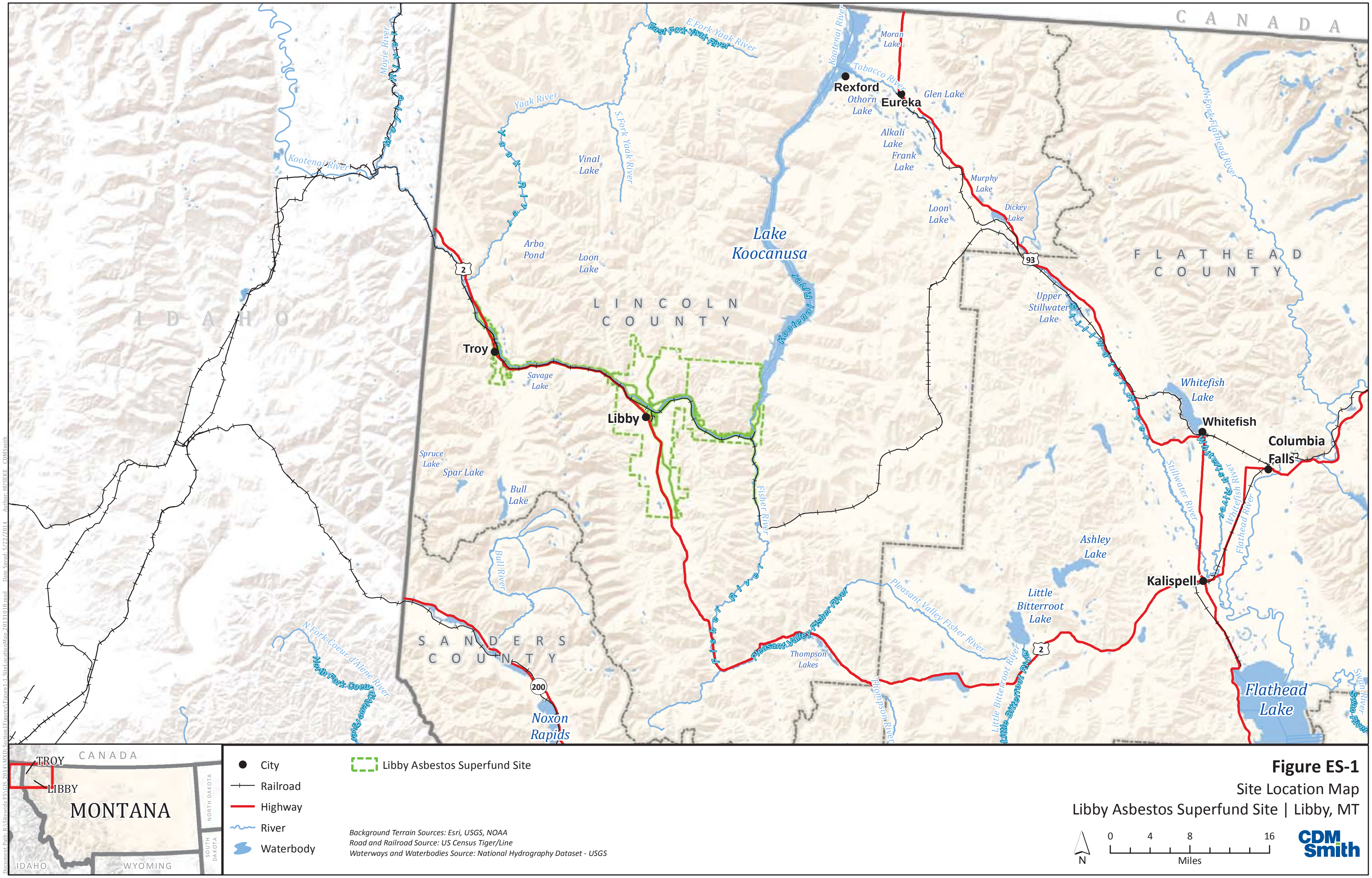


Figure ES-1
Site Location Map
Libby Asbestos Superfund Site | Libby, MT

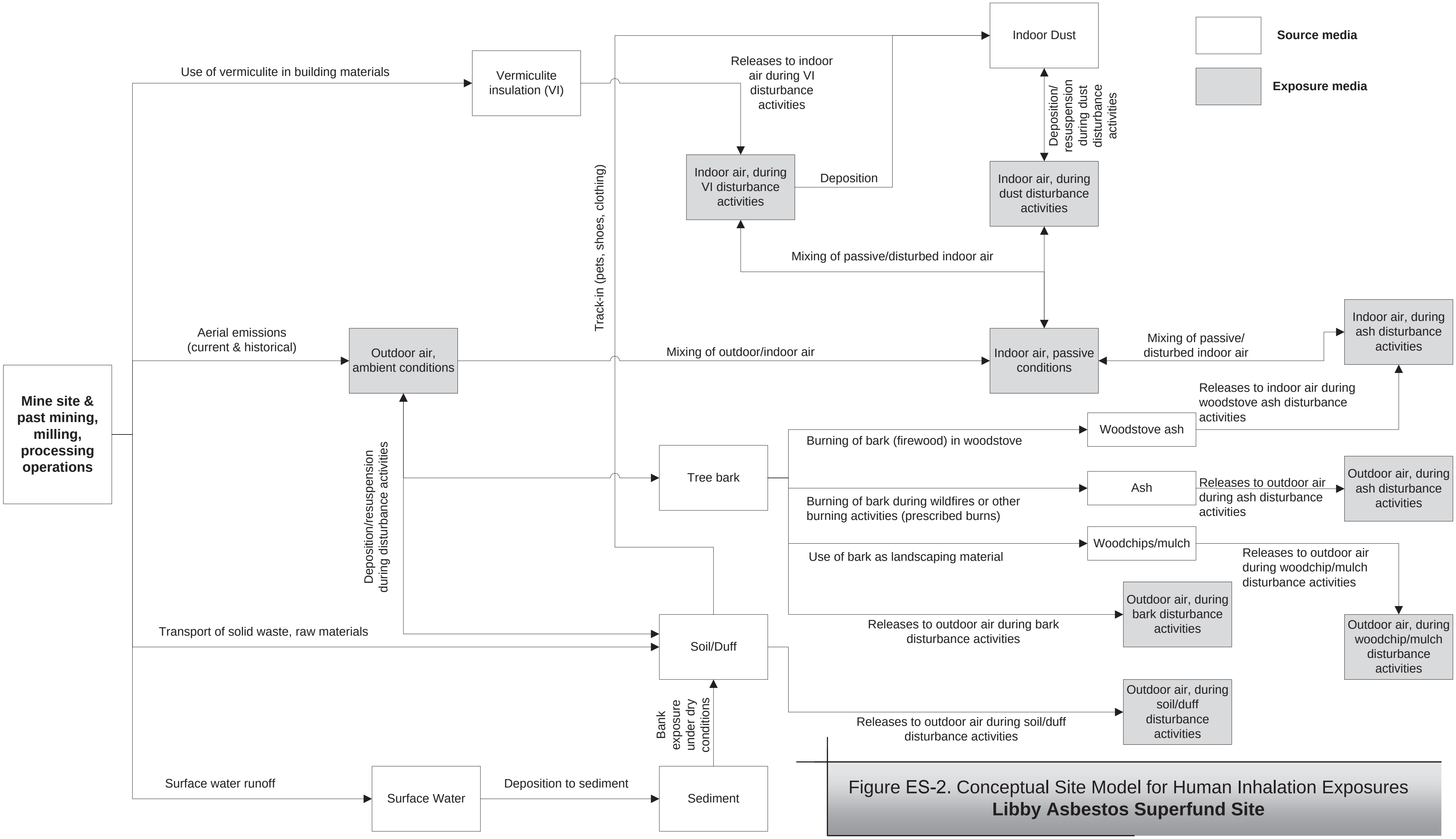


Figure ES-2. Conceptual Site Model for Human Inhalation Exposures
Libby Asbestos Superfund Site

FIGURE ES-3
Example of Exposure Area Spatial-Weighting Approach

Panel A: Exposure Area Soil Concentrations

Soil Sample #1:
Non-detect

Soil Sample #2:
Trace (<0.2%)

Soil Sample #3:
1%

Panel B: Estimated HQs* for Each Subarea

Non-detect
Soil Concentration HQ = 0.1

Trace (<0.2%)
Soil
Concentration
HQ = 2

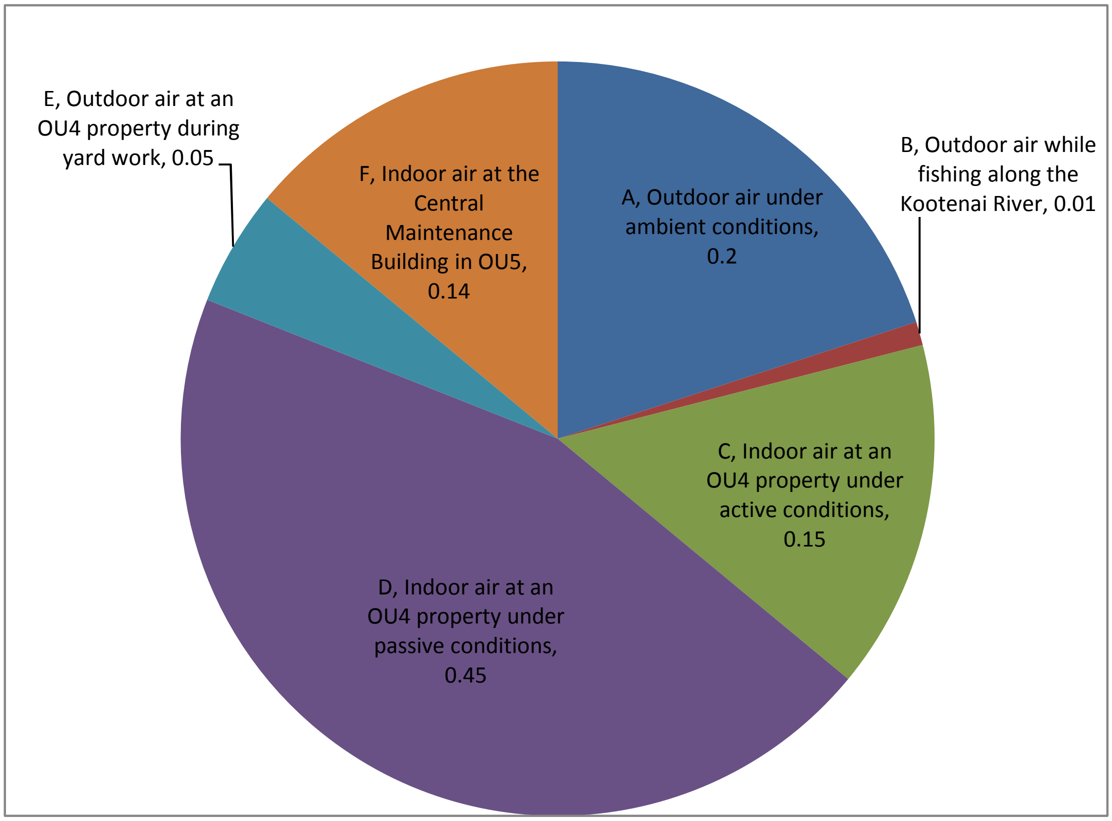
1%
Soil
Concentration
HQ = 7

Panel C: Estimated Average HQ for the Entire Exposure Area

Exposure Area HQ =
(0.1 · 0.5) +
(2 · 0.25) +
(7 · 0.25)
= **2**

*Based on Libby Yard Soil Disturbance Residential HQs (see **Table ES-2**)
HQ = hazard quotient

FIGURE ES-4. ILLUSTRATION OF CUMULATIVE ASSESSMENT TWF APPROACH



Exposure Scenario		TWF	% of total
A	Outdoor air under ambient conditions	0.20	20%
B	Outdoor air while fishing along the Kootenai River	0.03	3%
C	Indoor air at an OU4 property under active conditions	0.15	15%
D	Indoor air at an OU4 property under passive conditions	0.48	48%
E	Outdoor air at an OU4 property during yard work	0.03	3%
F	Indoor air at the Central Maintenance Building in OU5	0.11	11%
	cumulative:	**1.00**	

Notes:

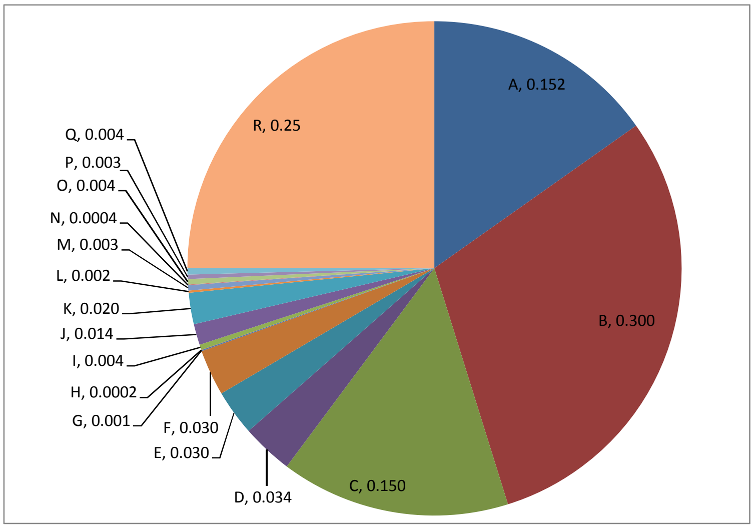
% - percent

OU - Operable Unit

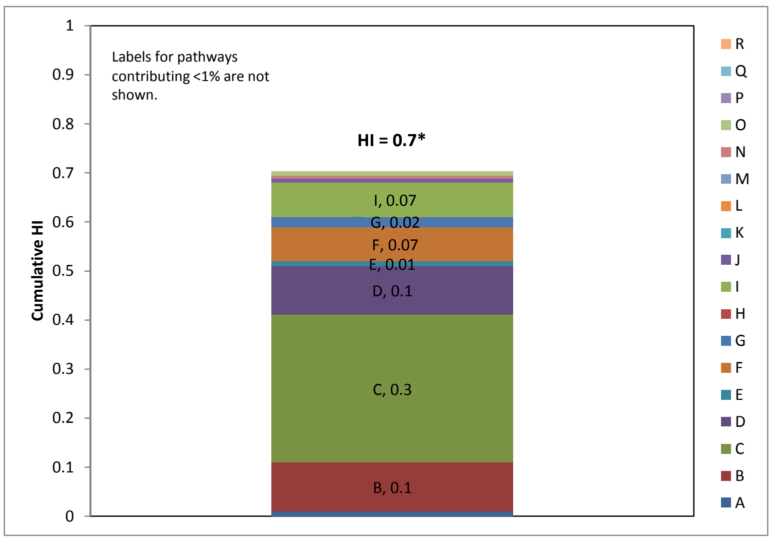
TWF - time-weighting factor

FIGURE ES-5. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 1

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI



	Exposure Scenario	TWF		Risk Estimates		
		Value	% of total	Risk	HQ	% of total
A	Ambient air, OU4	0.15	15%	2E-07	0.01	1%
B	Indoor air, OU4, post-removal, resident, passive	0.30	30%	2E-06	0.1	14%
C	Indoor air, OU4, post-removal, resident,active	0.15	15%	5E-06	0.3	43%
D	Outdoor air, yard soil, curb-to-curb	0.034	3%	2E-06	0.1	14%
E	Indoor air, OU4, no removal, worker, passive	0.030	3%	2E-07	0.01	1%
F	Indoor air, OU4, no removal, worker, active	0.030	3%	1E-06	0.07	10%
G	Outdoor air, OU4, Libby Middle, student	0.00070	0.07%	2E-07	0.02	3%
H	Outdoor air, OU4, Koot. Valley HS, student	0.00021	0.02%	0E+00	0	0%
I	Outdoor air, OU4, Libby Elem., student	0.0035	0.4%	1E-06	0.07	10%
J	Indoor air, OU4, student, Elem. School	0.014	1%	1E-07	0.009	1%
K	Outdoor air, OU7, Golf course, adult	0.02	2%	0E+00	0	0%
L	Outdoor air, OU4, biking, adult	0.0016	0.2%	0E+00	0	0%
M	Outdoor air, OU5, MotoX, participant	0.0034	0.3%	0E+00	0	0%
N	Outdoor air, OU4, LUA soil, ATV, A	0.00036	0.04%	7E-08	0.005	0.7%
O	Outdoor air, OU3, forest, hiking, far	0.0036	0.4%	1E-07	0.009	1%
P	Outdoor air, OU3, Kootenai, fishing	0.0029	0.3%	0E+00	0	0%
Q	Outdoor air, OU8, Driving in Libby	0.0041	0.4%	0E+00	0	0%
R	Offsite	0.25	25%	0E+00	0	0%
	cumulative*:	**1.000**		**1E-05**	**0.7**	

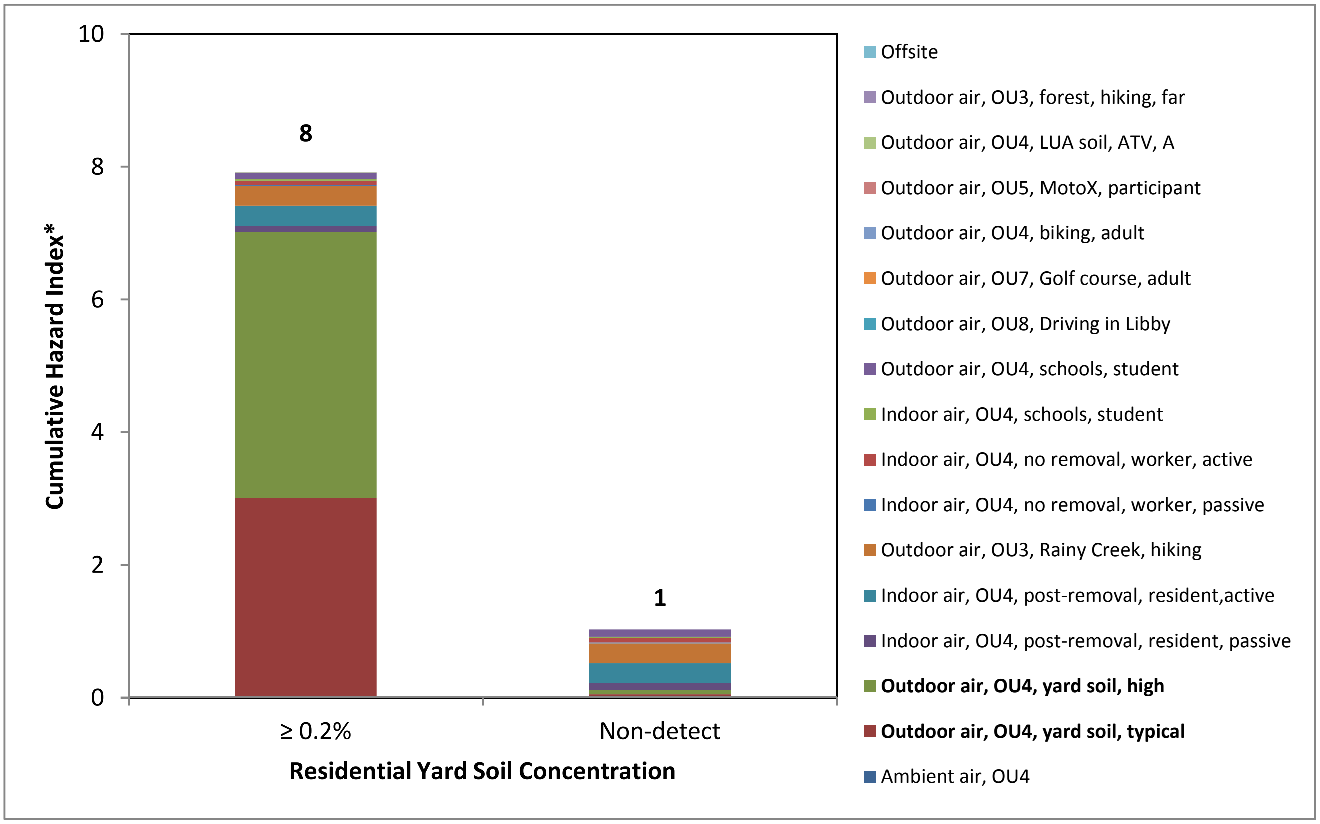
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

Notes:

% - percent
< - less than
ATV - all-terrain vehicle
HI - hazard index
HQ - hazard quotient
LUA - limited use area
MotoX - motorcross
OU - Operable Unit
TWF - time-weighting factor

FIGURE ES-6. ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT YARD SOIL CONCENTRATIONS

Libby Asbestos Superfund Site



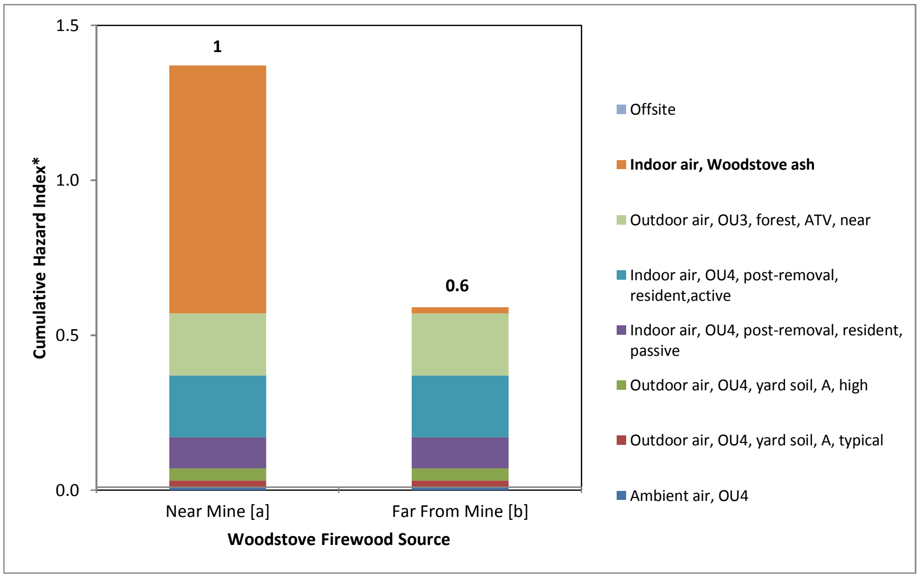
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

% - percent
ATV - all-terrain vehicle
HI - hazard index
HQ - hazard quotient
LUA - limited use area
MotoX - motorcross
OU - Operable Unit
PLM - polarized light microscopy

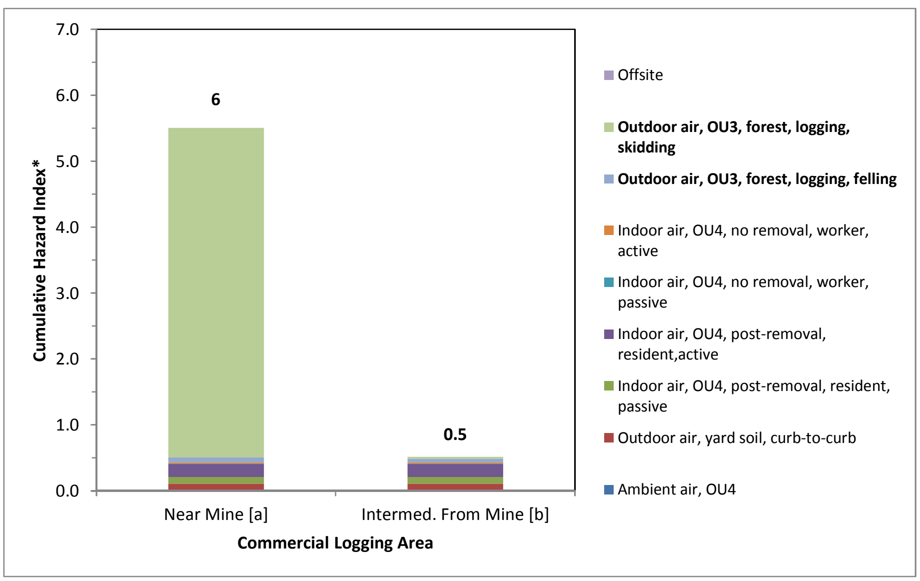
FIGURE ES-7. ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT ACTIVITY LOCATIONS *Libby Asbestos Superfund Site*

Panel A: Woodstove Firewood Source



[a] Near mine: firewood collected approximately one mile downwind of the mine site
[b] Far from mine: firewood collected approximately 10 miles south of Libby and outside the current NPL boundary

Panel B: Commercial Logging Area



[a] Near mine: Logging activities performed within 1 mile of the mine
[b] Intermed. from mine: Logging activities performed about 4 miles from the mine

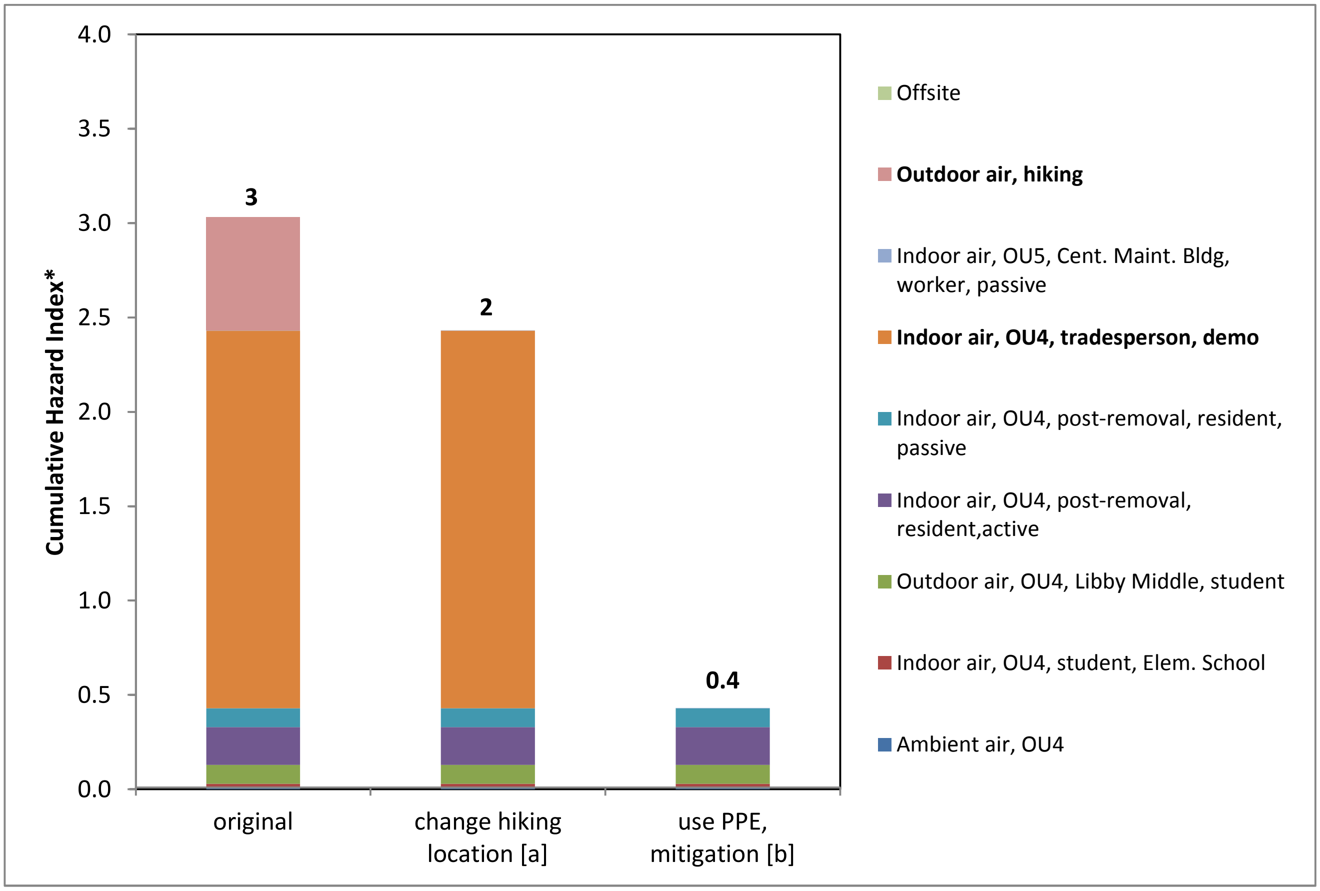
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

ATV - all-terrain vehicle
HI - hazard index
HQ - hazard quotient
NPL - National Priorities List
OU - Operable Unit

FIGURE ES-8. ILLUSTRATION OF CUMULATIVE HI CHANGE WHEN ADDRESSING MAIN RISK DRIVERS

Libby Asbestos Superfund Site



[a] Change hiking location from along Rainy Creek to along the Kootenai River

[b] Use appropriate personal protective equipment and employ dust mitigation measures during tradesperson

* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

HI - hazard index

HQ - hazard quotient

OU - Operable Unit

PPE - personal protective equipment

TABLE ES-1
Conceptual Site Model, Exposure Scenarios and Populations
Libby Asbestos Superfund Site

Exposure Media	Exposure Locations	Operable Unit	Disturbance Description	Exposure Population[a]					
							Worker		
				Resident	Recreational Visitor	Teachers/ students	Indoor Worker	Tradesperson	Outdoor Worker
Outdoor air, ambient conditions	Outdoor	All	---	●	●	●	●	●	●
Outdoor air, during soil/duff disturbance activities	Parks	OU1, OU4, OU7	lawn/park maintenance						●
			park use		●				
	Road ROW	OU2, OU8	mowing/brush-hogging						●
	Kootenai River	OU2, OU3	hiking on trails/paths		●				
			fishing/boating		●				
	Mine Site, Rainy Creek	OU3	hiking, ATV riding, rockhound		●				
	Forested Areas	OU3, OU4	hiking		●				
			building campfires		●				
			ATV riding		●				
			USFS forest maintenance						●
			cutting firelines						●
	Residential/Commercial Properties	OU2, OU4, OU7	yard work	●					●
			gardening	●					●
			playing on driveways	●					
			ATV riding in LUAs	●					
	Schools	OU4, OU7	outdoor maintenance						●
			playing on playgrounds			●			
	Bike Trails/Paths	OU4, OU5, OU7	riding bicycles		●				
	Roads	OU3, OU8	driving cars	●	●	●	●	●	●
	Motocross Track	OU5	motocross participant/spectator		●				
	Industrial Properties	OU5	site maintenance						●
	Railyard/Railroad Corridors	OU6	RR maintenance						●
Outdoor air, during tree bark disturbance activities	Forested Areas	OU3, OU4	local wood harvesting	●					
			commercial logging						●
			campfire burning		●				
			wildfire, prescribed burns	●	●	●	●	●	●
	Landfills	OU4, OU7	woodchipping						●
Outdoor air, during woodchip/mulch disturbance activities	Residential/Commercial Properties	OU2, OU4, OU7	gardening/landscaping	●					●
	Woodchip Piles	OU5	pile maintenance						●
Outdoor air, during ash disturbance activities	Forested Areas	OU3, OU4	after wildfire, prescribed burns						●
			after campfires		●				
Indoor air, passive conditions	Residential/Commercial Properties	OU4, OU7	---	●			●		
	Industrial Properties	OU5	---				●		
	Schools	OU4, OU7	---			●			
Indoor air, during VI disturbance activities	Residential/Commercial Properties	OU4, OU7	attic use, routine property maintenance	●				●	
			construction/demolition	●				●	
Indoor air, during indoor dust disturbance activities	Residential/Commercial Properties	OU4, OU7	cleaning (sweeping, dusting, vacuuming)	●					
	Commercial/Industrial Buildings	OU1, OU5	general				●		
	Schools	OU4, OU7	general			●			
Indoor air, during woodstove ash disturbance activities	Residential/Commercial Properties	OU4, OU7	woodstove ash removal	●					

[a] Note that a given individual may be a member of several exposure populations. For example, an individual may live in OU7, work in OU4, and recreate in OU3. In this example, aspects of the exposure scenarios for a resident, indoor worker, and recreational visitor would apply to the individual. The cumulative assessment addresses cumulative exposures that span multiple exposure scenarios.

Notes:

ATV - all-terrain vehicle
LUAs - limited-use areas
OU - operable unit
ROW - right-of-way
USFS - United States Forest Service
VI - vermiculite insulation
RR - railroad

TABLE ES-2
Estimated Risks from Residential Exposures to LA During Soil Disturbance Activities
Libby Asbestos Superfund Site

Location	Expsoure Scenario & Soil Concentration	Yard ABS Script Intensity	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Libby (OU4)	**Yards (Mowing, Raking, Digging)**								
	Non-detect	**high intensity**	0.0040	0.3	60	52	0.0015	**1E-06**	**0.07**
		typical intensity	0.00011	6.3	60	52	0.032	**6E-07**	**0.04**
							TOTAL	**2E-06**	**0.1**
	Trace (<0.2%)	**high intensity**	0.061	0.3	60	52	0.0015	**2E-05**	**1**
		typical intensity	0.0024	6.3	60	52	0.032	**1E-05**	**0.9**
							TOTAL	**3E-05**	**2**
	≥ 0.2%	**high intensity**	0.21	0.3	60	52	0.0015	**5E-05**	**4**
		typical intensity	0.0080	6.3	60	52	0.032	**4E-05**	**3**
							TOTAL	**1E-04**	**7**
	Gardens (Rototilling)								
	Trace (<0.2%)	---	0.039	2	2	52	0.00034	**2E-06**	**0.1**
	Gardens (Digging)								
	Non-detect	---	0.00020	3.3	40	52	0.011	**4E-07**	**0.03**
	Trace (<0.2%)	---	0.00066	3.3	40	52	0.011	**1E-06**	**0.08**
	≥ 0.2%	---	0	3.3	40	52	0.011	**0E+00**	**0**
	Driveway (Playing & Digging)								
	Non-detect	---	0	2	225	15	0.011	**0E+00**	**0**
	Trace (<0.2%)	---	0.0057	2	225	15	0.011	**1E-05**	**0.7**
	≥ 0.2%	---	0.0050	2	225	15	0.011	**9E-06**	**0.6**
	LUAs (ATV-riding)								
	Non-detect	---	0.0012	2	20	52	0.0034	**7E-07**	**0.05**
	Trace (<0.2%)	---	0.0014	2	20	52	0.0034	**8E-07**	**0.05**
Troy (OU7)	**Yards (Mowing, Raking, Digging)**								
	Non-detect	**typical intensity**	0.000062	6.6	60	52	0.034	**4E-07**	**0.02**
	Trace (<0.2%)	**typical intensity**	0	6.6	60	52	0.034	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Non-detect	---	0.000023	5.3	42	52	0.019	**7E-08**	**0.005**
	Trace (<0.2%)	---	0	5.3	42	52	0.019	**0E+00**	**0**
	Residential, Outdoor Driveway (Playing & Digging)								
	Non-detect	---	0.000079	2	225	15	0.011	**1E-07**	**0.01**
	Trace (<0.2%)	---	0.000085	2	225	15	0.011	**2E-07**	**0.01**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[++] Exposure time and frequency have been summed because the EPC is based on a combination of the activities.

Notes:

ABS - activity-based sampling
ATV - all- terrain vehicle
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
LUA - limited use areas
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor
% - percent
< - less than

Section 1

Introduction

The report presents the Site-wide human health risk assessment (HHRA) for the Libby Asbestos Superfund Site (Site) in Libby, Montana. This risk assessment uses available data to estimate the health risks to people who may breathe asbestos in air, either now or in the future, at the Site. The methods used to evaluate human health risks from asbestos are in basic accordance with U.S. Environmental Protection Agency (EPA) guidelines for evaluating risks at Superfund sites (EPA 1989), including guidance, the *Framework for Investigating Asbestos-Contaminated Superfund Sites (Asbestos Framework)* (EPA 2008a), that has been specifically developed to support evaluations of exposure and risk from asbestos.

1.1 Site Background

Libby is a community in northwestern Montana that is located near a former vermiculite mine (**Figure 1-1**). Vermiculite is a naturally-occurring silicate mineral that exhibits a sheet-like structure similar to mica (**Figure 1-2**). When heated, water molecules between the sheets change to vapor and cause the vermiculite to expand like popcorn into a light porous material (**Figure 1-2**). This process of expanding vermiculite is termed “exfoliation” or “popping.” Both unexpanded and expanded vermiculite have a range of commercial applications, the most common of which include packing material, attic and wall insulation, various garden and agricultural products, and various cement and building products.

The vermiculite mine near Libby began limited operations in the 1920s and was operated on a larger scale by the W.R. Grace Company (Grace) from approximately 1963 to 1990. Operations at the mine included mining and milling of the vermiculite ore. After milling, concentrated ore was transported down Rainy Creek Road by truck to a screening facility (known today as the former Screening Plant) adjacent to Montana Highway 37, near the confluence of Rainy Creek and the Kootenai River (**Figure 1-3**). Here the ore was size-sorted and transported by rail or truck to processing facilities in Libby and nationwide. At the processing plants, the ore was exfoliated by rapid heating and exported to market by rail or truck.

Historic maps show the location of a processing plant at the edge of the former Stimson Lumber Mill, near present day Libby City Hall. This older processing plant was taken off-line and demolished sometime in the early 1950s. Another processing plant (known today as the former Export Plant) was located near downtown Libby, near the intersection of the Kootenai River and Montana Highway 37 (**Figure 1-3**). Expansion operations at the Export Plant ceased sometime prior to 1981, although site buildings were still used to bag and export milled ore until 1990.

During mine operations, invoices indicate shipment of nearly 10 billion pounds of vermiculite from Libby to processing centers and other locations. Most of this was shipped and used within the United States and was often sold under the brand name Zonolite (**Figure 1-2**). Vermiculite material was used in a variety of commercial products that were marketed and sold to the general public. Before the mine closed in 1990, Libby produced approximately 80 percent (%) of the world’s supply of vermiculite.

While the mine was in operation, the milling process released airborne particulates into the atmosphere (**Figure 1-4**). In addition, waste products and off-specification materials were made available to the general public. Further, vermiculite products were used in numerous private residences, businesses, and public buildings across the Site. Vermiculite insulation (VI), both commercially purchased and/or obtained otherwise, was used frequently in Libby buildings. In the course of various Site investigations, EPA has encountered vermiculite used as an additive in mortar, plaster, and concrete; as insulation in attic and walls; in soils at depth around septic tanks, tree roots, underground pipe trenches, building foundations; and in surface soils in gardens, yards, driveways, and play areas (EPA 2014a).

1.2 Basis for Concern

Vermiculite from the mine near Libby contains varying concentrations of asbestos. Asbestos is the generic name for a group of naturally-occurring magnesium silicate minerals that crystallize in long thin fibers. The basic chemical unit of asbestos is $[SiO_4]^{-4}$. This basic unit consists of four oxygen atoms at the apices of a regular tetrahedron surrounding and coordinated with one silicon ion (Si^{+4}) at the center. The silicate tetrahedra can bond to one another through the oxygen atoms, leading to a variety of crystal structures. Based on crystal structure, asbestos minerals are usually divided into two groups: serpentine and amphibole. The only asbestos mineral in the serpentine group is chrysotile. There are several minerals in the amphibole group that occur in the asbestiform habit, including actinolite, tremolite, winchite, richterite, amosite (cummingtonite/grunerite), anthophyllite, and crocidolite (riebeckite). EPA's Toxic Substances Control Act identifies six types of regulated asbestiform varieties of asbestos: chrysotile, crocidolite, amosite, anthophyllite, tremolite, and actinolite.

The vermiculite deposit near Libby contains a distinct form of naturally-occurring amphibole asbestos that is comprised of a range of mineral types and morphologies (see **Figure 1-2**). In the spring of 2000, the U.S. Geological Survey (USGS) performed electron probe micro-analysis and x-ray diffraction analysis of 30 samples collected from asbestos veins at the mine (Meeker *et al.* 2003). The results indicated that there were several mineral varieties of amphibole asbestos present, including (in order of decreasing abundance) winchite, richerite, and tremolite, with lower levels of magnesio-riebeckite, edenite, and magnesio-arfvedsonite. Although Meeker *et al.* (2003) did not report the presence of actinolite, the authors note that, depending on the valence state of iron and data reduction methods utilized by other analytical laboratories, some minerals may also be classified as actinolite. The mixture of asbestos present at the Site is referred to as Libby amphibole asbestos or LA[2].

Historical mining, milling, and processing operations, as well as bulk transfer of mining-related materials, tailings, and waste to locations throughout the Kootenai Valley, are known to have resulted in releases of LA to the environment. Epidemiological studies revealed that workers at the mine had an increased risk of developing asbestos-related lung disease (McDonald *et al.* 1986a, 1986b, 2004; Amandus and Wheeler 1987; Amandus *et al.* 1987a,b; Whitehouse 2004; Sullivan 2007). Additionally, radiographic abnormalities were observed in 17.8% of the general population of Libby, including former workers, family members of workers, and other residents of Libby and Troy, Montana (Peipins *et al.* 2003; Whitehouse *et al.* 2008; Antao *et al.* 2012; Larson *et al.* 2010, 2012a, 2012b). Although the

[2] The *Toxicological Review for Libby Amphibole Asbestos* (EPA 2014c) uses the acronym LAA.

mine ceased operations in 1990, historical or continuing releases of LA from mine-related materials could be serving as a source of ongoing exposure and risk to individuals at the Site.

The Site includes homes and businesses that may have become contaminated with LA as a result of the vermiculite mining and processing conducted in and around Libby, as well as other areas that may have been affected by mining-related releases of LA. In addition to vermiculite mining and processing activities, LA contamination also occurred as a consequence of use of LA-contaminated vermiculite as building insulation in residential and commercial buildings and as soil amendments (e.g., gardens and flowerbeds), use of LA-contaminated building materials (e.g., mortar, chinking), and other uses.

1.3 Regulatory History

In November 1999, EPA responded to requests from the State of Montana, Lincoln County Health Board to investigate the potential exposure to asbestos related to the former mine operations and vermiculite processing. The initial investigation revealed that there were a large number of cases of asbestos-related diseases centered around Libby and that significant amounts of asbestos-contaminated vermiculite still remained in and around Libby (EPA 2000a).

Under Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), EPA has the authority to complete both removal and remedial actions. Initial actions taken under removal authority began at the former processing areas (Screening Plant and Export Plant) in May 2000 (EPA 2000a). As additional areas requiring removal were identified, such as Rainy Creek Road, residential/commercial properties in Libby, and schools in Libby, the initial Site action memorandum has been amended (EPA 2002a; 2006a, b; 2008b; 2009a, b). Nearly all removal activities performed at the Site since 2000 have been conducted using removal action authority to facilitate the timely removal of LA-contaminated materials. Remedial actions have been completed at the former processing areas; EPA is in the process of evaluating what remedial actions are necessary outside of the former processing areas to address potential LA exposures.

In October 2002, the Libby Site was listed on the National Priorities List (NPL), making it eligible to receive additional federal funds for investigation and removals. In 2009, for the first time in the history of the federal government, EPA and the Department of Human Health Services declared a Public Health Emergency in Libby to provide federal health care assistance for victims of asbestos-related disease.

1.4 Site Operable Units

For long-term management purposes, the Site has been divided into eight operable units (OUs):

- **OU1, Former Export Plant** - This OU is defined geographically by the parcel of land that included the former Export Plant and the Highway 37 embankments, and is situated on the south side of the Kootenai River, just north of the downtown area of the City of Libby. The property is bound by the Kootenai River on the north, the Burlington Northern and Santa Fe (BNSF) railroad thoroughfare on the south, and residential properties on the east and west.

- **OU2, Former Screening Plant** - This OU includes areas impacted by contamination released from the former Screening Plant. These areas include the former Screening Plant, the Flyway property, the Highway 37 right-of-way (ROW) adjacent to the former Screening Plant and/or Rainy Creek Road, and privately-owned properties. The Kootenai Bluff Subdivision area (the former Grace railroad loading station area), located directly across the Kootenai River from the former screening plant, was removed from OU2 and is now part of OU4.

- **OU3, Mine** – This OU is defined as the property in and around the Zonolite Mine owned by Grace or Grace-owned subsidiaries (excluding OU2) and any area (including any structure, soil, air, water, sediment, or receptor) impacted by the release and subsequent migration of hazardous substances and/or pollutants or contaminants from such property, including, but not limited to, the mine property, the Kootenai River and sediments therein, Rainy Creek, Rainy Creek Road and areas in which tree bark is contaminated with such hazardous substances and/or pollutants and contaminants.

- **OU4, Libby Residential/Commercial Areas -** OU4 is defined as residential, commercial, industrial (not associated with Grace mining operations), and public properties, including schools and parks, in and around the City of Libby, or those properties that have received material from Grace.

- **OU5, Former Stimson Lumber Mill -** This OU is defined geographically by the parcel of land that included the former Stimson Lumber Company. OU5 is bounded by the high bank of Libby Creek to the east, the Kootenai River to the north, and properties within OU4 to the south and west. This OU is currently occupied by various vacant structures/buildings as well as multiple operating businesses (e.g., lumber processing, log storage, excavation contractor). Within the OU5 boundary is the Libby Groundwater Superfund Site, which is not associated with the Libby Asbestos Superfund Site.

- **OU6, BNSF Railroad -** This OU is owned and operated by the BNSF railroad, and is defined geographically by the BNSF property boundaries from the eastern boundary of OU4 to the western boundary of OU7 and extent of contamination associated with the Libby and Troy rail yards.

- **OU7, Town of Troy** – This OU includes all residential, commercial, and public properties in and around the Town of Troy, located 20 miles west of downtown Libby.

- **OU8, Roadways** – This OU is comprised of the United States and Montana State Highways and ROWs within the OU4 and OU7 boundaries.

Figure 1-5 provides a map of the boundaries for each OU. Official boundaries have been established in the records of decision (RODs) for OU1 and OU2 (EPA 2010a, b). Official boundaries for the other OUs (OU3-OU8) will not be determined until the OU-specific RODs are published (the boundaries shown in the figure are "study boundaries" that will be finalized once the OU-specific RODs are published).

1.5 Document Purpose

This document estimates potential risks to people from exposure to LA at the Site. Because people may be exposed by multiple exposure scenarios, often across multiple OUs, potential exposures and risks are evaluated on a Site-wide basis, to provide a representation of potential cumulative exposures. Results of this risk assessment are intended to help inform Site managers and the public about the magnitude of potential risks attributable to LA and to guide the selection of final remedial actions for the Site.

This risk assessment differs from other "typical" Superfund risk assessments. Typically, a risk assessment is conducted as part of a remedial investigation (RI) and evaluates the potential exposures associated with the environmental contamination to determine if any action is warranted to mitigate risk. However, extensive interior and exterior removal actions have been conducted at the Site for more than 10 years, prior to the completion of the risk assessment, to allow for the timely removal of LA contamination while awaiting the necessary exposure and toxicity data needed complete a quantitative assessment of human health risk. Therefore, the purpose of this Site-wide risk assessment is to help risk managers determine if past removal actions have been sufficient to mitigate risk, if additional remedial actions are necessary to address risks, and if so, which exposure scenarios would need to be addressed in future remedial actions.

This risk assessment does not seek to quantify potential risks for specific individuals, but evaluates exposures for various receptor populations under numerous exposure scenarios. This document is intended only to assess potential risks; discussions and recommendations on how to manage potential risks are provided in the Site feasibility study (FS). The selection of Site remedial action levels, which will guide future remediation efforts, will be provided in the RODs[3].

1.6 Document Organization

In addition to this introduction, this document is organized as follows:

- **Section 2 –** This section presents the exposure assessment. This section presents a conceptual model of site contamination, identifies the human exposure scenarios of potential concern, and describes the approach for measuring human exposures to asbestos and calculating quantitative exposure estimates.
- **Section 3 –** This section presents the toxicity assessment. This section summarizes the cancer and non-cancer health effects associated with asbestos exposure and identifies the toxicity values that will be used to estimate cancer risk and non-cancer hazard.
- **Section 4 –** This section summarizes the risk characterization approach that will be used to quantify cancer risks and non-cancer hazards to humans exposed to LA at the Site.
- **Section 5 –** This section presents the quantitative estimates of cancer risk and non-cancer hazard to humans exposed to LA in outdoor ambient air at the Site.
- **Section 6 –** This section presents the quantitative estimates of cancer risk and non-cancer hazard to humans exposed to LA in outdoor air during soil/duff disturbance activities.
- **Section 7 –** This section presents the quantitative estimates of cancer risk and non-cancer hazard to humans exposed to LA during disturbances of wood-related materials (e.g., tree bark, mulch, wood chips, woodstove ash generated from firewood).
- **Section 8 –** This section presents the quantitative estimates of cancer risk and non-cancer hazard to humans exposed to LA in indoor air at the Site.

[3] The RODs are already complete for OU1 and OU2. The FS report for OU3 will be prepared separately from the other OUs (i.e., OU4-OU8). Likewise, two separate RODs, one for OU3 and one for OU4-OU8, will be issued.

- **Section 9 –** This section presents a cumulative risk assessment. This section describes the approach used to quantify cumulative exposures and summarizes estimates of cancer risk and non-cancer hazard across multiple exposure scenarios.
- **Section 10 –** This section presents the uncertainty assessment, and discusses the sources of uncertainty in the risk estimates for human receptors.
- **Section 11 –** This section presents the overall risk assessment conclusions.
- **Section 12 –** This section provides full citations for all EPA guidance documents, reports, analytical methods, Site-related documents, and scientific publications referenced in this HHRA.

All referenced tables, figures, and appendices are provided at the end of this document.

Section 2

Exposure Assessment

Exposure is the process by which receptors come into contact with contaminants in the environment. This section summarizes the exposure media, exposure scenarios, and human populations of potential concern at the Site. This section also describes how LA exposures were quantified and the derivation of the exposure point concentrations (EPCs) used in the risk characterization.

People may be exposed to LA by two exposure routes: inhalation and ingestion. Of these two exposure routes, inhalation exposure of LA is considered to be of greatest concern. To the extent that ingestion exposures may occur at this Site (e.g., ingestion of LA in drinking water or food), the added risk from ingestion is expected to be negligible compared to the risk from inhalation. As such, this exposure assessment and subsequent risk calculations focus only on inhalation pathways of exposure. **Appendix A** provides additional information regarding potential risks from LA ingestion exposures.

2.1 Conceptual Site Model

Figure 2-1 presents the conceptual site model (CSM) that depicts how LA in source media can be transported in the environment to exposure media that humans may encounter at the Site. **Table 2-1** summarizes the inhalation exposure scenarios and populations that will be evaluated in the HHRA. The main elements of the CSM are discussed below.

2.1.1 Source Media and Transport Mechanisms

As discussed above, vermiculite from the mine contains varying concentrations of LA. Historical mining, milling, and processing operations, use of vermiculite in building materials, transport of mining-related materials, tailings, and waste, and runoff from the mine site are known to have released LA to the environment (see **Figure 2-1**).

There have been numerous studies conducted at the Site which demonstrate that LA has been detected in a variety of source media, including indoor dust, VI in walls and attics, soil, tree bark and duff[4] in the forested areas, various wood products (e.g., wood chips, mulch), ash resulting from wood burning, surface water, and sediment. Detailed information on the levels of LA in source media at the Site are summarized in the OU-specific RI reports and data summary reports (EPA 2009c, d, 2014a; CDM Federal Programs Corporation [CDM Smith] 2015a; HDR Engineering, Inc. [HDR] 2013a, b; Kennedy/Jenks Consultants 2014; Tetra Tech EM Inc. [Tetra Tech] 2010, 2012a, 2013, 2014; MWH Americas, Inc. 2014).

As noted previously, when the mine was in operation, the milling process released airborne particulates into the atmosphere (see **Figure 1-4**). Once released to the air, dust particles and LA fibers were dispersed in the air and eventually settled out onto the ground and other surfaces at the Site. However, depositional estimates indicate that, outside of OU3, the impact of airborne deposition on resulting LA levels in soil is likely to be negligible (CDM Smith 2015b). Within OU3, the impact of

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[4] Duff consists of the un-decomposed twigs, needles, and other vegetation and the layer of partially- to fully-decomposed litter that occurs on top of the mineral soil in forested areas.

historical mine releases is evident from inspection of the spatial patterns of LA in tree bark and duff in the forested areas. **Figure 2-2** illustrates measured LA levels in tree bark (Panel A) and duff (Panel B) as a function of distance from the mine. As shown, LA levels tend to be highest closest to the mine (within about 2-4 miles).

Historically, waste products and off-specification materials were made available to the general public (e.g., for use as soil amendments in gardens, driveway base, and as fill material in yards). Vermiculite insulation (VI), both commercially purchased and/or obtained otherwise, was used frequently in Site buildings. The placement of LA-containing materials is likely to be the most important mechanism of LA transport outside of OU3.

LA has been detected in surface waters at the Site, including several creeks within the Rainy Creek watershed in OU3, in other Site tributaries to the Kootenai River, and in the Kootenai River. It is possible that, if these waters are used as irrigation sources, fibers in the water could increase the LA contamination in the soil. However, screening level estimates on the impact of a long-term water irrigation scenario indicate the increase in LA soil concentrations are likely to be small (well below the detection limit of traditional soil asbestos analysis methods) (CDM Smith 2013a).

2.1.1 Exposure Media

Asbestos fibers in source materials are typically not inherently hazardous, unless the asbestos is released from the source material into air where it can be inhaled (EPA 2008a). Asbestos fibers may become airborne in a number of ways. This may include natural forces, such as wind blowing over a contaminated soil, or human activities that disturb contaminated sources, such as soil or indoor dust. The two main types of exposure media are indoor air and outdoor air.

For indoor air, exposures are stratified based on the nature of the disturbance – under "passive" (ambient) conditions and under "active" disturbances of various source media that may be encountered in an indoor setting (i.e., VI, surficial dust, woodstove ash). Similarly, for outdoor air, exposures are stratified based on the nature of the disturbance – under ambient conditions and under active disturbances of various source media that may be encountered in an outdoor setting (i.e., soil/duff, tree bark, woodchips/mulch).

As illustrated in **Figure 2-1**, there are nine general types of exposure media that will be evaluated in the risk characterization when assessing inhalation exposures:

<u>Outdoor air</u>

- Outdoor air, under ambient conditions
- Outdoor air, during soil/duff disturbance activities
- Outdoor air, during tree bark disturbance activities
- Outdoor air, during woodchip/mulch disturbance activities
- Outdoor air, during ash disturbance activities

Indoor air

- Indoor air, under passive conditions
- Indoor air, during VI disturbance activities
- Indoor air, during dust disturbance activities
- Indoor air, during woodstove ash disturbance activities

2.1.2 Exposure Scenarios and Populations

The amount of LA in air, and hence the amount inhaled, will vary depending on the level of LA in the exposure medium, which can vary from location to location, and the intensity and duration of the disturbing force. Because of this, it is convenient to stratify inhalation exposure scenarios according to the disturbance activity and the location where the disturbance activity occurs. **Table 2-1** summarizes the exposure locations and general types of disturbances that may occur for each of the eight exposure media identified in **Figure 2-1**. It is recognized that not every possible disturbance activity is included in **Table 2-1**. The list of disturbance activities included is intended to be representative of the types of activities that are expected to occur more frequently and/or that have a higher potential for LA release. As shown, exposures to outdoor air under soil/duff disturbances are the most complex because the types of activities that may disturb soil/duff are so varied, ranging from playing on playgrounds and driveways, to hiking in the forest, to mowing lawn areas in parks.

Table 2-1 identifies several potential exposure populations that are evaluated quantitatively in the risk assessment, including residents, recreational visitors, teachers/students, and several types of workers. The types of exposures that are expected for each population are discussed below.

- **Residents** – By definition, residential exposures are expected to occur at residential properties located in OU4 and OU7. Expected residential exposure scenarios include both indoor and outdoor exposures to source materials at the residence (e.g., indoor dust, VI, soil, woodstove ash). Residents may also be exposed while engaging in local wood harvesting in the forested areas of the Site or while driving on roads and alleys in Libby and Troy.
- **Recreational visitors** – The primary types of exposure for a recreational visitor are related to outdoor exposure scenarios under a wide variety of activities that may disturb soil, duff, and tree bark. These recreational activities may include, but are not limited to, use of local parks, riding bicycles along trails and paths, hiking, camping, and riding all-terrain vehicles (ATVs) in the forested areas and at the mine site, fishing and boating along creeks and rivers, and riding motorcycles at the local motocross (MotoX) track (in OU5).
- **Teachers/students** – Teacher and student exposures are expected to occur at schools located in OU4 and OU7 and include both indoor and outdoor exposure scenarios. Indoor exposures would occur inside school classrooms and in common areas (e.g., hallways, cafeteria, gymnasium), while outdoor exposures are mainly related to exposures while playing on playgrounds and athletic fields.

For workers, several different types of workers are delineated based on the types of exposure scenarios that may be encountered while engaging in day-to-day occupational activities:

- **Indoor worker** – Examples of indoor workers include office administrative assistants, shop keepers, and restaurant staff. Exposures are expected to occur mainly inside buildings located in OU1, OU4, OU5, and OU7. The primary types of exposures expected for these workers are related to indoor exposure scenarios, during both passive conditions and under active disturbances of indoor dust.

- **Tradesperson** – Local tradespeople are a special type of indoor worker that are evaluated separately due to the increased frequency of potential exposures to VI or other asbestos-containing building materials. Examples of tradesperson exposures include an electrician accessing attics or crawlspaces for re-wiring, a plumber cutting holes in walls/ceilings, a carpet layer removing and installing new flooring, and a general contractor performing remodeling. The types of exposures expected for a tradesperson are related to indoor exposure scenarios, under active disturbances of VI or other asbestos-containing building materials during occupational activities. Although exposures may also occur during passive conditions, these are likely to be minor compared to active disturbance scenarios described above.

- **Outdoor worker** – The types of exposures expected for an outdoor worker are related to exposure scenarios under a wide variety of activities that may disturb soil/duff, tree bark, and woodchips/mulch at the Site. These occupational activities may include, but are not limited to, Montana Department of Transportation (MDT) workers performing mowing/brush-clearing along highway ROWs, maintenance workers mowing/weed-trimming at parks and schools, BNSF workers performing railroad maintenance, U.S. Forest Service (USFS) employees conducting forest maintenance activities, fire fighters responding to wildfires, local landfill workers chipping accumulated wood waste, and commercial loggers in the forested areas near the Site.

All exposure populations are assumed to have exposures to outdoor ambient air and outdoor air[5] while driving cars on Site roads. In the event of a wildfire, all exposure populations are assumed to have exposures to smoke in outdoor air derived from wildfires that may occur in forested areas at the Site.

Note that a given individual may be a member of several exposure populations. For example, an individual may live in Troy (OU7), work at a business in Libby (OU4), and recreate in the forest near the mine (OU3). In this example, aspects of the exposure scenarios for a resident, indoor worker, and recreational visitor would apply to the individual. The cumulative assessment addresses exposures that span multiple exposure scenarios (see Section 9).

2.2 Exposure Parameters

For every exposure scenario of potential concern, it is expected that there will be differences between different individuals in the level of exposure at a specific location due to differences in exposure time, exposure frequency, and exposure duration. Thus, there is normally a wide range of average daily exposures between different individuals of an exposed population. Because of this, all exposure calculations must specify what part of the exposure range is being estimated. Typically, attention is focused on exposures that are “average” or are otherwise near the central portion of the range, and on exposures that are near the upper end of the range (e.g., the 95th percentile). These two exposure

[5] For the purposes of the risk assessment, air inside vehicles is evaluated as outdoor air that may be influenced by disturbances of soil (e.g., airborne roadway dust).

estimates are referred to as central tendency exposure (CTE) and reasonable maximum exposure (RME), respectively. Both CTE and RME receptors will be evaluated in the HHRA.

When selecting CTE parameters, the exposure parameters for a specific exposure scenario (i.e., exposure time, exposure frequency, exposure duration) are usually based on mean or median values, such that the CTE represents the "typical" or "average" exposure. When selecting RME parameters, the exposure parameters are selected such that the combination of the exposure parameters results in a "reasonable maximum" estimate of the daily exposure (EPA 1989).

EPA has collected a wide variety of data to establish default exposure parameter values for use in HHRAs (EPA 1989, 1991a, 1993a, 1996, 2014b), and EPA's *Exposure Factors Handbooks* (EPA 2008c, 2011) provide information on activity-specific exposure patterns. Established default values were utilized in this HHRA when available. However, as appropriate, exposure parameters were adjusted to be Site-specific. For example, the default residential RME exposure frequency is 350 days per year (EPA 1991a), but for the purposes of evaluating exposures during soil disturbances, this default value was adjusted to reflect Site conditions and account for days when releases due to soil disturbance activities were unlikely, either due to snow cover or high soil moisture content (from November through March). Site-specific surveys have been conducted for several exposure scenarios (see **Appendix H**). Various groups and stakeholders have provided input on the selection of exposure parameters for selected receptor populations (e.g., Libby school administrators provided information on student, teacher, and maintenance worker exposures, the USFS provided input on forest-related exposure scenarios). If default or Site-specific values were not available, professional judgment was used in selecting appropriate exposure parameter values.

It is important to note that the selected exposure parameter values do not take into consideration any use restrictions or institutional controls. For example, under current conditions, access to the mine is restricted to prevent potential exposures from LA in soil and mine waste materials within this area. In accordance with EPA's *Risk Assessment Guidance for Superfund* (EPA 1989), the baseline risk assessment is to be performed under an assumption of 'no action', meaning in the absence of any actions to control or mitigate these releases. Thus, exposure parameters have been selected based on an assumption there are no access restrictions in any of the potential exposure areas.

The selected exposure parameters for each exposure scenario evaluated in this risk assessment are discussed and presented in each risk characterization section (Section 5 through Section 9).

2.3 Exposure Point Concentrations

2.3.1 Approach for Determining Exposure Concentrations

Previous investigations conducted at the Site have demonstrated that LA is present in a variety of environmental media. However, the detection of LA in a source medium, such as soil, tree bark, or indoor dust, does not necessarily indicate that human exposures to LA released to air during disturbances of these media would result in unacceptable exposures or risks. The amount of LA that could be released to air and inhaled will vary depending upon a number of factors, including the level of LA in the source medium, the nature, intensity, and duration of the disturbance activity, meteorological conditions (e.g., relative humidity, wind direction, and speed), and conditions of the source medium (e.g., soil moisture content, vegetation coverage). Because of this, predicting the LA levels in air based on measured LA levels in source media is extremely difficult. For this reason, EPA recommends an empiric approach for investigating asbestos-contaminated Superfund sites, where concentrations of asbestos in air from source disturbances are measured rather than predicted (EPA

2008a). This type of sampling is referred to as activity-based sampling (ABS) and involves the collection of air samples under representative source-disturbance conditions that can be used to calculate inhalation exposures and potential risks (EPA 2008a). This sampling methodology is similar to the exposure assessment methods used by the National Institute of Occupational Safety and Health (NIOSH) to monitor worker exposures.

It is not possible to perform an ABS study to evaluate every possible type of source-disturbance activity that could be performed at every location on the Site. Therefore, Site ABS investigations have focused on characterizing those activities that are representative of typical activities that may be performed by various receptor populations that disturb source media. To date, more than two dozen different ABS investigations have been conducted at the Site to evaluate potential exposures to LA from disturbances of source media. These studies have included a wide range of activities in every OU, including, but not limited to, dusting and vacuuming inside residences in OU4 and OU7, raking/mowing/digging in yard soil in OU4 and OU7, hiking and riding ATVs in OU3 and OU4, trespassing at the mine in OU3, commercial logging operations in OU3, biking in OU4 and OU5, performing railroad maintenance activities in OU6, during fire-related activities in OU3, and performing brush-clearing activities along roads in OU8.

Table 2-2 summarizes the ABS investigations that have been conducted at the Site which provide measured data on LA concentrations in ABS air that will be utilized in this HHRA. As shown, more than 3,100 ABS air samples have been collected at the Site since 2001. These ABS investigations have evaluated LA levels in air during disturbances of a variety of source media, including outdoor soil/duff (Panel A), various wood-related media (i.e., bark, mulch, wood chips, ash resulting from wood burning) (Panel B), and indoor sources (e.g., dust and VI) (Panel C). **Figure 2-2** provides example photographs of some of the types of ABS activities that have been conducted at the Site. The results of each investigation are discussed further in Section 5 through Section 8.

2.3.2 Methods for Measuring and Reporting Air Concentrations

Asbestos data reduction and interpretation methods differ from traditional chemistry methods. Understanding the differences in asbestos data reduction and interpretation methods is key to the proper use of asbestos data for site characterization and risk assessment. **Appendix B** provides a detailed discussion of basic concepts for asbestos sampling, analysis, and data reduction, including an overview of asbestos sampling and analysis methods, Poisson statistics, how to characterize uncertainty for individual samples, how samples are ranked as detect or non-detect, the differences between the analytical sensitivity and the detection limit, how to calculate the mean across multiple samples (i.e., treatment of non-detects), and issues associated with estimating the uncertainty bounds around the mean.

2.3.2.1 Overview of Sampling and Analysis Methods

Experience at the Site and at other asbestos sites has demonstrated that personal air samples (i.e., samples that collect air in the breathing zone of a person) tend to provide a better estimate of human exposures to LA in air than samples collected by a stationary monitor (EPA 2007a), especially if the person is engaged in an activity that disturbs an asbestos source. Thus, most of the ABS exposure estimates used in this risk assessment are based on personal air samples collected during simulated disturbance activities. These personal ABS air samples are collected by drawing a known volume of air through a filter that is located in the breathing zone of the individual performing the disturbance activity (see **Figure 2-2**) and determining the number of LA structures that become deposited on the filter surface.

In the past, the most common technique for analyzing asbestos on air filters was phase contrast microscopy (PCM). In this technique, the filter is examined in accordance with NIOSH Method 7400, Issue 2 (NIOSH 1994) and all structures that have a length greater than (>) 5 micrometers (µm) and an aspect ratio (the ratio of length to width) of 3:1 or greater are counted as "PCM fibers". The limit of resolution of PCM is about 0.25 µm (NIOSH 1994), so structures thinner than this are generally not observable.

A key limitation of PCM is that structure discrimination is based only on size and shape. Because of this, it is not possible to distinguish between asbestos and non-asbestos structures. For this reason, EPA (2008a) recommends the analysis of air samples by transmission electron microscopy (TEM). This method can operate at a higher magnification and is able to detect structures much smaller than can been seen by PCM. In addition, TEM instruments are fitted with accessory detectors that allow each structure to be classified according to asbestos mineral type, meaning that structures can be characterized as either chrysotile or amphibole, and further by amphibole asbestos type (e.g., actinolite, tremolite, crocidolite, amosite).

2.3.2.2 Results Reporting

At the Site, all ABS and ambient air samples have been analyzed by TEM using International Organization of Standardization (ISO) 10312:1995(E) (ISO 1995) counting and recording rules, as modified by Site-specific laboratory modification requirements[6]. During the analysis, detailed information for each observed asbestos structure (e.g., asbestos type, structure type, length, width) is manually recorded on a laboratory bench sheet. Once the analysis is complete, the total number of countable asbestos structures is determined. The concentration of asbestos in air in a given sample is given by:

$$C_{air} = N \cdot S$$

where:

C_{air} = Concentration of asbestos in air (s/cc)

N = Number of asbestos structures observed in the sample (s)

S = Achieved analytical sensitivity (per cubic centimeter of air, cc^{-1})

For air, the achieved analytical sensitivity is calculated as:

$$S = \frac{EFA}{GO \cdot Ago \cdot V \cdot 1000 \cdot F}$$

where:

S = Achieved analytical sensitivity (cc^{-1})

EFA = Effective area of the filter (square millimeters [mm^2])

GO = Number of grid openings examined

[6] The Libby-specific TEM ISO 10312 laboratory modifications are maintained on the *Libby Lab* eRoom and are available upon request.

Ago = Area of a grid opening (mm^2)

V = Volume of air passed through the filter (liters [L])

1000 = Conversion factor (cc/L)

F = F-factor, or fraction of primary filter deposited on secondary filter (if an indirect preparation is necessary; F = 1 for direct preparation)

There is no "preset" lower limit of analytical sensitivity for TEM. The achieved analytical sensitivity will depend upon the number of grid openings examined, and can be improved (i.e., lowered) by examining additional grid openings. Each of the air sampling investigations conducted at the Site have established investigation-specific target analytical sensitivity requirements based on the receptor and exposure scenario being evaluated.

If the sample has been analyzed more than once (e.g., a subsequent supplemental TEM analysis was performed to improve the achieved analytical sensitivity), the "pooled" concentration, which is inclusive of all analyses, is calculated as follows:

$$C_{air,\ pooled} = \sum N_i \,/\, \sum(1/S_i)$$

where:

$C_{air,\ pooled}$ = Pooled concentration of asbestos in air across analyses (s/cc)

N_i = Number of asbestos structures observed in analysis 'i' (s)

S_i = Achieved analytical sensitivity for analysis 'i' (cc^{-1})

2.3.2.3 Definition of PCME

For the purposes of estimating potential human health risks, the concentration of asbestos in air must be expressed in units of PCM fibers. This is because the risk models for estimation of risks from inhalation exposure to LA (EPA 2014c) are based on exposures expressed as PCM f/cc. Estimates of concentration used in this report are based on PCM-equivalent (PCME) structures observed during the TEM analysis. As noted above, in the PCM method (NIOSH 1994), a structure is counted as a PCM fiber if it has a length longer than 5 µm and an aspect ratio greater than or equal to (≥) 3:1. Although there is no thickness rule specified in the PCM method, particles thinner than about 0.25 µm are not usually detectable by PCM (see **Appendix C**). Hence, the TEM counting rules for PCME structures are: length > 5 µm, width ≥ 0.25 µm, and aspect ratio ≥ 3:1. Note that the upper width cut-off of 3 µm specified by EPA (2008a) has not been used, because structures wider than 3 µm are counted by the NIOSH PCM method (NIOSH 1994). This basis of this width criterion change is discussed in more detail in **Appendix C**.

Figure 2-3 graphically illustrates the concept of PCME. This figure summarizes the recorded dimensions of all LA structures observed during TEM analyses[7] of air samples collected at the Site. Only those structures within the area shaded in green of the figure meet PCME counting rules. As illustrated, about 35% of all LA structures observed in air samples rank as PCME.

[7] Restricted to analyses performed under high magnification (20,000x) using TEM ISO 10312 (ISO 1995) recording rules.

In this risk assessment, all air concentrations are reported as PCME LA s/cc. Although TEM analyses may have occasionally observed and recorded other amphibole asbestos types (e.g., anthophyllite) and/or chrysotile structures, exposures and risks are calculated for LA only, as this is the type of asbestos that is expected to be Site-related.

2.3.3 Approach for Calculating Exposure Point Concentrations

An exposure point (also referred to as an exposure unit or exposure area) is an area where exposure and risk are to be evaluated. It is assumed that random exposure occurs over the entire exposure area; thus, the risk is related to the mean concentration across the entire exposure area (EPA 1992). An EPC is an estimate of the average concentration of LA in air at the exposure area.

Ideally, the EPC used in the risk calculations for each exposure location would be the true average concentration within the exposure area, averaged across the exposure duration. However, the true average concentration at a location can only be approximated from a finite set of measurements, and the observed sample mean might be either higher or lower than the true mean.

To minimize the chances of underestimating the true level of exposure and risk, EPA generally recommends that risk calculations be based on the 95% upper confidence limit (95UCL) of the sample mean (EPA 1992). However, as discussed in **Appendix B**, there is no EPA-approved method for calculating the 95UCL for asbestos datasets[8]. Thus, in accordance with EPA guidance (EPA 2008a), risk calculations presented in the risk characterization utilize the sample mean. The sample mean is an unbiased estimate of the true concentration, but the true concentration may be either higher or lower. The potential magnitude of the difference between the sample mean and the true mean cannot presently be quantified. The uncertainty assessment (Section 10) provides additional information on the uncertainty that arises from use of the sample mean.

Note that, when computing the arithmetic mean of a set of air samples, all samples with a count of zero asbestos structures (non-detects) are evaluated using a concentration value of zero (EPA 2008a). This is important, because assigning any value greater than zero to such samples may tend to bias the sample mean high (EPA 1999, 2008a). This concept is demonstrated in **Appendix B**.

In some cases, all air samples within a dataset were non-detect. In these instances, the mean air concentration (i.e., a concentration of zero) was used as the EPC in the risk calculations. The uncertainty assessment (Section 10) provides additional information on risk estimates for datasets where all samples are non-detect.

2.3.4 Adjustment for Indirect Preparation Methods

Collected air filters are examined at the laboratory prior to analysis to determine if the filter can be prepared directly or if an indirect preparation is necessary. Indirect preparation is required if there is uneven loading, if the filter is considered overloaded (particulate coverage of greater than 25% on the filter), or if there is loose material in the cowl of the air cassette. If an air filter can be prepared directly, the filter is prepared for analysis by TEM in basic accordance with the filter preparation methods provided in International Organization of Standardization (ISO) 10312 (ISO 1995).

If an indirect preparation is required, the filter is prepared (usually with ashing) in accordance with the indirect filter preparation procedures in the Site-specific standard operating procedure (SOP)

[8] The equations and functions in ProUCL (EPA 2010c) are not designed for asbestos datasets and application of ProUCL to asbestos datasets is not recommended (EPA 2008a).

EPA-LIBBY-08. If no loose material is present within the cassette, the indirect preparation procedure in the SOP EPA-LIBBY-08 is similar to ISO 13794 (ISO 1999), except that the total solution volume is increased from 40 milliliters (mL) to 100 mL (to allow for the preparation of a series of indirect filters with different volumes) and to retain a portion of the original filter for archive. If loose debris is present within the cassette, the indirect preparation procedure in the SOP EPA-LIBBY-08 is similar to American Society for Testing and Materials (ASTM) D-5755 (ASTM 2009), with the addition of an ashing of the entire primary filter. In brief, loose debris is washed from inside the cassette and applied to a new filter, and the ashed residue from the original filter and the filter that collected the wash are suspended in water and sonicated. An aliquot of this water is applied to a second filter, which is then used to prepare a set of TEM grids. Reported air concentrations for indirectly prepared samples incorporate a dilution factor, or F-factor (see Section 2.3.2.2 for the air concentration equation).

For chrysotile asbestos, indirect preparation often tends to substantially increase structure counts due to dispersion of bundles and clusters (Hwang and Wang 1983; Health Effects Institute-Asbestos Research [HEI-AR] 1991; Breysse 1991). For amphibole asbestos, the effects of indirect preparation are generally much smaller (Bishop *et al.* 1978; Sahle and Laszlo 1996; Harris 2009). Site-specific studies on the effect of indirect preparation on reported LA air concentrations show that indirect preparation usually increased reported PCME LA air concentrations, but the concentrations were within a factor of about 2-4 compared to direct preparation (Goldade and O'Brien 2014). The relative insensitivity of PCME LA air concentration estimates to indirect preparation methods is likely due to the fact that, unlike chrysotile, complex LA structures (e.g., bundles, clusters) that might be subject to dispersal during an indirect preparation are not common in Libby air samples (EPA 2010g).

Because the PCM data used to derive toxicity factors for inhalation exposure to LA (EPA 2014c) are based on filters that were prepared directly for analysis in accordance with PCM methods, and to avoid potentially biasing calculated EPCs high due to the effect of indirect preparation, the reported PCME LA concentration for any air sample that was prepared using indirect preparation was adjusted as follows:

$$C_{adj} = C_{indirect} / AF_{indirect}$$

where:

C_{adj} = Air concentration, adjusted for indirect preparation (PCME LA s/cc)

$C_{indirect}$ = Reported air concentration for an indirectly prepared filter (PCME LA s/cc)

$AF_{indirect}$ = Indirect preparation adjustment factor

Appendix D provides detailed results for two more recent studies, conducted since the study presented in Goldade and O'Brien (2014), which provide additional data on the effect of indirect preparation on reported PCME LA air concentrations for ABS air samples collected at the Site. As demonstrated in **Appendix D**, the average ratio of PCME LA air concentrations for filters prepared using indirect preparation methods to those prepared directly was about 2.5, which is consistent with the range reported by Goldade and O'Brien (2014). Thus, an indirect preparation adjustment factor (AF) of 2.5 was used when calculating EPCs.

Appendix E provides more information on the frequency of indirect preparation for each of the datasets used in the risk assessment.

2.3.5 Calculated Exposure Point Concentration Values

As noted previously, there have been numerous investigations conducted at the Site to evaluate potential exposures to LA from various exposure scenarios. These investigations have included ambient air monitoring programs and a variety of indoor and outdoor ABS studies to evaluate LA releases during disturbances of source materials (see **Table 2-2**).

The applicable datasets and calculated EPCs for each exposure scenario evaluated in this risk assessment are discussed and presented in Section 5 through Section 8. **Appendix F** provides the detailed analytical results for all samples that were used in this HHRA. **Appendix E** provides a data quality assessment of the datasets that were used to calculate exposures and risks.

Section 3
Toxicity Assessment

The objective of a toxicity assessment is to identify what adverse health effects a contaminant may cause, and how the occurrence of those adverse effects depends on exposure level. The toxicity assessment is divided into two parts: the first characterizes and quantifies the carcinogenic (cancer) effects, while the second addresses the non-cancer effects. This two-part approach is employed because there are typically major differences in the shape of the exposure-response curve for cancer and non-cancer effects.

A detailed summary of the cancer and non-cancer effects of asbestos is provided in the Agency for Toxic Substances and Disease Registry (ATSDR) *Toxicological Profile for Asbestos* (ATSDR 2001) and in EPA's *Airborne Asbestos Health Assessment Update* (EPA 1986). A detailed summary of effects related specifically to LA is provided in the *Toxicological Review for Libby Amphibole Asbestos* (EPA 2014c). The following sections provide a summary of the cancer and non-cancer effects from exposure to asbestos in general and LA in particular.

3.1 Cancer Effects

Many epidemiological studies have reported increased mortality from cancer in workers exposed to asbestos, especially from lung cancer and mesothelioma. Based on these findings, and supported by extensive carcinogenicity data from animal studies, EPA has classified asbestos as a known human carcinogen (EPA 1993b).

3.1.1 Lung Cancer

Exposure to asbestos is associated with increased risk of developing all major histological types of lung carcinoma (adenocarcinoma, squamous cell carcinoma, and oat-cell carcinoma) (ATSDR 2001). The latency period for lung cancer generally ranges from about 10 to 40 years (ATSDR 2001). Early stages are generally asymptomatic, but as the disease develops, patients may experience coughing, shortness of breath, fatigue, and chest pain. Most lung cancer cases result in death. The risk of developing lung cancer from asbestos exposure is substantially higher in smokers than in non-smokers (Selikoff *et al.* 1968; Doll and Peto 1985; ATSDR 2001; National Toxicology Program [NTP] 2005).

3.1.2 Mesothelioma

Mesothelioma is a tumor of the thin membrane that covers and protects the internal organs of the body, including the lungs and chest cavity (pleura), and the abdominal cavity (peritoneum). Exposure to asbestos is associated with increased risk of developing mesothelioma (ATSDR 2001). The latency period for mesothelioma is typically around 20 to 40 years (Lanphear and Buncher 1992; ATSDR 2001; Mossman *et al.* 1996; Weill *et al.* 2004). By the time symptoms appear, the disease is most often rapidly fatal (British Thoracic Society 2001).

3.1.3 Other Cancers

A number of studies suggest asbestos exposure may increase risk of cancer of the larynx and ovarian cancer (IARC 2012). The National Academy of Science (NAS) reviewed evidence regarding the role of asbestos in gastrointestinal cancers primarily following occupational exposures (these are assumed to be primarily by the inhalation route) (NAS 2006). NAS concluded that data are "suggestive, but insufficient" to establish that asbestos exposure causes stomach or colorectal cancer. Data on esophageal cancer are mixed and were regarded as "inadequate to infer the presence or absence of a causal relationship to asbestos exposure".

Data on risks of gastrointestinal cancer following ingestion-only exposure are more limited. Some researchers (Conforti *et al.* 1981; Kjaerheim *et al.* 2005) have reported a significant correlation between oral exposure to asbestos in drinking water and the risk of gastrointestinal cancer. The World Health Organization (WHO 1996) concluded that data are not adequate to support the hypothesis that an increased cancer risk is associated with the ingestion of asbestos in drinking water. However, EPA has determined that there is an increased risk of developing benign intestinal polyps as a consequence of long-term ingestion of asbestos-contaminated drinking water. This finding is the basis for the maximum contaminant level (MCL) for asbestos in drinking water (EPA 1988). See **Appendix A** for additional information on the evaluation of ingestion exposures at the Site.

NAS (2006) reviewed available data on the relationship between asbestos exposure and laryngeal cancer and concluded that the data were "sufficient to infer a causal relationship between asbestos and laryngeal cancer." NAS (2006) concluded that data are "suggestive but not sufficient to infer a causal relationship between asbestos exposure and pharyngeal cancer."

Excess deaths from kidney cancer among persons with known exposure to asbestos have been reported by a number of researchers (Selikoff *et al.* 1979; Puntoni *et al.* 1979; Enterline *et al.* 1987). A review by Smith *et al.* (1989) evaluated these studies and concluded that asbestos should be regarded as a probable cause of human kidney cancer.

In a recent review, the International Agency for Research on Cancer (IARC) added ovarian cancer to the organ sites associated with asbestos exposure (IARC 2012).

3.1.4 Cancer Effects Observed in People Exposed to LA

A number of studies indicate that exposure to LA increases the risk of lung cancer and mesothelioma in humans. Amandus and Wheeler (1987), Amandus *et al.* (1987a,b), McDonald *et al.* (1986a, 2004), Sullivan (2007), and Larson *et al.* (2010) studied the cause of death in workers exposed to LA while working at the vermiculite mine and mill at Libby. All of these groups of researchers reported an increased incidence of lung cancer and mesothelioma in exposed workers, strongly supporting the conclusion that LA can cause increased risk of respiratory cancer when inhaled. In a follow-on investigation of workers from the O.M. Scott facility in Marysville, Ohio, three cases of mesothelioma have been reported (Dunning *et al.* 2012). This facility utilized vermiculite ore that originated from the vermiculite mine in Libby from 1959 to 1980.

3.2 Non-cancer Effects

3.2.1 Asbestosis

Asbestosis is a chronic pneumoconiosis associated with inhalation exposure to asbestos. It is characterized by the gradual formation of scar tissue in the lung parenchyma. Initially, the scarring may be minor and localized within the basal areas, but as the disease develops, the lungs may develop extensive diffuse alveolar and interstitial fibrosis (American Thoracic Society [ATS] 2004).

Build-up of scar tissue in the lung parenchyma results in a loss of normal elasticity in the lung, which can lead to the progressive loss of lung function. The initial symptoms of asbestosis are shortness of breath, particularly during exertion. People with fully-developed asbestosis tend to have increased difficulty breathing that is often accompanied by coughing or rales. In severe cases, impaired respiratory function can lead to death.

Asbestosis generally takes a long time to develop, with a latency period from 10 to 20 years. Mossman and Churg (1998) suggest that latency is inversely proportional to exposure level. The disease may continue to progress long after exposure has ceased (ATSDR 2001). The progression of the disease after cessation of exposure also appears to be related to the level and duration of exposure (ATS 2004).

3.2.2 Pleural Abnormalities

Exposure to asbestos may increase the risk of several types of abnormalities of the pleura (the membrane surrounding the lungs) (Broaddus *et al.* 2011), including:

- Pleural effusions are areas where excess fluid accumulates in the pleural space. Most pleural effusions last several months, although they may be recurrent (Lockey *et al.* 1984). Pleural effusions can be asymptomatic, although they may be associated with decreased ventilatory capacity, fever, and pain (Bourbeau *et al.* 1990).

- Pleural plaques are acellular collagenous deposits, often with calcification. Pleural plaques represent an irreversible pathological lesion of the pleural membranes. Pleural plaques are the most common manifestations of asbestos exposure (ATSDR 2001; ATS 2004; Rohs *et al.* 2008). Pleural plaques may also be asymptomatic in some, but not all, cases (Bourbeau *et al.* 1990).

- Diffuse pleural thickening (DPT) is a non-circumscribed fibrotic lesion (often described as a "basket weave of collagen") in the pleura that encases the lungs. Thickening may be extensive and cover a whole lobe or even an entire lung. DPT restricts the ability of the lung to expand mechanically, thereby reducing respiratory volume. DPT is strongly associated with reduced lung function (Baker *et al.* 1985; Churg 1986; Jarvholm and Larsson 1988; EPA 2014c). Severe effects are rare, although Miller *et al.* (1983) reported on severe cases of DPT that lead to death.

- Localized pleural thickening (LPT) may include both pleural plaques (focal areas of pleural thickening generally present at the parietal pleura, diaphragm or chest wall) and pleural thickening that does not involve blunting of the costophrenic angle (the angle between the diaphragm and the chest wall at the bottom of the lung). Thickening of the pleura is due to collagen deposition, and may occur on both the outer and inner surface of the pleura. LPT is generally considered to be a less severe lesion than DPT or asbestosis. However, EPA has performed a detailed review of the literature and concluded that LPT is associated with a decrement in pulmonary function (EPA 2014c; Kopylev et al. 2015; Lockey et al. 2015).

The latency period for pleural abnormalities is usually about 10 to 40 years (ATS 2004), although pleural effusions may occasionally develop as early as one year after first exposure (Epler and Gaensler 1982).

3.2.3 Other Non-Cancer Effects

Some epidemiological studies provide evidence that chronic exposure to asbestos can increase the risk of several other types of non-cancer effects including cor pulmonale (right-sided heart failure), retroperitoneal fibrosis (a fibrous mass in the back of the abdomen that blocks the flow of urine from the kidneys to the bladder), depressed cell-mediated immunity (ATSDR 2001), and autoimmune disease (Pfau *et al.* 2005; Noonan *et al.* 2006; Marchand *et al.* 2012; Serve *et al.* 2013; Ferro *et al.* 2014).

3.2.4 Observations of Non-Cancer Diseases in People Exposed to LA

Amandus and Wheeler (1987), McDonald *et al.* (1986a, 2004), and Sullivan (2007) studied the cause of death in workers exposed to LA while working at the vermiculite mine and mill at Libby. Each of these researchers reported that Libby workers were more likely to die of non-malignant respiratory disease (i.e., asbestosis, chronic obstructive pulmonary disease, pneumonia, tuberculosis and emphysema) compared to white males in the general U.S. population.

McDonald *et al.* (1986b) and Amandus *et al.* (1987b) evaluated the prevalence of chest radiographic changes in workers exposed to LA at the vermiculite mine and mill at Libby. These researchers observed increased prevalence in several types of pleural abnormalities, including pleural calcification, pleural thickening, and profusion of small opacities. Rohs *et al.* (2008) studied the prevalence of pleural changes in the lungs of workers exposed to LA at the O.M. Scott facility in Marysville, Ohio, where Libby vermiculite ore was exfoliated and used as an inert carrier for lawn care products. Rohs *et al.* (2008) observed an increased incidence of pleural plaques (LPT), DPT, and interstitial changes (irregular opacities) in exposed workers. Peipins *et al.* (2003), Muravov *et al.* (2005), and Whitehouse (2004) also observed increased incidence in pleural abnormalities in workers at Libby. Recent continuing research on the Libby workers shows that several pulmonary health outcomes that may affect respiratory function are associated with cumulative fiber exposure levels (Larson *et al.* 2012a).

Community-based studies in Libby have documented the occurrence of a range of asbestos-related non-neoplastic diseases, ranging from pleural plaques (LPT) and DPT to chronic obstructive pulmonary disease (McDonald *et al.* 1986b; Amandus *et al.* 1987a, b; Amandus and Wheeler 1987; ATSDR 2001; Peipins *et al.* 2003; Whitehouse 2004; Sullivan 2007; Larson *et al.* 2010). These diseases affect not only the miners and millers who worked at the Grace facilities, but also community members who lived in Libby and Troy and the surrounding areas. The ATSDR health screening conducted during 2000 and 2001 of over 7,300 Libby community members revealed the presence of significant levels of pleural abnormalities and elevated morbidity and mortality. Continuing medical surveillance of the Libby population by researchers from the ATSDR and Mount Sinai Medical Center reveals pulmonary disorders in young adults who were exposed to asbestos in early childhood (Vinikoor *et al.* 2010) and cardiovascular effects in former miners who experienced high cumulative fiber exposures (Larson *et al.* 2010). Researchers at the University of Montana and Idaho State University have reported elevated levels of autoimmune diseases in the Libby population (Noonan *et al.* 2006; Pfau *et al.* 2008; Marchand *et al.* 2012).

3.3 Toxicity Values

In 1986, EPA utilized data that were available at the time to establish quantitative exposure-response models for both lung cancer and mesothelioma (EPA 1986). These models were based on data from all forms of asbestos, including chrysotile as well as several forms of amphibole asbestos. In the exposure-response models that were developed, the magnitude of cancer risk depended not only on exposure concentration, but also age at first exposure and duration of exposure. EPA (2008a) summarizes the approach and provides a table of inhalation unit risk (IUR) values for a range of different age at first exposure and exposure duration values. This approach is also described on EPA's

Integrated Risk Information System (IRIS) web page for asbestos. No method was established at that time for quantification of non-cancer hazards.

More recently, EPA has performed a detailed toxicological review of available studies on the cancer and non-cancer effects specifically associated with exposure to LA. EPA released a draft for public review and comment in August 2011. EPA's Scientific Advisory Board (SAB) reviewed and commented on the draft report, and issued final review comments in January 2013. EPA revised the draft document in accordance with the SAB comments and issued the final *Toxicological Review of Libby Amphibole Asbestos* in December 2014 (EPA 2014c). This final document provides detailed descriptions of the data and methods used to derive LA-specific values for characterization of both cancer and non-cancer effects. The following sections provide brief summaries of the derivation of these values.

3.3.1 Cancer

Under EPA's *Guidelines for Carcinogen Risk Assessment* (EPA 2005a), LA is classified as being "carcinogenic to humans" following inhalation exposure based on epidemiologic evidence that shows a convincing association between exposure to LA fibers and increased lung cancer and mesothelioma mortality (EPA 2014c). These results are further supported by animal studies that demonstrate the carcinogenic potential of LA fibers in rodent bioassays (EPA 2014c).

EPA (2014c) developed the IUR value for LA based on exposure-response data from workers employed at the vermiculite mining and milling operation in Libby. The IUR for LA is defined as the excess lifetime cancer risk estimated to result from continuous exposure to one PCM fiber of LA per cubic centimeter of air (1 PCM f/cc). In contrast to the approach developed previously (EPA 1986), the cancer exposure-response model selected for LA does not depend on age at first exposure or exposure duration, so only a single IUR value is needed to quantify cancer risk. This LA-specific IUR, referred to as IUR_{LA}, is 0.17 $(PCM\ f/cc)^{-1}$ (EPA 2014c). This IUR includes the risk of both lung cancer and mesothelioma.

3.3.2 Non-cancer

Non-cancer hazard from inhalation exposure is characterized by comparing the Site-related exposure to a reference concentration (RfC) value. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure that is likely to be without an appreciable risk of deleterious effects in humans (including sensitive subgroups) during a lifetime (EPA 2009e). Exposures less than the RfC are considered to be without risk of adverse non-cancer health effects, while exposures greater than the RfC may cause an effect, depending on the exposure level.

The LA-specific RfC, referred to as RfC_{LA}, was derived from exposure-response data obtained from a cohort of workers employed at the O.M. Scott Plant in Marysville, Ohio (EPA 2014c). LPT was selected as the critical effect endpoint for the derivation of the RfC_{LA}. As noted above, LPT is an irreversible pathological change associated with a statistically and biologically significant decrement in pulmonary function (EPA 2014c). EPA evaluated a wide range of alternative exposure-response models, and ultimately selected a model that depended only on average exposure concentration. The resulting RfC_{LA} is 0.00009 PCM f/cc (EPA 2014c).

The derivation of the RfC_{LA} includes the application of uncertainty factors (UFs) to account for uncertainties in the available data and the exposure-response model. The overall (composite) UF is a factor of 300 (EPA 2014c). The composite UF of 300 is comprised of an intra-species UF of 10 to account for human variability and potentially susceptible individuals, a data-informed subchronic-to-chronic UF of 10 to address uncertainty due to increasing risk of LPT over the course of a lifetime, and a database UF of 3 to account for data deficiencies in the available health effects literature for LA (EPA 2014c).

Section 4

Risk Characterization Approach

4.1 Basic Equations

As described previously in Section 3.3, EPA has recently developed an IUR and an RfC for exposure to LA (EPA 2014c). This section describes how these toxicity factors were used to estimate cancer risks and non-cancer hazards to people who are exposed to LA in air at the Site. The basic approach for evaluating potential cancer and non-cancer risks from inhalation exposures to LA is consistent with the inhalation dosimetry methodology described in *Risk Assessment Guidance for Superfund (Part F, Supplemental Guidance for Inhalation Risk Assessment)* (EPA 2009e), except as discussed below.

4.1.1 Cancer

The basic equation used to estimate excess lifetime cancer risk from inhalation exposures to LA under a range of differing exposure scenarios is as follows:

$$Risk_s = \bar{C}_{LT,s} \cdot IUR_{LA}$$

where:

$Risk_s$ = Lifetime excess risk of developing cancer (lung cancer or mesothelioma) as a consequence of inhalation exposure to LA for the specific exposure scenario "s" being assessed.

$\bar{C}_{LT,s}$ = Lifetime average exposure concentration (PCME s/cc) associated with exposure scenario "s"

IUR_{LA} = LA-specific lifetime inhalation unit risk (PCM s/cc)$^{-1}$

For exposure scenarios in which exposure is not continuous over a lifetime, the value of $\bar{C}_{LT,s}$ is calculated by adjusting the scenario-specific exposure concentration (EPC_s, PCME s/cc) by a scenario-specific time-weighting-factor (TWF_s) that accounts for the less-than-continuous exposure:

$$\bar{C}_{LT,s} = EPC_s \cdot TWF_s$$

where:

EPC_s = Exposure point concentration of LA in air (PCME LA s/cc). The EPC is an estimate of the long-term average concentration of LA in inhaled air for the specific exposure scenario "s" being assessed.

TWF_s = Time-weighting factor. The value of the TWF term ranges from zero to one, and describes the average fraction of a lifetime during which exposure occurs from the specific exposure scenario "s" being assessed.

Combining these equations yields:

$$Risk_s = EPC_s \cdot TWF_s \cdot IUR_{LA}$$

Excess cancer risk can be expressed in several formats. A cancer risk expressed in a scientific notation format as 1E-06 is equivalent to 1 in 1,000,000 (one in a million) or $1x10^{-6}$. Similarly, a cancer risk of 1E-04 is equivalent to 1 in 10,000 (one in ten thousand) or $1x10^{-4}$. For the purposes of this risk assessment, all cancer risks are presented in a scientific notation format (i.e., 1E-04) and expressed to one significant figure (EPA 1989).

The derivation of cumulative cancer risk estimates (the total cancer risk to a receptor resulting from exposure to LA across multiple exposure scenarios) is presented in Section 9.

4.1.1.1 Exposure Point Concentrations

Section 2.3 provides a detailed discussion of the methods used in deriving EPCs for LA. As noted previously, although other amphibole asbestos types and/or chrysotile may have been noted in some air samples, exposures and risks are calculated for LA only, as this is the type of asbestos that is expected to be Site-related.

The applicable datasets and calculated EPCs for each exposure scenario evaluated in this risk assessment are discussed and presented in Section 5 through Section 8. **Appendix F** provides the detailed analytical results for all samples that are used in this HHRA. **Appendix E** provides a data quality assessment of the datasets that are used to calculate exposures and risks.

4.1.1.2 Time-Weighting Factor for Cancer

As noted previously (see Section 3.3.1), the IUR_{LA} is defined as the excess cancer risk estimated to result from continuous lifetime exposure to 1 f/cc. Exposures at the Site are estimated for a lifetime. Since there are multiple exposure scenarios that occur during a lifetime, it is necessary to evaluate the contribution of each source to the total lifetime exposure. Therefore, each exposure scenario was evaluated as a fraction of the total lifetime exposure by adjusting the scenario-specific EPCs using a scenario-specific TWF.

The value of the TWF for cancer exposures is calculated as:

$$TWF_s = ET_s/24 \cdot EF_s/365 \cdot ED_s/70$$

where:

ET_s = Exposure time (hours per day) that the exposed person is engaged in exposure scenario "s"

EF_s = Exposure frequency (days per year) the exposed person is engaged in exposure scenario "s"

ED_s = Exposure duration (years) the exposed person is engaged in exposure scenario "s"

As noted above, the TWF_s ranges from zero to one, and describes the average fraction of a lifetime (70 years) during which asbestos exposure from scenario "s" occurs. It is important to note that the derivation of the TWF presented above differs from the approach described in EPA (2008a) in that the TWF equation includes the ED term. This is because the approach developed by EPA (1986) and detailed in EPA (2008a) accounts for differing exposure durations by adjusting the IUR term rather than the TWF term.

The calculated TWFs for each exposure scenario evaluated in this risk assessment are discussed and presented in Section 5 through Section 8. *TWFs for the evaluation of cumulative exposures, across multiple exposure scenarios, are determined using a modification of this methodology (see Section 9).*

4.1.1.3 LA-specific Inhalation Unit Risk Value

As discussed in Section 3.3.1, the IUR_{LA} is 0.17 (PCM f/cc)$^{-1}$ and is derived from a cohort of workers employed at the vermiculite mine in Libby (EPA 2014c). It is important to understand that the IUR_{LA} is not age- or duration-dependent; thus, the less-than-lifetime IUR derivation procedures presented in Appendix E of EPA (2008a) do not apply when using the LA-specific cancer toxicity value.

4.1.2 Non-cancer

The basic equation used to characterize non-cancer hazard from inhalation exposures to LA under a range of differing exposure scenarios is as follows:

$$HQ_s = \bar{C}_{LT,s} / RfC_{LA}$$

where:

HQ_s = Hazard quotient from inhalation exposure to LA for the specific exposure scenario “s” being assessed.

$\bar{C}_{LT,s}$ = Lifetime average exposure concentration (PCME s/cc) associated with exposure scenario “s”

RfC_{LA} = LA-specific reference concentration (PCM s/cc)

For exposure scenarios in which exposure is not continuous over a lifetime, the value of $\bar{C}_{LT,s}$ was calculated by adjusting the scenario-specific exposure concentration (EPC_s, PCME s/cc) by the scenario-specific time-weighting-factor (TWF_s) that accounts for the less-than-continuous exposure:

$$\bar{C}_{LT,s} = EPC_s \cdot TWF_s$$

where:

EPC_s = Exposure point concentration of LA in air (PCME LA s/cc). The EPC is an estimate of the long-term average concentration of LA in inhaled air for the specific exposure scenario “s” being assessed.

TWF_s = Time-weighting factor. The value of the TWF term ranges from zero to one, and describes the average fraction of a lifetime during which exposure occurs from the specific exposure scenario “s” being assessed.

Combining these equations yields:

$$HQ_s = EPC_s \cdot TWF_s / RfC_{LA}$$

The derivation of cumulative non-cancer hazard index (HI) estimates (the hazard resulting from exposure of a receptor across multiple exposure scenarios) is presented in Section 9. All non-cancer HQs and HIs are expressed to one significant figure. This approach is consistent with EPA guidance (EPA 1989) and mathematical principles for expressing numerical significance, as the RFC_{LA} is also expressed to one significant figure.

4.1.2.1 Exposure Point Concentrations

The EPCs used to calculate non-cancer hazards are the same as those used to calculate cancer risks (see Section 4.1.1.1).

4.1.2.2 Time-Weighting Factor for Non-Cancer

As noted previously (see Section 3.3.2), the RfC_{LA} is defined as an estimate of the exposure concentration that is likely to be without an appreciable risk of adverse health effects in the general population (including sensitive subgroups) following <u>continuous lifetime</u> exposure. Exposures at the Site are estimated for a lifetime. Since there are multiple exposure scenarios that occur during a lifetime, it is necessary to evaluate the contribution of each source to the total lifetime exposure. Therefore, each exposure scenario was evaluated as a fraction of the total lifetime exposure by adjusting the scenario-specific EPCs using a scenario-specific TWF.

$$\bar{C}_{LT,s} = EPC_s \cdot TWF_s$$

The scenario-specific TWF values used at the Site for non-cancer exposures were calculated using the same equation as described above for cancer:

$$TWF_s = ET_s/24 \cdot EF_s/365 \cdot ED_s/70$$

Notice that this approach differs from the approach that is generally used for other (non-asbestos) inhalation toxicants (EPA 2009e) in that the averaging time is assumed to be 70 years, rather than setting the averaging time equal to ED. This is because the approach developed by EPA (2009e) was derived mainly to evaluate hazards from volatile organic compounds, and was not intended for application to durable fibers that remain in the lung and continue to trigger biological responses long after exposure has ceased. Rather, EPA (2009e) recommends that EPA's Technical Review Workgroup (TRW) for Asbestos be consulted when evaluating risks from inhalation exposure to asbestos. The approach above was evaluated and approved for use at the Site by the Asbestos TRW (EPA 2014d).

4.1.2.3 LA-specific Reference Concentration

As discussed in Section 3.3.2, the RfC_{LA} is 0.00009 PCM f/cc and is derived from a cohort of workers from an O.M Scott plant that utilized vermiculite ore which originated from the vermiculite mine in Libby. LPT was selected as the critical effect endpoint for the derivation of the RfC_{LA} (EPA 2014c).

4.2 Sensitive Effects Endpoint

For most chemicals that cause both cancer and non-cancer effects, cancer is usually the endpoint that drives risk management decisions. That is, as exposure concentration increases, the cancer risk estimate reaches EPA's threshold of 1E-04 before the non-cancer HQ reaches a threshold of 1. However, this is not the case for LA exposures. For LA, for any given exposure scenario, non-cancer effects are the more sensitive endpoint. This observation (which is specific to LA) is derived from the basic equations for non-cancer HQ and cancer risk presented above, as follows:

$$HQ_S = EPC_S \cdot TWF_S / RfC_{LA}$$

$$Risk_S = EPC_S \cdot TWF_S \cdot IUR_{LA}$$

$$Risk_S/HQ_S = IUR_{LA} \cdot RfC_{LA} = 0.17 \cdot 0.00009 = 1.5E\text{-}05$$

Thus, for LA, when the non-cancer HQ is 1, the excess cancer risk is approximately 1E-05.

4.3 Risk Characterization Approach and Organization

As illustrated in **Figure 2-1**, there are nine general types of exposure scenarios that were evaluated in the risk characterization:

- Outdoor air, under ambient conditions (see Section 5)
- Outdoor air, during soil/duff disturbance activities (see Section 6)
- Outdoor air, during tree bark disturbance activities (see Section 8)
- Outdoor air, during woodchip/mulch disturbance activities (see Section 8)
- Outdoor air, during ash disturbance activities (see Section 8)
- Indoor air, under passive conditions (see Section 7)
- Indoor air, during VI disturbance activities (see Section 7)
- Indoor air, during dust disturbance activities (see Section 7)
- Indoor air, during woodstove ash disturbance activities (see Section 8)

As shown in **Table 2-1**, there are multiple types of activities and locations that were evaluated as part of the risk characterization for exposures to air under source-disturbance conditions. In this document, potential exposures and risks for each exposure scenario are presented in Section 5 through Section 8 (as identified above). Within each section, an overview of the applicable air exposure dataset is provided, EPCs are derived, selected exposure parameters and calculated TWFs for each receptor and exposure scenario are presented, and estimated cancer risks and non-cancer HQs are calculated. Section 9 presents a cumulative assessment of potential exposures across multiple exposure media, disturbance activities, and locations for several example cumulative exposure scenarios.

4.4 Risk Interpretation

EPA's Office of Solid Waste and Emergency Response (OSWER) Directive #9355.0-30, "*Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*" (EPA 1991b) provides guidance on the interpretation of estimated risks. The level of cancer risk that is of concern is a matter of personal, community, and regulatory judgment. In general, EPA considers cumulative excess cancer risks less than 1E-06 to be so small as to be negligible, and risks greater than 1E-04 to be sufficiently large that some form of remedial action is desirable. Excess cancer risks that range between 1E-04 and 1E-06 are generally considered to be acceptable, although this is evaluated on a case-by-case basis, and EPA may determine that risks lower than 1E-04 are not sufficiently protective and warrant remedial action.

For non-cancer, if the cumulative HI is less than or equal to 1, then remedial action is generally not warranted unless there are adverse environmental impacts. If an HI exceeds 1, there is some possibility that non-cancer effects may occur, although an HI greater than 1 does not indicate an effect will definitely occur. This is because of the margin of safety inherent in the derivation of all toxicity values (see Section 3.3.2). However, the larger the HI value, the more likely it is that an adverse effect may occur. Note that risk management decisions generally consider the sum of all the risks contributed by differing exposure scenarios into account, rather than simply evaluating each one independently.

Section 5

Risks from Exposures to Outdoor Ambient Air

Every receptor population at the Site is expected to be exposed to LA in outdoor ambient air. Several air monitoring studies have been conducted to measure LA concentrations in air under "typical" ambient conditions that may be encountered at the Site. The following sections summarize the results of these monitoring studies, describe how these data were used to calculate exposures, present estimated cancer risks and non-cancer HQs from exposures to ambient air, and discuss how air concentrations at the Site compare to levels measured at other offsite locations and to historical Site conditions.

5.1 Data Summary

5.1.1 Overview of Ambient Air Investigations

Since 2006, EPA has conducted outdoor monitoring in Libby to measure LA concentrations in ambient air. As part of this program, 25 different stationary monitors in Libby (the number of monitors varied by year) were sampled across multiple days at regular intervals to provide data on ambient air concentrations of LA (EPA 2006c, 2007b; CDM Smith 2010a, 2011a, 2012a, 2013b). **Figure 5-1** provides a map of the ambient air monitoring stations in Libby. Prior to 2010, the primary focus of this ambient air monitoring program was to measure ambient air concentrations throughout the Libby community (stations L1-L18). Beginning in 2010, the focus of the monitoring program shifted to evaluate ambient air concentrations along transportation corridors in Libby (stations L20-L26 were added, and only stations L8 and L12 continued to be sampled post-2010). In addition, two stationary monitors in Eureka and Helena, Montana were also sampled for the purposes of providing a frame of reference to which observations at the Site could be compared. **Figure 5-2** illustrates the sampling event durations for each ambient air monitor. Detailed results of the ambient air monitoring program in Libby are summarized in EPA (2009f) and EPA (2014e).

The Montana Department of Environmental Quality (DEQ) conducted a similar outdoor ambient air monitoring program in Troy from 2009 to 2013. As part of this program, 18 stationary monitors in Troy were sampled across multiple days at regular intervals to provide data on ambient air concentrations of LA in Troy (Tetra Tech 2009). **Figure 5-3** provides a map of the ambient air monitoring stations in Troy. As shown, the monitoring stations were stratified into four zones. **Figure 5-4** illustrates the sampling event durations for each ambient air monitor in Troy. Detailed results of the ambient air monitoring program in Troy are summarized in eleven *Outdoor Ambient Air Monitoring Study Quarterly Memoranda*[9].

Beginning in late 2013, the Lincoln County Asbestos Resource Program (ARP) took over responsibility for the implementation of the long-term ambient air monitoring programs for Libby and Troy.

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[9] Data from the final six sampling events in 2013 have not been summarized in any quarterly memorandum. Copies of all quarterly memoranda are available on EPA's project website: http://www2.epa.gov/region8/libby-asbestos-ou7-outdoor-ambient-air-study-quarterly-reports

Outdoor ambient air sampling was also conducted near the mine site (OU3) during the fall of 2007 and summer of 2008. As part of this sampling program, 12 stationary monitors were sampled across multiple days at regular intervals to provide data on ambient air concentrations of LA near the mine site. Sampling was conducted by Grace's contractors in accordance with EPA-developed sampling and analysis plans (SAPs) (EPA 2007c, 2008d). **Figure 5-5** provides a map of the ambient air monitoring stations near the mine. Detailed results for the ambient air monitors at the mine are summarized in CDM Smith (2015a).

Table 5-1 presents summary statistics of the ambient air monitoring results for each station.

5.1.2 Calculation of EPCs

Figure 5-6 presents the average ambient air concentrations by month across all Libby community monitors (i.e., stations L1-L18). As shown, average LA air concentrations in the Libby community tend to vary temporally, with concentrations tending to be highest in the spring and summer months and lowest in the fall and winter. Because of this temporal variability, and because the sampling frequency has not been equal across months (as seen in **Figure 5-2** and **Figure 5-4**), for the purposes of calculating long-term average exposures over multiple years, the ambient air EPC is calculated using the following approach. First, for a given monitoring location, the average ambient air concentration was calculated for each month across years for which data were available. Then, for each month, the average ambient air concentration was calculated across locations ($\bar{X}_i$). The EPC used in the risk assessment was calculated as follows:

$$EPC = \sum \bar{X}_i \cdot 1/12$$

where:

EPC = Long-term average ambient air exposure point concentration (PCME LA s/cc)

$\bar{X}_i$ = Average ambient air concentration in month 'i' across locations (PCME LA s/cc)

1/12 = One-month weighting factor

As noted above, because the focus of the ambient air monitoring program in Libby shifted in 2010 to focus on monitoring concentrations along transportation corridors, which may yield higher ambient air concentrations than in the general community, EPCs for Libby were calculated separately for stations in the community (L1-L18) and for stations along transportation corridors (L20-L26). For Troy, because there do not appear to be differences in ambient air concentrations by zone (see **Table 5-1**), EPCs were calculated across all stations (regardless of zone). The long-term average EPCs for outdoor ambient air that were used in the risk calculations are presented in **Table 5-2**.

5.2 Exposure Populations and Parameters

Exposure to ambient air occurs during outdoor activities, with the exposure time (hours/day) and frequency (days/year) tending to differ between different receptors and different activity patterns. However, for simplicity, risk estimates from exposures to ambient air were calculated for each exposure area based on the maximally-exposed receptor. (If risks are below a level of concern for the maximally-exposed receptor, it is assumed that risks would also be below a level of concern for other receptors with lower exposures.) For example, although teachers/students, recreational visitors, and workers may all be exposed to LA in ambient air in Libby and Troy, risk estimates were calculated based on a residential exposure scenario, because this population is likely to have the highest exposure (i.e., the highest TWF). Because residential exposures are not expected in OU3 (i.e., there are no residential properties at the mine site), risk estimates were calculated based on a recreational visitor exposure scenario.

Table 5-3 presents the selected RME and CTE exposure parameters values and calculated TWFs for each receptor type. This table identifies the basis of the selected exposure parameter and notes if any Site-specific adjustments were applied. It is important to note that the exposure parameters and resulting TWFs presented in **Table 5-3** are selected for the purposes of evaluating potential risks from the ambient air exposure scenario only (i.e., the cumulative assessment may utilize different TWFs).

5.3 Risk Estimates

Table 5-4 presents the estimated cancer risks and non-cancer HQs for exposures to LA in outdoor ambient air based on RME (Panel A) and CTE (Panel B). As shown, RME cancer risks are less than or equal to 1E-06 and HQs are less than 0.1 for all Site exposure locations; CTE cancer risks and HQs are even lower. These results indicate that exposures to LA in ambient air are not likely to be of concern to individuals at the Site and are not likely to contribute significantly to cumulative risks.

5.4 Comparison to Ambient Air in Other Locations

Asbestos is a naturally-occurring material and has also been widely used in commercial products in the past. Because of this, asbestos fibers are often detectable in air at locations that are not associated with any specific sources.

As noted above, the Libby ambient air monitoring program included sampling locations in Eureka and Helena (see **Table 5-1**) for the purposes of providing a frame of reference to which Site observations could be compared. In Eureka, a total of 32 ambient air sampling events were conducted from October 2006 to September 2007 and all samples were non-detect for PCME LA (mean achieved analytical sensitivity of 0.000037 cc^{-1}). In Helena, a total of 39 ambient air sampling events were conducted from October 2006 to June 2008, and PCME LA was detected in four events, with an average ambient air concentration of about 0.0000054 PCME LA s/cc.

SRC, Inc. (2013a) summarizes data from published reports on the levels of asbestos (all forms of asbestos, including chrysotile) that have been reported in air at a number of locations across the country. Average asbestos concentrations in outdoor ambient air tended to range between about 0.00001 and 0.0004 s/cc, with an overall mean of about 0.00003 s/cc (concentrations are based on structures longer than 5 µm), but there was a high degree of variability observed between individual samples. In general, ambient air concentrations in rural areas tended to be lower than urban areas.

As shown in **Table 5-2**, average ambient air concentrations of LA in the Libby community (0.0000048 PCME LA s/cc) and in Troy (about 0.0000015 PCME LA s/cc) under current conditions are consistent with asbestos levels that have been measured in Eureka and Helena, as well as across the country. The predominant type of asbestos observed in Libby and Troy is LA; the presence of chrysotile fibers has only been noted in about 5% of the ambient air samples collected, and other types of amphibole asbestos (e.g., anthophyllite, crocidolite) have been observed in only five samples (0.3% of all ambient air samples).

5.5 Comparison to Historical Ambient Air in Libby

Very few data are available that provide measured air concentrations under historical conditions within the Libby community. In 1975, when the mine was in operation, ambient air concentrations of 0.67 to 1.5 PCM f/cc were measured in downtown Libby (Grace 1975). Although these results are based on PCM and may be biased high with regard to airborne asbestos concentrations, these data demonstrate that ambient air at the Site under current conditions has significantly improved relative to historical conditions (i.e., current ambient air concentrations are 100,000 times lower).

Section 6

Risks from Exposures During Soil/Duff Disturbances

To date, there have been about 20 different outdoor ABS investigations conducted at the Site to evaluate potential exposures to LA from disturbances of soil/duff. **Table 2-2** (Panel A) summarizes the types of outdoor ABS investigations that have been conducted during soil/duff disturbances for each OU. For most exposure areas, the source medium is soil; however, in forested areas the source medium is likely a mixture of soil and duff materials and in the disturbed area of the mine it is a mixture of soil and mine waste materials.

As shown in **Table 2-1**, there is the potential for exposures to LA during disturbances of soil in every OU for a wide range of receptor types and exposure scenarios. Because the exposure scenarios differ by location, each location is evaluated separately, as follows:

- Section 6.1 – Residential and Commercial Properties in OU4 and OU7
- Section 6.2 – Schools and Parks in OU4 and OU7
- Section 6.3 – Trails and Bike Paths in OU4 and OU7
- Section 6.4 – OU1
- Section 6.5 – OU2
- Section 6.6 – OU3
- Section 6.7 – OU5
- Section 6.8 – OU6
- Section 6.9 – OU8

Section 6.10 presents an evaluation of LA concentrations in "background" soil and summarizes potential exposures and risks associated with disturbances of background soil. Section 6.11 summarizes the overall conclusions regarding potential risks from exposures to LA during soil disturbances.

Each of the following sections discuss the exposure populations of interest and present the selected RME and CTE exposure parameters values and calculated TWFs for each exposure scenario. Each section identifies the basis of the selected exposure parameters and notes if any Site-specific adjustments were applied. It is important to note that the exposure parameters and resulting TWFs are selected for the purposes of evaluating potential risks from each individual exposure scenario (i.e., the cumulative assessment may utilize different TWFs).

6.1 Residential and Commercial Properties in OU4 and OU7

6.1.1 Exposure Populations and Parameters

There are several populations who may be exposed to LA in air during outdoor soil disturbances at residential and commercial properties in OU4 and OU7. The primary receptor population of interest is residents. Because residential exposures may differ as a function of location within a property (i.e., the amount of time in spent in yards is expected to be different than time spent in a garden), exposure parameters were specified separately for each of four exposure locations – yards, gardens/flowerbeds, driveways, and limited-use areas (LUAs). LUAs are portions of the property that are used on a more limited basis, such as pastures and mowed fields.

A second receptor population of interest is outdoor workers, such as local landscapers and lawncare maintenance workers. These individuals have the potential to perform soil disturbance activities on a more frequent basis than residents. As such, exposures to LA in air during outdoor soil disturbances at residential and commercial properties in OU4 and OU7 were evaluated separately for residents and outdoor workers.

For commercial properties, it is anticipated that exposures to LA in air during outdoor soil disturbances will be primarily associated with outdoor worker activities. However, because it is possible that future land use could transition from commercial to residential (and vice versa), commercial properties were not assessed separately from residential properties.

Table 6-1 (Panel A) presents the selected RME and CTE exposure parameters values and calculated TWFs for disturbances of surface soils at OU4/OU7 properties by exposure location.

6.1.2 Investigation Summary

The following subsections briefly summarize the outdoor ABS investigations that have been performed at residential and commercial properties in OU4 and OU7 to evaluate potential exposures to LA during soil disturbances in yards, gardens/flowerbeds, driveways, and LUAs.

6.1.2.1 Yards

There have been several different outdoor ABS investigations conducted in OU4 and OU7 to evaluate potential exposures to LA during disturbances of soils in yards. Although there have been some differences in the study designs from investigation to investigation, the basic study designs for yards have been generally similar. In general, the outdoor ABS studies of yards have evaluated three different soil disturbance activities – mowing, raking, and digging (see **Figure 2-2** for example photographs of these ABS activities). ABS activities were performed by EPA or DEQ contractors in accordance with specified ABS "scripts". The ABS script specifies how the sampling team conducts the ABS activity (i.e., what disturbance activities to perform, where they should be performed, how to conduct the activity, and for how long each activity should be performed). ABS air samples were collected using personal air monitors (i.e., the air sampling cassette was worn by the individual performing the disturbance activity). Unless specified otherwise below, co-located 30-point soil composite samples were collected for each ABS area at the time of the ABS activity to provide data on the LA concentrations in the soil being disturbed. In addition, estimates of visible vermiculite (VV) were determined at the time of the soil sampling. Yards selected for outdoor ABS evaluation included a range of soil LA concentrations, and included both yards where soil removals had and had not been performed.

There have been four different yard ABS investigations conducted in OU4 and one yard ABS investigation in OU7. Each of these studies is described briefly below.

In the summer of 2005, outdoor ABS was conducted during disturbances of yard soils as part of the *OU4 Supplemental RI Quality Assurance and Project Plan* (referred to as the SQAPP) (EPA 2005b). Outdoor ABS samples were collected during digging, raking, and mowing. A total of 18 ABS areas were selected to represent yards with soil LA concentrations ranging from non-detect to greater than 1%. Co-located soil composite samples were collected at the time of the ABS; however, the sample sampling methodology employed at the time differed from current sampling protocols in that the sample was usually only a 4-point or 10-point composite (current protocol is to collect 30-point composites). Detailed results of the OU4 SQAPP outdoor ABS investigation are summarized in EPA (2007a). Because the SQAPP soil collection methodology differed from current protocols and subsequent outdoor ABS programs, outdoor ABS data from the SQAPP were not included in this risk assessment.

The largest outdoor ABS program in OU4 occurred from 2007-2008 (EPA 2007d). This sampling investigation performed outdoor ABS during disturbances of yard soils at 75 properties. Similar to the SQAPP investigation, outdoor ABS samples were collected during digging (simulating a child playing in an area of bare dirt with a bucket and shovel), raking, and mowing. Two rounds of outdoor ABS were conducted at each ABS area to span a range of soil moisture and meteorological conditions. The first sampling event was performed in the summer of 2007 (July to August) and the second sampling event was performed in the spring of 2008 (April to June). During each ABS sampling event, soil disturbance activities were performed over a 6-hour time interval, divided into three sub-periods of two hours each (one for each disturbance scenario). One ABS air sample was collected for each disturbance scenario for each sampling event. Detailed results of the 2007-2008 OU4 outdoor ABS investigation are summarized in EPA (2010d). In addition, CDM Smith (2013c, d) summarizes the results of a subsequent soil re-analysis effort for this investigation.

In 2010, EPA conducted another outdoor ABS investigation during yard soil disturbances in OU4 (CDM Smith 2010b). Unlike previous investigations, the digging scenario was modified to simulate a sprinkler maintenance activity (i.e., digging a hole using a long shovel and trowel). The mowing and raking scenarios were performed on a yard-wide basis, to reduce the amount of localized stress in one area that occurred during the 2007-2008 ABS study, and the ABS duration was reduced to one hour (20 minutes per disturbance scenario). In addition, unlike the previous investigations, a single ABS air sample was collected during each sampling event, representing a composite across all three soil disturbance scenarios (mowing, raking, and digging). A total of ten properties were selected for evaluation; three sampling events were conducted at each property in the summer of 2010, with events spaced about one month apart. ABS air samples were originally analyzed in 2010; a subset of the samples underwent a supplemental TEM analysis to improve the achieved analytical sensitivity in 2013. Detailed results of the 2010 OU4 outdoor ABS investigation (including the supplemental analyses) are summarized in CDM Smith (2014a).

In 2011, EPA conducted several residential ABS studies in OU4 to evaluate potential exposures from the disturbance of yard soils. These residential ABS investigations consisted of three different yard sampling scenarios. The specific objectives and study designs of each sampling scenario are described in the governing SAP, *2011 Residential Activity-Based Sampling SAP* (CDM Smith 2011b). In brief, the first scenario evaluated potential differences in ABS LA air concentrations as a function of the raking, mowing, and digging disturbance intensity (see Section 6.1.4.1.1 for a detailed discussion of differences in ABS script intensity), the second scenario evaluated potential differences in measured ABS LA air concentrations at a given property across sampling years, and the third scenario evaluated potential differences in measured ABS LA air concentrations during mowing activities pre- and post-irrigation. Multiple sampling events were conducted at each selected property in the summer of 2011. Detailed results of the 2011 OU4 outdoor ABS investigation are summarized in CDM Smith (2014b).

For OU7, DEQ conducted an outdoor ABS investigation during yard soil disturbances in 2011 (Tetra Tech 2011). This ABS study was conducted using an ABS script equivalent to the raking, mowing, digging script used in the 2010 OU4 outdoor ABS investigation (see above). A total of 20 properties were selected for evaluation; ten properties to represent yards where a soil removal had been completed and ten properties to represent yards where no soil removal was deemed necessary (based on a property assessment and removal status at the time of the ABS). Two sampling events were conducted at each property, one in the spring and one in the summer of 2011. Detailed results of the OU7 outdoor ABS investigation are summarized in Tetra Tech (2013).

6.1.2.2 Gardens and Flowerbeds

There have been two outdoor ABS investigations conducted in OU4 gardens and flowerbeds and one outdoor ABS investigation in OU7 gardens. Each of these studies is described briefly below.

In 2001, a small-scale outdoor ABS study was performed at one residential property in OU4 to evaluate potential exposures when garden soil was actively disturbed by rototilling. This scenario was chosen both because vermiculite is known to have been added to a number of gardens in Libby, and because rototilling is a realistic and aggressive garden soil-disturbance scenario. A single garden, where previously collected soil samples showed trace levels of LA, was selected for evaluation. Two personal air monitoring samples were collected while rototilling the garden soil – one for the individual performing the rototilling and one for the rototiller assistant. Results of the rototilling ABS are summarized in EPA (2005b).

A larger outdoor ABS investigation of potential exposures during soil disturbances in gardens and flowerbeds OU4 was conducted in the summer of 2010 (CDM Smith 2010b). As part of this investigation, ABS was performed to simulate an adult gardening (i.e., digging in the soil with trowel and hands) to disturb the soil to a depth of 12 inches at six discrete locations distributed across the garden. A total of 20 residential properties were selected for evaluation; ten properties with VV noted in the garden/flowerbed (i.e., a soil removal was deemed necessary but had not yet been performed at the time of the ABS) and ten properties where no VV was observed (i.e., no soil removal was deemed necessary). Three sampling events were conducted at each property in the summer of 2010, with events spaced about one month apart. For each sampling event, a composite soil sample was collected to be representative of the entire garden/flowerbed ABS area. ABS air samples were originally analyzed in 2010; a subset of the samples underwent a supplemental TEM analysis to improve the achieved analytical sensitivity in 2013. Detailed results of the 2010 OU4 garden/flowerbed ABS investigation (including the supplemental analyses) are summarized in CDM Smith (2014a).

For OU7, an outdoor ABS investigation of potential exposures during soil disturbances in gardens was conducted in 2011 (Tetra Tech 2011). As part of this investigation, a composite ABS sample was collected that was representative of an adult gardening (i.e., digging in the soil with trowel and hands) at nine discrete locations distributed across the garden and performing rototilling of the entire garden. A total of 20 residential properties were selected evaluation; ten properties where a garden removal had been completed and ten properties where a garden removal was not deemed necessary (based on a property assessment). Two sampling events were conducted at each property, one in the spring and one in the summer of 2011. For each sampling event, a composite soil sample was collected to be representative of the entire garden. Detailed results of the OU7 garden ABS investigation are summarized in Tetra Tech (2013).

6.1.2.3 Driveways

Two outdoor ABS investigations have been performed to evaluate potential exposures to LA during disturbances of unpaved driveways, one investigation was performed in OU4 in 2010 (CDM Smith 2010b) and one investigation was performed in OU7 in 2012 (Tetra Tech 2011). In both investigations, an (adult) EPA or DEQ contractor simulated a child playing on an unpaved driveway; the playing activities included both digging and biking activities. The child digging activity was conducted with the contractor sitting on the ground while digging or scraping the top surface of the driveway, pushing soil/rock to the side, and then replacing it at six discrete locations evenly distributed across the entire driveway. For the child biking activity, the contractor rode a small non-motorized tricycle with minimal ground clearance across the driveway in straight lines covering the entire area of the driveway (see **Figure 2-2** for an example photograph of this ABS activity).

For the OU4 investigation, a total of 20 residential properties were selected for evaluation; ten properties with VV noted in the driveway (i.e., a soil removal was deemed necessary, but had not yet been performed at the time of the ABS) and ten properties where no VV was observed (i.e., no soil removal was deemed necessary). Three sampling events were conducted at each property in the summer of 2010, with events spaced about one month apart. For each sampling event, a composite soil sample was collected to be representative of the entire driveway. Detailed results of the 2010 OU4 driveway ABS investigation are summarized in CDM Smith (2014a).

For the OU7 investigation, a total of 20 residential properties were selected evaluation; ten properties where a driveway removal had been completed and ten properties where a driveway removal was not deemed necessary (based on a property assessment). Two sampling events were conducted at each property, one in the spring and one in the summer of 2011. For each sampling event, a composite soil sample was collected to be representative of the entire driveway. Detailed results of the OU7 driveway ABS investigation are summarized in Tetra Tech (2013).

6.1.2.4 Limited-Use Areas

As described above, most outdoor ABS efforts conducted at properties in OU4 and OU7 have focused on common-use areas (CUAs), such as the yard, and specific-use areas (SUAs), such as gardens, flowerbeds, and driveways. However, outdoor ABS studies have also been conducted in portions of the property that are used on a more limited basis (i.e., LUAs). In the summer of 2011, an outdoor ABS investigation was performed in OU4 to evaluate potential exposures to LA during soil disturbances in LUAs (CDM Smith 2012b).

Several types of soil-disturbance activities could be performed in LUAs, such as mowing, haying (i.e., cutting/bailing hay), horseback riding, and ATV riding. For the purposes of the LUA outdoor ABS investigation, ATV riding was selected for evaluation because this exposure scenario is likely to occur on a more frequent basis than other activities, is likely to generate more airborne dust, and is an activity that likely applies to more individuals in the community than other exposure scenarios.

A total of ten LUAs were selected for evaluation from seven residential properties in OU4, spanning a range of LA concentrations in soil (non-detect and trace). A total of three sampling events were performed at each LUA in the summer of 2011. During each sampling event, two EPA contractors rode an ATV across the LUA for one hour (see **Figure 2-2** for an example photograph of this ABS activity). For the first 30 minutes, riders engaged in activities that were representative of riding in a single-file line (i.e., one rider leading, one rider following), with the leader/follower switching positions after 15 minutes. For the last 30 minutes, riders rode separately and covered as much of the LUA as possible. During each sampling event, a soil sample was collected to be representative of the entire LUA.

Detailed results of the OU4 LUA ABS investigation are summarized in CDM Smith (2014b).

6.1.3 Role of Soil Data in Evaluating Risks

There are more than 5,000 residential/commercial properties in OU4 and more than 1,000 residential/commercial properties in OU7. To date, EPA and DEQ have performed outdoor ABS at about 200 properties in OU4 and OU7. Because it is not feasible to evaluate risks by conducting outdoor ABS at every property, it is necessary to use the measured ABS data from the properties where ABS has been performed to draw risk conclusions about properties where ABS has not been performed. For outdoor ABS associated with disturbances of soil (e.g., residential disturbances of yard soil), this is accomplished by assuming that LA concentrations in ABS air will be similar for locations with similar levels of LA in soil and similar disturbance activities. An inherent assumption of this approach is that the many random variables that influence release of LA from yard soil to air will tend to average out over time, and that it is soil LA concentration alone that is the key determinant of the long-term average concentration in outdoor ABS air.

Soil samples collected at the Site are analyzed for LA using polarized light microscopy (PLM). Prior to analysis, each soil sample is dried and sieved through a ¼-inch screen. Particles retained on the screen (if any) are referred to as the coarse fraction. Particles passing through the screen are referred to as the fine fraction, and this fraction is ground by passing it through a plate grinder. The resulting material is referred to as the fine ground fraction. The coarse fraction (if any) is examined using stereomicroscopy, and any particles of asbestos (as confirmed by PLM) are removed and weighed to provide a mass fraction of the LA content in accordance with Site-specific SOP SRC-LIBBY-01 (referred to as PLM-Grav). Only a limited number of soils collected as part of the outdoor ABS sampling programs had a coarse fraction; and most of these coarse fractions were reported as non-detect for LA when analyzed by PLM-Grav. Because of this, soil results utilized in the risk assessment focus only on the PLM results for the fine ground fraction.

An aliquot of the fine ground fraction is analyzed using the Site-specific visual area estimation PLM method, as detailed in SOP SRC-LIBBY-03 (referred to as PLM-VE). PLM-VE is a semi-quantitative method that utilizes Site-specific LA reference materials to allow assignment of fine ground samples into one of four concentration "bins", as follows:

- *Bin A (ND):* non-detect
- *Bin B1 (Trace):* detected at levels lower than the 0.2% (by mass) LA reference material
- *Bin B2 (<1%):* detected at levels lower than the 1% (by mass) LA reference material but greater than or equal to the 0.2% LA reference material
- *Bin C:* LA detected at levels greater than or equal to the 1% LA reference material; estimated soil concentrations are reported to the nearest whole percent

As noted above, for the 2007-2008 yard ABS investigation (see Section 6.1.2.1), a subset of the collected soil samples were subsequently reanalyzed by PLM-VE by a different analytical laboratory (CDM Smith 2013c, d). The higher of the two reported laboratory results is used to represent the LA soil concentration for these samples. In addition, as part of the general quality control (QC) program for the Site, some soil samples are randomly selected for reanalysis (e.g., preparation duplicates, laboratory duplicates, inter-laboratory analyses). In cases where multiple analyses are available for a soil sample, the highest result is used to represent the soil concentration.

6.1.4 Calculation of EPCs

6.1.4.1 Yards

6.1.4.1.1 Accounting for Differences in Yard ABS Script Intensity

The outdoor ABS studies conducted for OU4 yards have utilized ABS scripts with varying intensities of soil disturbance. The 2007-2008 OU4 outdoor ABS investigation (see Section 6.1.2.1) utilized ABS scripts that are ranked as "high intensity" scripts. Under the "high intensity" yard script, mowing, raking, and digging disturbance activities were performed on a sub-area of the yard for approximately two hours per activity (i.e., two hours raking, two hours mowing, two hours digging). Often, this resulted in the sub-area being mowed/raked multiple times over the course of the sampling activity duration. As a result, grass was typically worn down and bare patches of soil were often observed by the end of the sampling period, which may have resulted in elevated LA releases during sampling.

The 2010 and 2011 OU4 outdoor ABS investigations and the OU7 outdoor ABS investigation (see Section 6.1.2.1) mainly[10] utilized ABS scripts that are ranked as "typical intensity" scripts. Under the "typical intensity" yard script, ABS was conducted on a yard-wide basis, the sampling duration per disturbance scenario was reduced (i.e., 20 minutes versus two hours per scenario), and the mowing/raking activities were more representative of expected behaviors (i.e., one pass over the yard), thus reducing the amount of localized stress in one area.

Because it is expected that individuals at a property may disturb soil under different intensities over time, use of only the high intensity ABS results, may tend to bias long-term exposure estimates high. Likewise, use of only the typical intensity ABS results, may tend to bias long-term exposure estimates low. Thus, to account for differences in disturbance intensity in long-term exposure estimates, the risk calculations utilized both types of ABS results, but weighted exposures based on the script intensity as follows:

$$\text{Risk} = (EPC_{high} \cdot TWF_{high} \cdot IUR_{LA}) + (EPC_{typical} \cdot TWF_{typical} \cdot IUR_{LA})$$

$$\text{HQ} = (EPC_{high} \cdot TWF_{high} \,/\, RfC_{LA}) + (EPC_{typical} \cdot TWF_{typical} \,/\, RfC_{LA})$$

where:

EPC_{high} = Exposure point concentration, outdoor ABS during yard disturbances under high intensity ABS script (PCME LA s/cc)

$EPC_{typical}$ = Exposure point concentration, outdoor ABS during yard disturbances under typical intensity ABS script (PCME LA s/cc)

TWF_{high} = Time-weighting factor for yard soil disturbances under high intensity disturbance activities (unitless)

$TWF_{typical}$ = Time-weighting factor for yard soil disturbances under typical intensity disturbance activities (unitless)

[10] Scenario 1 of the 2011 outdoor ABS program included sample collection during both "high intensity" and "typical intensity".

For the purposes of this risk assessment, it was assumed that 5% of the total yard disturbance time is spent performing high intensity disturbance activities:

$$TWF_{high} = TWF_{total} \cdot 0.05$$

$$TWF_{typical} = TWF_{total} \cdot 0.95$$

The uncertainty assessment (see Section 10.1.6) provides additional information on how risk estimates would change if the time spent performing high intensity disturbance activities were higher than assumed.

6.1.4.1.2 Accounting for Differences in Yard ABS Activities

ABS scripts for the evaluation of yard soil disturbances have typically included three different disturbance activities – raking, mowing, and digging. These three activities are considered realistic examples of soil disturbance activities that may occur in yards. For outdoor exposures during soil disturbance activities, the EPC was calculated as the average ABS air concentration, combining across activities (mowing, raking, digging) and across time (spring and summer). This is because the goal is to estimate the long-term average concentrations over many years of various types of outdoor yard soil disturbance activities.

6.1.4.1.3 Stratification by Soil Concentration

As noted above, because it is not feasible to perform outdoor ABS at every property, it is necessary to use data on LA in soil to extrapolate to properties without ABS. In this regard, EPCs were calculated by grouping the outdoor ABS air samples using the co-located yard soil LA concentration, as determined based on the results of the PLM-VE analysis.

Table 6-2 (Panel A) presents the calculated EPCs associated with disturbances of yard soil at properties in OU4 and OU7. As seen, the majority of outdoor ABS air samples during yard soil disturbances have been collected from properties where the soil concentration is Bin A or Bin B1. Although the 2010 ABS program sought to identify and evaluate properties with higher soil concentrations, because soil removal efforts have targeted properties with higher soil concentrations, there are limited or no data for Bin B2 and Bin C soil concentrations under the typical intensity ABS script. Therefore, for the purposes of the risk assessment, these two soil concentration bins were combined (Bin B2/C).

6.1.4.2 Gardens

For gardens, two different types of soil disturbance activities have been performed – an aggressive ABS scenario (rototilling) and a more typical activity scenario (digging with a trowel or shovel). Because potential LA releases are likely to be much higher during rototilling, and because rototilling is an activity that is likely to occur less frequently than typical gardening activities, when possible, EPCs for these two garden ABS scenarios were calculated separately.

Because it is necessary to extrapolate the garden ABS results to properties without ABS, EPCs were calculated by grouping the outdoor ABS air samples using the co-located garden soil LA concentration. The same soil concentration categories described for yards (see Section 6.1.4.1.3) are used for gardens. **Table 6-2** (Panel B) presents the calculated EPCs associated with disturbances of garden soil at properties in OU4 and OU7.

6.1.4.3 Driveways and Limited-Use Areas

For driveways and LUAs, the ABS scripts did not differ from investigation to investigation; thus, there was no need to stratify EPCs by script activity or intensity. However, it was necessary to calculate EPCs separately for each LA soil concentration bin to extrapolate ABS results to properties where ABS activities have not been performed. The same soil concentration categories described for yards (see Section 6.1.3.1.3) were used for driveways and LUAs. **Table 6-2** presents the calculated EPCs associated with disturbances of driveway soil (Panel C) and LUA soil (Panel D) at properties in OU4 and OU7.

6.1.5 Risk Estimates

6.1.5.1 Yards

Table 6-3 presents estimated cancer risks and non-cancer HQs from exposures to LA during soil disturbances at residential and commercial properties in OU4 and OU7. **Table 6-3a** presents risks for residential exposures and **Table 6-3b** presents risks for outdoor worker exposures. For both tables, Panel A presents risks based on RME and Panel B presents risks based on CTE.

<u>OU4</u>

For residential exposures (**Table 6-3a**) to LA during yard soil disturbances in OU4, although estimated RME cancer risks are less than or equal to 1E-04 for all soil concentration categories, RME non-cancer HQs are greater than 1 when LA is detected in yard soils (i.e., both for Bin B1 and Bin B2/C soil concentrations). High intensity and typical intensity disturbances each account for approximately half of the total HQ. The RME HQ is 0.1 based on Bin A soil concentrations (non-detect for LA). Estimated CTE cancer risks are less than 1E-05 and non-cancer HQs are less than 1 for all soil concentration categories.

For outdoor worker exposures (**Table 6-3b**) to LA during yard soil disturbances in OU4, RME and CTE cancer risks are less than or equal to 1E-04, but RME non-cancer HQs are greater than 1 when LA is detected in yard soils. The CTE HQ is also greater than 1 for Bin B2/C soil concentrations. The estimated RME and CTE non-cancer HQs are less than 1 based on Bin A soil concentrations.

It is important to note that an HQ greater than 1 does not necessarily mean that adverse non-cancer effects will occur. As noted previously, there is a margin of safety built into the RfC through the application of an UF (EPA 2014d). However, the probability of an adverse effect tends increase as the HQ increases. The contribution of OU4 yard soil disturbance exposure scenarios to cumulative risk is discussed in Section 9.

<u>OU7</u>

For OU7, estimated RME and CTE cancer risks are less than 1E-06 and non-cancer HQs are less than 0.1 for exposures to LA during yard soil disturbances for both receptors. However, the OU7 ABS data have two important limitations. First, the ABS activities performed are only representative of typical intensity disturbances, no data were collected under high intensity disturbances. As shown for OU4, high intensity disturbances account for approximately half of the total HQ. Thus, OU7 risk estimates are likely biased low. Second, nearly all of the ABS data were collected in yards where no LA was detected (Bin A); only one ABS air sample was collected from a yard with Bin B1 (trace) soil concentrations and no samples were collected in yards with Bin B2/C soil concentrations (see **Table 6-2**). Therefore, these data may not be representative of potential exposures when LA is detected in yard soil. In this regard, the risk estimates from OU4 can be used to infer potential risks for properties in OU7.

6.1.5.2 Gardens, Driveways, Limited-Use Areas

For residential exposures (**Table 6-3a**), estimated RME and CTE cancer risks are less than or equal to 1E-05 and non-cancer HQs are less than 1 during soil disturbances in gardens, driveways, and LUAs for all soil concentration categories. For outdoor worker exposures (**Table 6-3b**), with the exception of the garden rototilling scenario, estimated RME and CTE cancer risks are less than 1E-06 and non-cancer HQs are less than 0.1 for all soil concentration categories. Outdoor worker exposures while rototilling in gardens with trace (Bin B1) concentrations of LA resulted in an estimated RME non-cancer HQ of 4; both the RME and CTE cancer risks are less than 1E-04 and CTE HQ is less than 1. The contribution of garden, driveway, and LUA soil disturbance exposure scenarios to cumulative risk is discussed in Section 9.

The majority of ABS air samples collected from gardens, driveways, and LUAs are representative of soil concentrations with lower levels of LA (Bin A or Bin B1). It is expected that exposures and risks would be higher when soil concentrations are Bin B2/C, but the available data are too limited to provide reliable information on the magnitude of the potential increase in exposure.

6.1.6 Extrapolation to Properties Without ABS

6.1.6.1 Determining Exposure Area-wide Risk Estimates

In interpreting these risk estimates, it is important to understand that these calculations are intended to represent a given LA soil concentration. However, a specified exposure area for a property may have varying LA soil concentrations, ranging from Bin A to Bin C by PLM-VE, with differing spatial extents. As discussed in Section 2.3.3, the evaluation of risk is based on the average exposure across the entire exposure area. Thus, for exposure areas that encompass varying LA soil concentrations, it is necessary to derive a spatially-weighted average risk estimate for the entire exposure area. **Figure 6-1** presents a simplified example of this approach. As shown in this example, soil concentration information is available from three subareas within the exposure area (Panel A). These soil concentration data are translated into a corresponding non-cancer HQ value (based on the OU4 yard soil residential RME HQ estimates presented in **Table 6-3a**) – i.e., the Bin A soil concentration is assigned an HQ value of 0.1, the Bin B1 soil concentration is assigned an HQ value of 2, and the Bin C concentration is assigned an HQ value of 7 (Panel B). Therefore, in this example, exposure area-wide average HQ is calculated by weighting each area appropriately (based on its spatial contribution to the total exposure area), yielding an exposure area-wide HQ of 2 (Panel C). This same approach can be used to derive exposure area-wide estimates of cancer risk.

6.1.6.2 Overview of Soil Concentrations Remaining at Properties

Since 2000, EPA has completed exterior soil removals at more than 1,600 properties in OU4 and 40 properties in OU7 as part of the emergency response removals. Soil removal efforts have sought to address "worst first", meaning that properties with the highest levels of contamination were prioritized first for removal. The "triggers" that have been used to determine the need for soil removal differ by use area (i.e., triggers for yards differ from the triggers for gardens) and have changed over time. A summary of the soil removal triggers is provided in the *Libby Asbestos Site Residential/Commercial Cleanup Action Level and Clearance Criteria Technical Memorandum* (EPA 2003a) and two subsequent memorandum amendments (*Amendment A* – CDM Smith 2011c; *Amendment B* – CDM Smith 2014c).

In general, at the time of this risk assessment, properties in OU4 and OU7 can be classified into four basic categories:

1. Properties where soil removals have already been completed.

2. Properties where soil removal has not been deemed necessary based on an evaluation of property-specific conditions relative to the current soil removal triggers.

3. Properties where soil removal is deemed necessary, but has not been performed (this includes properties that are currently in the removal queue and properties where the owner has refused or deferred removal efforts).

4. Properties where no soil information is available (e.g., owner has refused property access and no evaluation of property-specific conditions has been performed).

Prior to 2014, the primary soil removal triggers were the presence of VV in SUAs, such as gardens, flowerbeds, and driveways, and/or LA levels ≥1% (Bin C) in CUAs, such as yards. Once EPA removal contractors were at a property, soil removal efforts would consist of excavating all soils in these areas with detected LA (i.e., Bin B1, Bin B2, and Bin C conditions would be removed and replaced with topsoil fill materials) up to a depth of about 12-18 inches.

Table 6-4 summarizes the expected surface soil concentrations at properties in OU4 and OU7 where soil removals have and have not been completed. As shown, for properties where a soil removal has been completed (Category #1), surface soils that remain "post-removal" should be[11] a mixture of Bin A (non-detect for LA) and topsoil fill materials (which are also non-detect for LA). As shown in **Table 6-3**, LA exposures due to disturbances of Bin A soils in yards, gardens, flowerbeds, and driveways yield estimated RME cancer risks less than 1E-04 and non-cancer HQs less than 1.

For properties where no soil removal had been deemed necessary prior to 2014 (Category #2), soil concentrations could be as high as Bin B2 across the total exposure area (Bin C concentrations would have triggered a soil removal). As discussed above, properties where yard soil concentrations are Bin B1 or Bin B2 have the potential to result in RME non-cancer HQs greater than 1 (see **Table 6-3**), depending upon their spatial extent. Therefore, there may be properties in OU4 and OU7 where soil removal actions have not yet been completed that have the potential to result in elevated LA exposures if soils are disturbed. Beginning in 2014, the soil removal triggers were modified to conduct soil removals at properties with Bin B1 (depending upon their spatial extent) and Bin B2 (regardless of spatial extent) soil concentrations. Specifics on these modified soil triggers are presented in *Amendment B* (CDM Smith 2014c). Bin B1 (trace) surface soils are allowed to remain in place in SUAs and CUAs, provided that their spatial extent is less than 25% of the total exposure area. This decision was based on the finding that, if 75% or more of the total exposures area is Bin A and the remainder is Bin B1, the estimated area-wide RME non-cancer HQ (see Section 6.1.6.1) will be about 0.6.

For properties where soil removal is deemed necessary, but has not been performed (Category #3), the potential exposures and risks from soil disturbance activities will depend upon the nature and extent of the LA concentrations in soil present at the property. However, it is possible that Bin C concentrations may be present. As illustrated in **Figure 6-1**, properties where yard soil concentrations

[11] On occasion, subsequent soil sampling efforts at "post-removal" properties have identified LA detections.

are Bin C have the potential to result in area-wide RME non-cancer HQs greater than 1, even if their spatial extent is small.

For properties where no soil information is available (Category #4), potential exposures and risks from soil disturbance activities cannot be determined.

6.1.6.3 Uncertainties in Extrapolating Using Soil Data

There are several challenges in extrapolating ABS results to properties without ABS using soil data, especially when using historical soil data.

First, soil sampling methodologies have changed over time. As noted above, most of the soil samples collected as part of outdoor ABS investigations are 30-point composite samples, which encompass the extent of the ABS area. Prior to 2007, soil samples collected at the Site were usually collected as five-point composite samples. Thus, there is expected to be more variability in these historical soil samples relative to the 30-point composites. In addition, the number of soil samples collected at each property varied, depending upon the types of use areas identified (e.g., yards, driveways) and the size of the use area, and sampling efforts tended to focus on more frequently used areas. Any extrapolation of ABS results based on historical soil samples should consider these data limitations.

Second, unlike traditional chemistry methods, where analytical results are based on the output of a laboratory instrument, the PLM-VE method is inherently subjective. In this method, the PLM analyst utilizes visual estimation techniques (e.g., standard area projections, photographs, drawings, or trained experience) to estimate the asbestos content of the soil. Results are reported semi-quantitatively for levels below 1%, based on visual comparisons to LA-specific reference materials. Results of inter-laboratory assessments for the PLM-VE method show that there are differences between the analytical laboratories in results reporting (CB&I Federal Services, LLC [CB&I] 2012, 2014; CDM Smith 2012c, 2014d). In particular, EPA's Environmental Services Assistance Team, Region 8 (ESATR8) laboratory has demonstrated proficiency in detecting the presence of "trace" levels of LA (Bin B1) in soil compared to other (non-ESATR8) PLM laboratories (CDM Smith 2014d). Because the majority of the soil samples that were used to group the ABS air data into soil concentration categories were analyzed by the ESATR8 laboratory, it may not be appropriate to extrapolate ABS results based on soil concentrations estimated by non-ESATR8 laboratories.

In summary, extrapolation of outdoor ABS data to properties without ABS using soil data is most appropriate when the soil samples have been collected using a 30-point composite sampling methodology and when PLM-VE results are based on analyses performed by the ESATR8 laboratory. Uncertainties associated with between-laboratory variability and changes in soil sampling methodology are discussed further in Sections 10.1.4 and 10.1.5, respectively.

6.1.7 Risks from Contaminated Subsurface Soil

As noted above, during soil removal efforts conducted at properties in OU4 and OU7, soils with detected LA are removed and replaced with topsoil fill materials. However, at some properties, contamination was still present at the maximum soil removal excavation depth[12]. In the event that digging occurs in areas where subsurface soil contamination was left in place at depths greater than the extent of the topsoil fill material, such as a resident digging a deep hole to plant a tree or an outdoor worker digging a new sewer line, it is possible that individuals may be exposed to LA-

[12] In cases where 1% or greater was left behind, the excavation depth was increased to 36 inches (i.e., there should be about 3 feet of topsoil fill material covering the subsurface contamination).

contaminated subsurface soils. It is expected that these exposures would occur less frequently than exposures to surface soils, but may have the potential to result in higher exposures because the subsurface materials being disturbed could have higher LA concentrations.

Table 6-1 (Panel B) presents the selected RME and CTE exposure parameters values and calculated TWFs for disturbances of subsurface soils at OU4/OU7 properties. For the resident, it is assumed that all subsurface soil exposures occur at their residence. However, for the outdoor worker it is likely that they may be exposed to subsurface soils across multiple residential/commercial properties with varying levels of subsurface contamination. For the purposes of these risk calculations, it is assumed that 65% of their subsurface soil exposure is to Bin A (non-detect) concentrations, 15% of their subsurface exposure is to Bin B1 (trace) concentrations, and 20% of their subsurface exposure is to Bin B2/C concentrations. This is based on the observation that, of the more than 1,600 properties in OU4 where an outdoor soil removal effort has been completed, the confirmation soil samples (taken from the bottom of the excavation area) showed about 65% were non-detect for LA, about 34% had LA concentrations reported as <1%[13] at the bottom of the excavation area, and less than 2% had LA concentrations of 1% or greater at the bottom of the excavation area (EPA 2014a).

There are no ABS air data that are specific to subsurface soil disturbance scenarios in OU4/OU7. However, a subset of the ABS air samples from the yard soil disturbance activities (see Section 6.1.2.1) included a digging disturbance scenario (simulating a child playing in an area of bare dirt). While it is expected that this type of digging scenario is likely to be biased high, as it is representative of a high intensity disturbance condition, it is used in these calculations to provide screening level risk estimates for potential exposures from disturbances of subsurface soil for each soil concentration category (i.e., Bin A, Bin B1, Bin B2/C).

Table 6-5 presents estimated cancer risks and non-cancer HQs from exposures to LA during subsurface soil disturbances at residential and commercial properties in OU4 and OU7. Panel A presents risks based on RME and Panel B presents risks based on CTE. As shown, when this exposure scenario is considered alone, estimated RME cancer risks are less than 1E-04 and non-cancer HQs are less than or equal to 1 during subsurface soil disturbances for all soil concentration categories for residents. However, for the outdoor worker, RME cancer risks approach 1E-04 and non-cancer HQs are greater than 1, primarily due to digging in areas where concentrations are Bin B2/C. These results show that this exposure scenario alone has the potential to approach or exceed EPA's acceptable risk limits. However, it is important to recall that these are screening level estimates that have the potential to be biased high. The contribution of subsurface soil disturbance exposure scenarios to cumulative risk is discussed in Section 9.

Note that these subsurface soil risk estimates apply only to exposures during the digging activity itself. If contaminated subsurface soils that are unearthed during these digging activities are not managed properly and surface soils become re-contaminated as a result, it is possible that unacceptable exposures and risks could result, depending upon the type of subsurface contamination encountered and the spatial extent that it is spread at the surface (see **Table 6-3**).

[13] Confirmation soil samples are analyzed by PLM using NIOSH 9002, which does not stratify concentrations below 1% into Bin B1 or Bin B2, simply reporting results as "<1%". It is assumed that half of all results reported by NIOSH 9002 as <1% would have been ranked as Bin B1 and half as Bin B2.

6.2 Schools and Parks in OU4 and OU7

6.2.1 Exposure Populations and Parameters

For schools, the receptor populations of interest for evaluating exposures during soil disturbances include students and outdoor maintenance workers. Because the student population differs by the type of school (i.e., younger children attend elementary school, older children attend high school), student exposure parameters were determined separately by school. Because different worker maintenance activities are likely performed at different frequencies for different schools, exposures were evaluated separately by school for mowing/edging school lawns, power-sweeping sidewalks, and general maintenance activities on school grounds (e.g., digging and raking).

For parks, the primary receptor population of interest is recreational visitors. The type of recreational visitor evaluated (children, adults) depends upon the anticipated park use. For example, playgrounds were assumed to be used primarily by younger children, whereas the ball fields and golf courses were assumed to be primarily used by older children and adults. For golf courses, exposures were also evaluated for outdoor workers that perform course maintenance activities, such as mowing, aerating turf, and raking bunkers.

Table 6-6 presents the selected exposure parameters values and calculated TWFs for disturbances of soils at schools and parks in OU4 and OU7. For OU4 schools, the exposure parameters are based on information provided by school administrators. Because the basis (RME/CTE) of the exposure parameters provided by school administrators was not specified and because there is not likely to be substantial variability in the student exposures for a given school, only one set of exposure parameters were determined (i.e., RME and CTE values were not selected).

In reviewing these exposure parameters, it is acknowledged that several of the exposure durations are less than 10 years (e.g., childhood exposures at daycare, high school sporting activities). Typically, these types of shorter exposure duration scenarios are not evaluated individually because the exposure duration is less than the basis of the toxicity values, which are intended to apply to a lifetime exposure scenario. However, this risk assessment calculates exposure and risk for all exposure scenarios, regardless of exposure duration, to demonstrate the pathway-specific contribution to lifetime exposures to inform decision-making.

6.2.2 Investigation Summary

In June and July 2005, outdoor ABS samples were collected at the Cabinet View Country Club Golf Course while course workers performed various maintenance activities (e.g., mowing, aeration, raking bunkers) on the course fairways, greens, and tees. A total of seven personal air monitoring samples were collected. Detailed results from the outdoor ABS at the golf course are presented in EPA (2007a).

In June 2008, outdoor ABS was performed at each of five school buildings in Libby (EPA 2009g). Outdoor activity scenarios for students and maintenance staff were selected based on interviews with school administrators. For students, this included playing sports (e.g., soccer, baseball) in designated sports areas, playing on playground equipment (e.g., swing sets), and walking/running over various ground materials (i.e., grass, sand). For outdoor maintenance workers, this included digging and raking on school grounds, manual sweeping of blacktop play areas and sidewalks, power sweeping parking lots, and mowing and edging school lawns (see **Figure 2-2** for example photographs of these ABS activities). At each school, the administrators identified outdoor areas that were most commonly used by students or maintenance staff for typical outdoor behaviors. In general, one to three distinct areas used for play or sports activities were selected at each school for conducting student scenarios, while maintenance worker scenarios took place across the school grounds. The power sweeping scenario was performed in the parking lots at two schools (Libby Administration Building and Libby High School). Detailed results from the outdoor ABS at the OU4 schools are presented in (EPA 2010e). A subset of the outdoor ABS air samples underwent a supplemental TEM analysis to improve the achieved analytical sensitivity in 2010; these supplemental analyses were included in EPC calculations.

In 2011, DEQ conducted outdoor ABS to evaluate potential exposures during soil disturbance activities at playgrounds and ball fields at parks and schools in Troy (Tetra Tech 2011). At Morrison Elementary School and the Roosevelt Park playground, the types of ABS activities evaluated included playing on playground equipment, such as swing sets, merry-go-rounds, jungle-gyms, and see-saws, and digging in sand boxes. At the Roosevelt Park ball fields and the Timber Beast Disk Golf Course, ABS activities included playing baseball, football, soccer, and/or Frisbee® golf. **Figure 2-2** provides example photographs of these ABS activities. Two sampling events were conducted at each school/park, one in the spring and one in the summer of 2011. Detailed results from the outdoor ABS schools and parks in OU7 are presented in Tetra Tech (2013).

6.2.3 Calculation of EPCs

Table 6-7 presents summary statistics of the measured outdoor ABS air concentrations for each type of soil disturbance activity for each school, park, and golf course in OU4 and OU7. Because potential exposure durations and conditions differ by location, EPCs were calculated separately by location. A cumulative evaluation of potential exposures across multiple schools (e.g., exposure for a receptor that attends Libby schools beginning in elementary school through high school), is presented in Section 9.

6.2.4 Risk Estimates

Table 6-8 presents estimated cancer risks and non-cancer HQs from exposures to LA during soil disturbances at each school, park, and golf course in OU4 and OU7. These results indicate that, when these exposure scenarios are considered alone, estimated cancer risks are less than 1E-05 and non-cancer HQs are less than or equal to 0.1 for all exposure scenarios. The contribution of these exposure scenarios to cumulative risk is discussed in Section 9.

6.3 Trails/Bike Paths in OU4 and OU7

6.3.1 Exposure Populations and Parameters

Recreational visitors are the receptor population of interest for the purposes of evaluating potential exposures to LA while riding bicycles on trails, bike paths, and along roads in OU4 and OU7. Two scenarios were evaluated: riding a bike (assumed to be older children and adults) and riding in a trailer attached to a bike (young children). Because exposure concentrations could differ between riders and children in bicycle trailers, exposures were determined separately for each scenario.

Table 6-9 presents the selected RME and CTE exposure parameter values and calculated TWFs for disturbances of soils while bicycling in OU4 and OU7.

6.3.2 Investigation Summary

Two different ABS investigations have been conducted at the Site to evaluate potential exposures while riding bicycles on trails, bike paths, and along roads. In the summer of 2010, an investigation was performed by EPA to evaluate exposures in OU4 (CDM Smith 2010b). In the summer of 2011, an analogous investigation was performed by DEQ to evaluate exposures in OU7 (Tetra Tech 2011).

For both investigations, the biking activity was conducted with two EPA or DEQ contractors riding non-motorized, two-wheeled bicycles equipped for use on non-paved roads. In addition, a bicycle trailer, built to transport a 50-pound child, was affixed to the back of one (OU4) or both (OU7) of the bicycles for the entire event and an air monitor was mounted inside the trailer. Two types of ABS air samples were collected as part of this scenario – adult rider samples and trailer samples. The two riders traveled in single file along the path (which included both paved and unpaved trails, roads, and alleys), with the riders alternating positions (leading and trailing) throughout the sampling event, and the trailing riders trying to ride in the dust cloud of the rider in front (as much as was safe and practical) (see **Figure 2-2** for an example photograph of this ABS activity). During these events, the bicycle riders varied their speed between 3 and 15 miles per hour (mph), with a target average speed of 8 mph, adjusted as appropriate to meet path conditions.

For OU4, because it is expected that some riders will tend to favor the use of trails/paths in smaller subareas of Libby rather than riding at random across the entire city, the ABS investigation was conducted in three different sectors (see **Figure 6-2**). A total of ten one-hour sampling events were conducted in each of the three sectors. ABS air samples were originally analyzed in 2010; a subset of the samples underwent a supplemental TEM analysis to improve the achieved analytical sensitivity in 2013. Detailed results of the OU4 bicycling ABS investigation (including the supplemental analyses) are summarized in CDM Smith (2014a).

For OU7, a total of ten one-hour sampling events were conducted, with each sampling event performed across the entire town of Troy (see **Figure 6-3**). Results of the OU7 bicycling ABS investigation are summarized in Tetra Tech (2013).

6.3.3 Calculation of EPCs

Table 6-10 (Panel A) presents summary statistics for outdoor ABS air associated with disturbances of soil while riding bicycles in OU4 (stratified by sector) and OU7. As seen, all ABS air samples collected in OU4 were non-detect regardless of sector; therefore, risk estimates were not calculated separately by sector for OU4. Because the bicycle riding ABS scenarios were conducted in such a way that they are representative of the frequently used bike paths and trails in OU4 and OU7, there was no need to extrapolate ABS air results to un-sampled locations using soil data. Thus, it was not necessary to calculate EPCs stratified by soil concentration. However, because path conditions could differ between OU4 and OU7, EPCs were calculated separately for OU4 and OU7. EPCs were also calculated separately for each exposure location (i.e., rider and trailer).

6.3.4 Risk Estimates

Table 6-10 presents estimated cancer risks and non-cancer HQs from exposures to LA while bicycling on trails, bike paths, and along roads in OU4 and OU7 based on RME (Panel B) and CTE (Panel C). These results indicate that, when these exposure scenarios are considered alone, estimated RME and CTE risks are less than 1E-06 and non-cancer HQs are much less than 0.1 for all bicycling exposure scenarios. The contribution of these exposure scenarios to cumulative risk is discussed in Section 9.

6.4 Exposures in OU1

OU1 includes areas affected by contamination released from the former Export Plant. The former Export Plant is situated on the south side of the Kootenai River, just north of the downtown area of the City of Libby, Montana (see **Figure 1-5**). OU1 covers roughly 17 acres and is divided into three areas (Area 1, Area 2, and Area 3) (see **Figure 6-4**). Area 1, the former Export Plant area, has been converted to a landscaped park with paved access and parking, with the exception of an area used by

David S. Thompson Search and Rescue. Area 2, the former Riverside Park, has been combined with Area 1 to create the Riverfront Park serving a variety of recreational visitors. The main features of the park include two boat ramps, a pavilion with surrounding lawn areas and picnic tables. Area 3, the embankments, consists of undeveloped land owned and maintained by MDT. MDT currently performs only periodic maintenance of these embankments as needed (e.g., application of herbicides, replacement of guardrails, and maintenance of roadside light posts).

Numerous investigations and removal activities have occurred at OU1. Details of investigation and remediation activities conducted at the OU1 are provided in the *OU1 RI* (EPA 2009c), the *OU1 Record of Decision* (ROD) (EPA 2010a), and the *OU1 Remedial Action Report* (CDM Smith 2013e). Remedial actions at OU1 are complete and included removal (excavation and disposal) and containment (with soil covers) of asbestos-containing source materials. There are no areas within OU1 with LA-contaminated soils remaining at the surface. However, because buried residual vermiculite and contaminated subsurface soil remains at OU1, institutional controls (ICs) are in place which restrict subsurface disturbance activities (e.g., construction activities that involve soil excavation or earthwork) to mitigate potential future exposures from contamination left at depth.

6.4.1 Exposure Population and Parameters

There are two potential receptor populations that may be exposed to LA during soil disturbance activities at Riverfront Park in OU1 – recreational visitors and outdoor workers (park maintenance worker). While search and rescue volunteers/workers may use facilities in OU1, it is assumed that exposures will primarily occur inside the David S. Thompson Search and Rescue building (see Section 7.4 for an evaluation of indoor worker exposures).

Visitors to the park may engage in a variety of activities, such as picnicking in the pavilion and recreating on the lawn areas. Park maintenance workers are responsible for maintaining the lawn areas and landscaping of the Riverfront Park. Different areas of the park require different types of lawn maintenance equipment. Because exposure conditions and exposure duration could differ depending upon the maintenance activity being performed, exposure parameters were determined separately for each of two activities – mowing and weed-trimming.

Table 6-11 presents the selected RME and CTE exposure parameter values and calculated TWFs for disturbances of soils in OU1 by park maintenance workers and recreational visitors.

6.4.2 Investigation Summary

In 2013, outdoor ABS was conducted to determine possible exposures to City workers that maintain the park during disturbances of soil (CDM Smith 2013f). Because the construction of the remedial action at the former Export Plant (OU1) has been completed, the purpose of the 2013 outdoor ABS investigation was to collect data to support a post-construction risk assessment of the effectiveness of the remedy.

As noted above, the ABS activities focused on outdoor worker exposure scenarios because workers are expected to have greater exposure potential than recreational visitors (i.e., the types of activities performed by park maintenance workers would tend to result in more frequent and higher intensity soil disturbances than the types of activities performed by recreational visitors). Two types of outdoor maintenance scenarios were evaluated at the park – mowing and weed trimming. For the mowing ABS scenario, EPA contractors mowed the grass in Riverfront Park using walk-behind mowers[14]. For the lawn edging/weed trimming ABS scenario, EPA contractors operated a weed edger/trimmer (i.e., weed whacker). A total of three sampling events were conducted in the summer of 2013. Detailed results for the OU1 post-construction ABS investigation are presented in the *Post-Construction Human Health Risk Assessment* (CDM Smith 2015c) for OU1.

6.4.3 Calculation of EPCs

Table 6-12 (Panel A) presents summary statistics for outdoor ABS air associated with disturbances of soil at OU1. Because the ABS scenarios were conducted in such a way that they are representative of the full extent of maintained park areas in OU1, there was no need to extrapolate ABS air results to un-sampled locations using soil data. Thus, it was not necessary to calculate EPCs stratified by soil concentration. EPCs were calculated separately for each type of maintenance activity.

The EPC estimated for the mowing scenario was used as a surrogate EPC to evaluate the recreational visitor exposure scenario. As noted above, the mowing scenario is considered a conservative estimate of potential exposures for park visitors who may engage in soil disturbance activities at OU1.

6.4.4 Risk Estimates

Table 6-12 presents estimated cancer risks and non-cancer HQs from exposures to LA during soil disturbance activities in OU1 based on RME (Panel B) and CTE (Panel C). These results indicate that, when these exposure scenarios are considered alone, estimated RME and CTE cancer risks are less than 1E-06 and non-cancer HQs are less than 0.1 for both worker exposure scenarios and the recreational visitor scenario based on post-construction conditions. The contribution of these exposure scenarios to cumulative risk is discussed in Section 9.

However, if future excavation or construction activities occur in areas of OU1 where residual contamination remains at depth, a number of potential exposure scenarios might become complete due to subsurface soil contamination. Disturbances of residual LA contamination in subsurface soils in OU1 have the potential to result in unacceptable exposures and risks.

6.5 Exposures in OU2

OU2 includes areas that were affected by contamination released from the former Grace Screening Plant. Subareas within OU2 include the former Screening Plant (Subarea 1), the Flyway (Subarea 2), a privately-owned property (Subarea 3), and the Rainy Creek Road frontages (Subarea 4) (see **Figure 6-5**). EPA has taken extensive actions to remove the mine-related waste materials and contaminated soils at OU2. Details of investigation and remediation activities conducted at each OU2 subarea are provided in the *OU2 RI* (EPA 2009d), the *OU2 ROD* (EPA 2010b), and the *OU2 Remedial Action Report* (EPA 2012a). Exposure to the contamination was largely mitigated by removal of surface soils and the placement of an extensive cap during removal activities prior to the OU2 ROD, with the exception of two isolated locations within the Flyway (Subarea 2), which were subsequently remediated in 2010. Residual contamination remains at varying depths over a considerable portion of OU2. Because buried residual vermiculite and contaminated subsurface soil remains at OU2, ICs are (or will be) in place

[14] It is recognized that this type of equipment may differ from the commercial riding mowers used by City workers, but due to a lack of available equipment, this alternate mowing scenario was used. Using a walk-behind mower is considered a more conservative soil disturbance activity than a riding mower.

that will protect the remedy and limit soil excavations to mitigate potential future exposures from contamination left at depth.

6.5.1 Exposure Populations and Parameters

In OU2 areas that have been remediated, and where surface soil is either capped or backfilled with clean soil, there are no complete exposure scenarios to LA at present. However, there are several areas within the Flyway where soils have not been remediated. There are two receptor populations that may be exposed to LA during soil disturbance activities in the Flyway – visitors that recreate or trespass (either intentionally or inadvertently) along the Kootenai River and MDT outdoor workers that maintain the ROW along Highway 37.

Table 6-13 presents the selected RME and CTE exposure parameter values and calculated TWFs for disturbances of soils in the Flyway area of OU2.

6.5.2 Investigation Summary

Because the construction of the remedial action at the former Screening Plant (OU2) has been completed, the purpose of the 2012 outdoor ABS investigation was to collect data to support a post-construction risk assessment of the effectiveness of the remedy. Because Subarea 1 (former Screening Plant), Subarea 3, and Subarea 4 (Rainy Creek Road frontages) are all privately-owned, and the owners opted not to participate in post-construction sampling activities, the focus of the post-construction ABS investigation was on Subarea 2 (Flyway) in areas that had not been remediated, and thus have the maximum potential for exposure (i.e., “worst case”).

Two ABS scenarios representative of soil disturbance activities that may take place in the Flyway were evaluated as part of the OU2 outdoor ABS investigation (CDM Smith 2012d). Scenario 1 was conducted to determine possible exposures to MDT workers that mow the ROW on the west side of Highway 37 (**Figure 6-5**). The ROW has approximately 1,500 feet of road frontage. Scenario 2 was conducted to evaluate possible exposures to individuals that recreate (e.g., hike) or otherwise trespass along river frontage in the Flyway adjacent to the Kootenai River (**Figure 6-5**). The river frontage within the Flyway is approximately 2,100 feet.

For the mowing ABS scenario, EPA contractors mowed the grass along the ROW using walk-behind mowers[15]. A total of three mowing ABS events were performed in late August/early September 2012 separated in time by one week.

For the recreational/trespass ABS scenario, two EPA contractors hiked along the river frontage stopping at obvious areas of river access when encountered, switching positions (leading/following) every five minutes as they hiked. A total of three 30-minute hiking ABS events were performed sequentially on the morning of August 21, 2012, with each ABS event taking place along different paths/routes, traversing both above and below the high water mark along the river frontage. Detailed results for the OU2 post-construction ABS investigation are presented in the *Post-Construction Human Health Risk Assessment* (CDM Smith 2015d) for OU2.

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[15] It is recognized that this type of equipment may differ from the commercial riding mowers used by MDT workers, but using a walk-behind mower is considered a more conservative soil disturbance activity than a riding mower due to the greater potential of generating dust in the breathing zone.

6.5.3 Calculation of EPCs

Table 6-14 (Panel A) presents summary statistics for outdoor ABS air associated with disturbances of soil in the Flyway in OU2. Because the ABS scenarios were conducted in such a way that they are representative of the full extent of the potential exposure area, there was no need to extrapolate ABS air results to un-sampled locations using soil data. Thus, it was not necessary to calculate EPCs stratified by soil concentration. However, because exposure conditions could differ by disturbance scenario (mowing versus hiking), EPCs were calculated separately for each type of activity. As seen, all ABS air samples were non-detect.

6.5.4 Risk Estimates

Table 6-14 presents estimated cancer risks and non-cancer HQs from exposures to LA during soil disturbance activities in OU2 based on RME (Panel B) and CTE (Panel C). As shown, because EPCs were zero, the resulting cancer risks and non-cancer HQs are also zero for all exposure scenarios in OU2 based on post-construction conditions. The uncertainty assessment (Section 10) provides additional information on risk estimates for datasets where all samples are non-detect.

However, if future excavation or construction activities occur in areas of OU2 where residual contamination remains at depth, a number of potential exposure scenarios might become complete due to subsurface soil contamination. Disturbances of residual LA contamination in subsurface soils in OU2 have the potential to result in unacceptable exposures and risks.

6.6 Exposures in OU3

OU3 includes the property in and around the former vermiculite mine and the geographic area surrounding the mine that has been impacted by releases and subsequent migration of contaminants from the mine, including several ponds, Rainy Creek, Carney Creek, Fleetwood Creek, and the Kootenai River (see **Figure 1-5**). Rainy Creek Road is also included in OU3. Most of the land in OU3 is forested and characterized by steep and rugged terrain. Much of the land surrounding the mine is managed by the USFS, although some parcels are owned by the State of Montana and are managed by the Department of Natural Resources and Conservation.

6.6.1 Exposure Populations and Parameters

A range of different human receptor populations may be exposed to LA during soil/duff disturbances in OU3, including:

- Trespassers or "rockhounds" in the mined area – This population includes individuals who trespass on Grace's property in the area that has been disturbed by past mining activities.
- Recreational visitors in the forested area – This population includes individuals who engage in activities, such as camping, hiking, dirt bike riding, ATV riding, hunting, etc.
- Recreational visitors along rivers, streams, and ponds – This population includes individuals who hike, fish, wade/swim, or explore site drainages. In the absence of access restrictions, this might include the streams and ponds along Fleetwood Creek, Carney Creek, and Rainy Creek, as well portions of the Kootenai River that may be impacted by site releases.
- USFS firefighters in the forested area – This population includes employees of the USFS who provide ground-based response to forest fires that occur within OU3. Research has shown that

firefighter activities, such as fire line construction, have the potential to result in exposures to LA when these activities are conducted in the forest near the mine (Hart *et al.* 2009).

Note that there are other potential receptor populations of interest for OU3, including local wood harvesters, USFS forest maintenance workers, and commercial loggers; however, because exposures for these populations are primarily associated with disturbances of wood-related materials, these receptor populations are evaluated in Section 8. (Exposures to ground-based USFS firefighters are evaluated in this section, as this type of exposure scenario is mainly associated with soil/duff disturbance activities. Section 8.1.7 provides additional information on potential firefighter exposures to LA during and after fires.)

Table 6-15 presents the selected RME and CTE exposure parameter values and calculated TWFs for disturbances of soil/duff in OU3.

6.6.2 Investigation Summary

Outdoor ABS air samples have been collected at OU3 as part of several sampling investigations to evaluate a variety of soil/duff disturbance scenarios. Two ABS investigations (referred to as the Phase III and Phase IV, Part A studies) were conducted to evaluate potential exposures in the forested area surrounding the mine area and along Rainy Creek. A third ABS investigation was conducted (as part of the Phase V, Part A study) to evaluate potential exposures at one of the sand bars located in the Kootenai River near the confluence with Rainy Creek. In 2014, an ABS investigation was conducted in the forested areas along the NPL boundary to characterize the potential nature and extent of LA contamination in the forest to inform decisions on the OU3 boundary. In addition, in 2015, an ABS investigation was conducted to evaluate potential exposures to mine trespassers.

Unless noted otherwise below, a comprehensive summary of the study design and results for all investigations conducted in OU3 is provided in the *OU3 Data Summary Report* (CDM Smith 2015a). Each of these outdoor ABS investigations is described briefly below.

6.6.2.1 Phase III (2009)

The Phase III sampling program for OU3 (EPA 2009h) focused on the collection of ABS data to evaluate LA exposures to recreational visitors in the forested area while riding an ATV in the forest, walking or hiking in the forest, gathering firewood, clearing a fire pit area, and building/burning a campfire.

A total of 11 ABS areas were selected for evaluation (see **Figure 6-6**). These areas tended to be predominately in the downwind direction (north-northeast of the mine), and were selected based primarily on a consideration of the large-scale spatial variability of measured LA levels in forest soil, duff, and tree bark. For each ABS area, two Grace contractors performed the scripted recreational ABS activities. During the ATV riding scenario, riders rode in a single-file line (i.e., one rider leading, one rider following), with the leader/follower switching positions after half of the sampling time had elapsed. One set of ABS samples was submitted for analysis, the other set was archived. ABS events were conducted at each ABS area approximately every 10 days, starting at the end of August through the beginning of November 2009. **Figure 6-6** illustrates the actual locations where ABS activities were performed during each sampling event; ATV riding routes are shown in red, walking/hiking routes are shown in orange, and wood gathering/fire pit activities are shown in blue.

6.6.2.2 Phase IV, Part A (2010)

The Phase IV, Part A sampling program for OU3 (EPA 2010f) included the collection of ABS data to evaluate LA exposures to individuals driving on roads in OU3, recreational visitors hiking along Rainy Creek near the mine, and USFS firefighters while cutting fire lines in the forested area in OU3. The Phase IV, Part A sampling program also included several ABS activities related to residential wood harvesting and USFS workers; however, these data are evaluated in Section 8 as these exposures are mainly associated with wood-related disturbances. The ABS scripts for each exposure scenario related to soil/duff disturbances are described below.

Hiking. This ABS activity evaluated recreational visitor exposures while hiking along lower Rainy Creek between Highway 37 and the Grace property line (see the “ABS-LRC Study Area” in **Figure 6-7**). During each sampling event, two Grace contractors walked up and down the banks of the creek for approximately one mile (round trip), disturbing bushes and other vegetation as needed to advance along the creek. Personnel switched positions (leader/follower) after half of the sampling time had elapsed (i.e., after 30 minutes). A total of five sampling events were conducted in August 2010.

Driving. This ABS activity evaluated potential exposures to individuals while driving on roads in OU3. During each sampling event, two Grace contractors (one driver, one passenger) rode in a pickup truck with the windows open along both Rainy Creek Road and unpaved service roads to three designated wood harvesting areas in the forest within OU3 (ABS-02, ABS-07, and ABS-06’[16]; see large red dots in **Figure 6-7**). A total of five sampling events were conducted in each ABS area between July and August 2010.

Firefighting. This ABS activity simulated exposures to USFS firefighters while cutting fire lines in the forested area near OU3. The script included two types of activities – a) cutting fire lines by hand using a Pulaski tool (see blue dots in **Figure 6-7**), and b) cutting fire lines using heavy equipment (e.g., a bulldozer or tractor plow) (see black dots in **Figure 6-7**). During each sampling event, two Grace contractors performed the scripted activities in each of three ABS areas in the forest within OU3 (ABS-02, ABS-07, and ABS-06’[16]; see **Figure 6-7**). A total of five sampling events were conducted in each ABS area between July and August 2010.

6.6.2.3 Phase V, Part A (2012)

The Phase V, Part A sampling program for OU3 (CDM Smith 2012e) focused on the collection of ABS data to evaluate exposures to LA by recreational visitors along the Kootenai River. The ABS was conducted on a sand bar in the Kootenai River immediately downstream of Rainy Creek. The ABS script was designed to simulate activities that are representative of actions that might be performed by local river guides and recreational visitors on the sand bar. The script was performed by two Grace contractors and included landing a boat on the sand bar, walking around and simulating an individual fishing along the edges of the sand bar, and departing by boat. ABS air samples were collected on the sandbar on the afternoon of September 19, 2012, during low-flow conditions within the Kootenai River.

6.6.2.4 Nature & Extent in the Forest (2014)

As noted above, an ABS investigation was conducted in the forested areas along the NPL boundary in 2014 to characterize the nature and extent of LA contamination in the forest to inform decisions on

[16] Although the Phase IV, Part A study design was to perform ABS activities in area ABS-10, the location of the activities was modified at the time of collection to be located about 1 mile further downwind, closer to the Phase III ABS-06 area. Thus, to avoid potential confusion, the location of this area is referred to as ABS-06’.

the OU3 boundary (CDM Smith 2014e). This ABS investigation simulated exposures to USFS firefighters while cutting fire lines by hand using a Pulaski tool. During each sampling event, two ABS personnel (EPA contractors) performed the scripted activities in each of ten ABS areas in the forested areas along the NPL boundary (see **Figure 6-8**). A total of three sampling events were conducted in each ABS area in September 2014. Results of the *2014 Nature and Extent ABS* study in the forest are summarized in CDM Smith (2014f).

6.6.2.5 Mine Trespasser (2015)

In September 2015, an ABS investigation was conducted at the mine to evaluate potential exposures to mine trespassers. This ABS investigation evaluated three different exposure scenarios: an on-road ATV riding scenario on unpaved roads and trails, an off-road ATV riding scenario on the disturbed area of the mine, and a rockhound scenario on the disturbed area of the mine. During the ATV riding scenario, riders rode in a single-file line (i.e., one rider leading, one rider following), with the leader/follower switching positions after half of the sampling time had elapsed. During the rockhound scenario, individuals traversed across the disturbed area of the former mine looking for interesting rock and mineral specimens by examining outcrops, rock faces, and waste rock piles and collecting rock specimens in a bag. **Figure 6-9** illustrates the ATV riding routes and mine areas that were included in this investigation. A total of three ABS events were performed. For each ABS event, two Grace contractors performed the scripted trespasser ABS activities. Results of the *Trespasser ABS* study are summarized in CDM Smith (2015e).

6.6.3 Calculation of EPCs

Previous investigations conducted at the Site have demonstrated that LA concentrations in soil and duff in the forest areas surrounding the mine tend to be highest near the mine site and decrease as a function of distance from the mine (CDM Smith 2015a, 2013g). Because of the complex nature of the source materials in these forested areas, the difficulty in characterizing the LA concentrations in these source media, and the difficulty in establishing a reliable quantitative relationship between LA levels in source materials and ABS air, EPCs were not calculated based on source media LA concentration. Rather, EPCs were calculated as a function of distance from the mined area, and grouped into four exposure datasets – near the mine (within 2 miles of the mined area[17]), intermediate from the mine (about 2-6 miles from the mined area), far from the mine (greater than 6 miles from the mined area), and along the NPL boundary (includes all locations evaluated in the *2014 Nature and Extent in the Forest* study described in Section 6.6.2.4). Outdoor ABS data from each ABS area within each designation were grouped together for the purposes of calculating EPCs.

For OU3 ABS studies conducted outside of the forested areas (i.e., along Rainy Creek or at the mined area), EPCs were calculated as the mean ABS air concentrations across the entire ABS area.

Table 6-16 presents summary statistics for outdoor ABS air associated with disturbances of soil at OU3.

6.6.4 Risk Estimates

Table 6-17 presents estimated cancer risks and non-cancer HQs from exposures to LA during soil/duff disturbance activities in OU3 based on RME (Panel A) and CTE (Panel B). These results indicate that, when these exposure scenarios are considered alone, with one exception, estimated RME and CTE cancer risks are less than 1E-04 and non-cancer HQs are less than 1 for all recreational and

[17] As estimated from the approximate center point of the mined area.

USFS firefighter exposure scenarios. For rockhounds in the disturbed area of the mine, the RME non-cancer HQ is 2, but the CTE non-cancer HQ is less than 1 and cancer risks for both RME and CTE are less than 1E-04. These results show that this exposure scenario alone has the potential to exceed a non-cancer HQ of 1. The contribution of each OU3 soil disturbance exposure scenario to the cumulative risk is discussed in Section 9.

6.6.4.1 Extrapolation to Areas Without ABS

The OU3 Study Area encompasses approximately 32,000 acres of forest; as such, it is not feasible to evaluate risks by conducting ABS throughout this entire area. Thus, it is necessary to use the ABS data from the areas that have been investigated to draw risk conclusions about areas that have not been studied by ABS. The approach taken for OU3 to quantify exposures was to collect ABS samples in the predominantly downwind direction from the mine (i.e., to the northeast) and to assume that the risks calculated at these locations are equal to or greater than the risks at equal distances from the mine in the crosswind and upwind directions (see Section 10.1.3 for additional discussion of the potential uncertainties of this assumption). For example, any risk conclusions drawn for the 'forest, near the mine' EPC grouping are assumed to apply to all other areas within this distance range (i.e., within 2 miles of the mine), including areas crosswind and upwind. Therefore, the EPC grouping locations effectively represent a series of concentric circles centered on the mine.

6.6.4.2 Calculation of Area-Specific and Area-Weighted Risks

Appendix G.1 summarizes potential exposures and risks in OU3 on an ABS area-specific basis. These calculations illustrate how exposures and risks vary on a smaller scale than the EPC groupings provided in **Table 6-16**.

The calculations presented in **Table 6-16** assume the entire exposure time is spent within the EPC grouping location (e.g., within 2 miles of the mined area, within 2-6 miles of the mined area, greater than 6 miles from the mined area). However, it is likely long-term receptor exposures could encompass multiple EPC grouping locations. For example, over the span of multiple years, an ATV rider could ride in forested areas near, intermediate, and far from the mine. In this scenario, the total exposure and risk estimates would need to provide an area-weighted estimate, adjusted based upon the frequency of each areas use. For the purposes of these calculations, the exposure frequency for each EPC grouping location in the forested areas was determined based on relative areal extent (i.e., acreage of the concentric circle) as well as the estimated access potential (i.e., what proportion of the area was in proximity to forest service roads and trails). The total exposure frequency is the same as presented in **Table 6-16**, but is split across multiple exposure locations. **Appendix G.2** illustrates the area-weighted risks from exposures to LA during soil/duff disturbance activities in forested areas within OU3 based on RME. As shown, estimated total RME cancer risks are less than 1E-04 and non-cancer HQs are less than 1 for all area-weighted forest exposure scenarios.

Appendix G.2 also illustrates the area-weighted exposures and risks from exposures to LA while ATV riding in the mined area. For the purposes of these calculations, ATV riding time is assumed to be split equally across the three on-road routes and the off-road riding area. As shown, estimated total RME cancer risks are less than 1E-05 and non-cancer HQs are less than 1 for this area-weighted exposure scenario. However, it is notable that the majority (88%) of the exposure for this scenario is contributed by on-road Route C and the off-road riding within the disturbed area (see **Figure 6-9**).

6.7 Exposures in OU5

OU5 includes the former Stimson Lumber Mill and all properties owned by Kootenai Business Park Industrial District (KBPID) (see **Figure 6-9**). Historically, there have been many lumber processing facilities located throughout OU5, but the majority of lumber production activities ceased in 2003 when Stimson Lumber Company sold the property to the Lincoln County Port Authority and ownership was subsequently transferred to KBPID. The majority of OU5 is un-vegetated. Several wood chip and waste bark piles from historical lumber processing activities were left onsite. OU5 is currently being redeveloped for a variety of uses, both recreational and commercial/industrial.

OU5 contains an area that has been developed as a MotoX park for dirt-biking and a recreational path along Libby Creek that is popular for hiking and bicycle riding (see **Figure 6-10**). A walking path and fishing pond were also recently constructed in the northeast corner of OU5 near Libby Creek. Currently, there is no residential land use in OU5, but residential neighborhoods surround OU5 to the west and northwest.

The *OU5 RI* (HDR 2013a) summarizes the various removal efforts that have been conducted and the post-removal soil concentrations that remain. In brief, these efforts have included both removals of vermiculite and asbestos-containing materials from inside buildings as well as outdoor soil. Typically, soil removals were focused on specific areas near buildings or in locations where re-development efforts were occurring. The majority of surface soil samples collected at OU5 were non-detect for LA (PLM-VE Bin A). When LA was detected in soil, concentrations were usually trace (PLM-VE Bin B1), but some locations have LA concentrations up to 1%. Varying levels of VV have been noted across OU5. The highest LA soil concentrations and VV levels are associated with an area that was a former tree nursery, where raw vermiculite product was added as a growth medium and fill material.

6.7.1 Exposure Populations and Parameters

There are two main types of receptor populations of interest for the purposes of evaluating exposures to LA during soil disturbances in OU5 – recreational visitors and outdoor workers.

Recreational visitors include individuals that hike or bicycle on the recreational path along Libby Creek and individuals that use the MotoX Park. It is assumed that exposures to hikers and bicyclists on the recreational path are likely to be similar; thus, only one type of recreational receptor is evaluated for this exposure scenario. Because potential exposures concentrations could differ between adult bicycle riders and children in trailers attached to the back of the bicycle, exposures are determined separately for each scenario.

There are two types of individuals that are likely to use the MotoX Park – riders and spectators. Information on exposure parameters for riders at the MotoX Park was obtained from six volunteers who participated in the MotoX Park ABS investigation (EPA 2008e). **Appendix H** presents the results of the MotoX Park survey. Risk estimates for participants at the MotoX Park are based on the exposure parameters derived from the volunteer responses.

As noted above, OU5 may be re-developed for a variety of commercial and/or industrial uses (future residential use is not expected). Thus, exposure parameters for outdoor workers were based on a default industrial worker scenario. However, default exposure values were adjusted to focus on the exposure interval when soil disturbances are occurring (i.e., a worker may be outdoors 8 hours/day, but it is unlikely that they would be disturbing soil over this entire time interval). It was assumed that outdoor workers would engage in soil disturbance activities for about one-half the work day (i.e., 4 hours/day).

Table 6-18 presents the selected RME and CTE exposure parameter values and calculated TWFs for disturbances of soils in OU5.

6.7.2 Investigation Summary

Three different outdoor ABS investigations were conducted at OU5 in September/October of 2008 to evaluate potential exposures to LA during soil disturbance activities. Each of the outdoor ABS investigations is described briefly below.

6.7.2.1 Recreational Visitors

In September of 2008, two outdoor ABS studies were performed to evaluate potential exposures to recreational visitors in OU5 from soil disturbance activities.

The first study was conducted at the MotoX Park (see **Figure 6-11**) to evaluate potential exposures to motorcycle riders and spectators during park use (EPA 2008e). Soil samples collected at the MotoX Park show a mixture of PLM-VE Bin A (non-detect) and Bin B1 (trace) conditions at the track. During each of two sampling events, two types of air monitoring samples were collected: 1) personal air monitors were mounted to the handle bars of the motorcycles for several volunteer riders (see **Figure 2-2** for an example photograph of this ABS activity), and 2) five stationary air monitors were placed around the perimeter of the track to characterize potential exposures to spectators.

The second study was conducted to evaluate potential exposures to bicycle riders on the recreational path adjacent to Libby Creek (see **Figure 6-11**) (EPA 2008f). On four separate days, three EPA contractors wore personal air monitors while bicycling along the entirety of the path. Sampling was conducted separately for the paved and unpaved portions of the path. On the paved path[18], an air monitor was also mounted in a trailer attachment to one of the bicycles to characterize potential exposures to a young child.

6.7.2.2 Outdoor Workers

As part of the OU5 outdoor worker ABS investigation, sampling was conducted at eight ABS areas in September/October of 2008 (EPA 2008g). Each ABS area was approximately 1-1.5 acres in size. These eight ABS areas were selected based on previously reported VV conditions to represent the range of expected soil contamination conditions at the OU5 site, with Area 1 representing the low end of the soil range and Area 8 (the former tree nursery) representing the high end of the range (see **Figure 6-11**). During each of three separate sampling events, two workers wore personal air monitors while performing an outdoor ABS script to simulate soil disturbance activities at each ABS area. The outdoor worker ABS script included a 120-minute scenario split equally into raking activities and bobcat operation activities. At the time of each sampling event at each ABS area, 30 grab samples and one 30-point composite soil sample were collected[19]. During the soil sample collection, the field team recorded information on VV for each sampling point (i.e., 30 grab sampling points and 30 composite sampling points).

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[18] Samples from the trailer were not collected from the unpaved portion of the path because the unpaved portion of the path was steep and narrow in sections, and not safe for pulling a trailer.

[19] Due to the high frequency of non-detect soil results, PLM-VE analyses were only performed for a subset of soil samples collected as part of the ABS investigation; 451 of 744 soil samples (61%) were analyzed, the remainder were archived.

6.7.3 Calculation of EPCs

6.7.3.1 Recreational Visitors

Because the MotoX and bicycle riding ABS scenarios were conducted in such a way that they are representative of the full extent of the MotoX track and bike path in OU5, there was no need to extrapolate ABS air results to un-sampled locations using soil data. Thus, it was not necessary to calculate EPCs stratified by soil concentration. For the bicycling scenario, EPCs were calculated separately for adult riders and trailers. **Table 6-19** (Panel A) presents the calculated EPCs associated with disturbances of soil at the MotoX Park and while riding bicycles in OU5.

6.7.3.2 Outdoor Workers

As described above, there were eight ABS areas selected for evaluation based on previously reported LA soil concentrations and VV conditions to represent the range of expected soil contamination conditions at OU5 (see **Figure 6-11**). For the purposes of estimating risks, EPCs were calculated separately for each ABS area to illustrate the potential range of exposure conditions. **Table 6-19** (Panel A) presents the calculated EPCs associated with disturbances of soil during worker activities in OU5 for each ABS area.

6.7.4 Risk Estimates

Table 6-19 presents estimated cancer risks and non-cancer HQs from exposures to LA during soil disturbance activities in OU5 based on RME (Panel B) and CTE (Panel C). As shown, these results indicated that, when the recreational visitor exposure scenarios are considered alone, estimated RME and CTE cancer risks are less than 1E-06 and non-cancer HQs are less than 0.1 for all scenarios, including while riding bicycles along bike path, while riding motorcycles at the MotoX Park, and while observing riders at the MotoX Park.

For exposures to outdoor workers, when this exposure scenario is considered alone, estimated RME cancer risks are less than 1E-04 and non-cancer HQs are less than or equal to 1 for all ABS areas (Area 5 had an HQ of 1). Estimated CTE cancer risks are less than or equal to 1E-05 and non-cancer HQs are less than 1 for all ABS areas.

The contribution of the OU5 soil disturbance exposure scenarios to cumulative risk is discussed in Section 9.

6.7.5 Extrapolation to Areas Without Outdoor Worker ABS

The OU5 Site encompasses about 400 acres. Because it is not feasible to evaluate outdoor worker risks by conducting ABS sampling on every acre, it was necessary to use the ABS data from the eight ABS areas that have been investigated to draw risk conclusions about areas that have not been studied by ABS. This was done by assessing the degree to which soil results from other areas are similar to the soil results for areas with ABS data.

Figure 6-11 illustrates the LA soil concentrations at OU5 based on PLM-VE results. A four-color scheme is used to indicate the data: green = Bin A (non-detect), yellow = Bin B1 (trace), orange = Bin B2 (<1%), red = Bin C (≥1%). In this figure, individual grab samples (primarily collected within the outdoor worker ABS areas) are shown as triangles, and composite samples are shown as circles plotted at the mid-point[20] of the sample collection area. The OU5 outdoor worker ABS specifically targeted ABS areas

[20] Composite samples are representative of a larger area beyond the plotted point presented in this figure.

to encompass the full range of expected levels of LA soil contamination at OU5. As shown, LA soil concentrations outside of the ABS areas are similar to or lower than concentrations inside the ABS areas. These data support the conclusion that outdoor worker exposures and risks across OU5 from soil disturbances are likely to be similar to, or lower than, exposures and risks calculated for the ABS areas.

6.8 Exposures in OU6

6.8.1 Exposure Populations and Parameters

OU6 is owned by the BNSF railroad and is defined geographically by the BNSF property boundaries from the eastern boundary of OU4 to the western boundary of OU7, including the Libby and Troy rail yards. Thus, the primary receptor population of interest for OU6 is BNSF railroad workers who may be exposed to LA during soil disturbances along the railroad tracks as a consequence of regular rail maintenance activities. In addition, local on-lookers or pedestrian trespassers may also be exposed during these maintenance activities.

The ambient air evaluation (Section 5) addressed potential exposures of individuals that reside near railroad tracks, as two of the ambient air monitoring stations were intentionally placed near rail lines in OU6 (see **Figure 5-1**).

Table 6-20 presents the selected RME and CTE exposure parameter values and calculated TWFs for disturbances of soils in OU6.

6.8.2 Investigation Summary

BNSF performed outdoor ABS in September 2008 (EMR Inc. 2010a, b) to measure the concentration of LA released into air during railroad maintenance activities along the OU6 rail corridor. This ABS study was designed to evaluate potential exposures to BNSF workers and the general public. The worker scenario simulated two types of railroad workers: a general laborer performing duties on the track as part of larger group of workers and workers operating machinery with an open air cab. Two types of public exposure scenarios were planned: on-lookers and pedestrian trespassers; however, due to manpower limitations when the ABS was conducted, the two scenarios were essentially the same.

ABS was conducted by BNSF contractors at seven locations along a 30 mile stretch of rail line in OU6, from mile post (MP) 1312 to MP 1341 (see **Figure 6-12**) in areas of planned rail maintenance activities. These ABS samples underwent a supplemental TEM analysis to improve the achieved analytical sensitivity in 2013. Detailed results of the BNSF ABS investigation for OU6 (including the supplemental analyses) are presented in CDM Smith (2014g) and Kennedy/Jenks Consultants (2014).

The outdoor ABS samples collected in 2008 were determined to be representative of exposure conditions that are reasonably expected to be present in OU6 at the time of the study (2008) and under present conditions. This conclusion is based on the fact that, in general, removal actions within OU6 were completed prior to 2008. As such, the 2008 outdoor ABS air samples are likely to be representative of conditions that could reasonably be encountered by current and future workers and the general public within OU6.

6.8.3 Calculation of EPCs

Table 6-21 (Panel A) presents summary statistics of the OU6 outdoor ABS investigation results. As seen, all ABS air samples were non-detect. The mean air concentration (i.e., a concentration of zero) was used as the EPC in the risk calculations.

6.8.4 Risk Estimates

Table 6-21 presents estimated cancer risks and non-cancer HQs from exposures to LA during soil disturbance activities in OU6 based on RME (Panel B) and CTE (Panel C). As shown, because EPCs were zero, the resulting cancer risks and non-cancer HQs are also zero for all exposure scenarios. The uncertainty assessment (Section 10) provides additional information on risk estimates for datasets where all samples are non-detect.

Although ABS data are not available for all 40 miles of the rail line at the Site, it is considered likely that the ABS data that are available are representative of conditions along most of the line. Barring any train car derailments (the historical documentation that has been reviewed does not indicate any such events), outside of the train car loading area (which has already been addressed by prior soil removal actions), there is no reason to expect that contamination levels are spatially dependent as a function of distance along the rail line (i.e., if spillage were occurring due to railcar jostling, contamination at mile A should be similar to mile B). Based on this conceptual model of contamination, the risk estimates are likely to be applicable to the entire rail line within OU6.

6.9 Exposures in OU8

6.9.1 Exposure Populations and Parameters

OU8 includes roads and ROWs[21] within Libby and Troy. Individuals that drive on highways, roads (paved and unpaved), and alleys in Libby and Troy have the potential to be exposed to LA while driving. As noted previously, for the purposes of the risk assessment, air inside vehicles is evaluated as outdoor air that may be influenced by disturbances of soil (e.g., airborne roadway dust). The two primary populations of interest that have the potential to be exposed to LA during soil disturbances in the ROW include outdoor workers that maintain the ROW (e.g., mowing or brush-clearing) and individuals that walk, bike, or ride ATVs along the ROW.

Table 6-22 presents the selected RME and CTE exposure parameter values and calculated TWFs for disturbances of soils in OU8.

6.9.2 Investigation Summary

6.9.2.1 While Driving on Roads in Libby and Troy

Two different ABS investigations have been conducted to evaluate potential exposures while driving on roads at the Site. In 2010, an investigation was performed by EPA to evaluate exposures in Libby (CDM Smith 2010b). In 2011, an analogous investigation was performed by DEQ to evaluate exposures in Troy (Tetra Tech 2011).

For both investigations, the driving activity was conducted by an EPA or DEQ contractor driving a full size automobile (car or truck). Both paved roads and unpaved roads/alleys were traveled, with travel evenly distributed throughout the OU. The contractor maintained a reasonable speed during the activity, following all posted speed limits. During sample collection, the two front windows of the vehicle were fully open, and the two back windows were open approximately 1 inch. All samples were collected from the right shoulder of the contractor. The specific driving routes were documented utilizing a portable global positioning system (GPS) unit to record the route.

[21] Excludes the ROW along Highway 37 in OU2.

In Libby, a total of 20 two-hour driving events were conducted in the summer of 2010. Because it was not possible to travel every road within OU4 during each sampling event, each event covered areas missed in previous events such that the sum of all 20 events comprehensively covered most of the roads in Libby. **Figure 6-13** provides a map of the roads that were traveled during the driving ABS events in Libby. ABS air samples were originally analyzed in 2010; a subset of the samples underwent a supplemental TEM analysis to improve the achieved analytical sensitivity in 2013. Detailed results of the Libby driving ABS investigation (including the supplemental analyses) are summarized in CDM Smith (2014a).

In Troy, a total of 10 one-hour driving events were conducted in the summer of 2011. Each event included driving once along most of the roads in Troy and multiple times along more commonly-traveled roads. **Figure 6-14** provides a map of the roads that were traveled during the driving ABS events in Troy. Detailed results of the Troy driving ABS investigation are summarized in Tetra Tech (2013).

6.9.2.2 Along Road Right-of-Ways

In 2010 and 2011, EPA performed outdoor ABS studies to measure levels of LA in air under a variety of soil disturbance activities that could occur in OU8 ROWs (TechLaw, Inc. 2010). Specifically, outdoor ABS data were collected while ATV riding, mowing, and brush-clearing in the ROW along a segment of Highway 37 (see **Figure 6-15**). Outdoor ABS data were also collected while rotomilling (i.e., road resurfacing) along Highway 37 between Highway 2 and East 2nd Street. ABS locations were selected based on VV field observations and PLM-VE soil results, intentionally selecting locations with higher levels of LA, in proximity to the town of Libby, and actual areas of expected exposure activities. Detailed results of the OU8 ROW ABS investigation are summarized in the *OU8 RI* (HDR 2013b).

6.9.3 Calculation of EPCs

Because the driving ABS scenarios were conducted in such a way that they are representative of most roads and alleys in Libby and Troy, there was no need to extrapolate ABS air to un-sampled locations based on soil concentration. However, because road conditions may differ between Libby and Troy, EPCs were calculated separately for each city. EPCs for each city were calculated as the average air concentration across all sampling events.

For the ROW outdoor ABS studies, because each type of disturbance activity could result in different releases and because the exposure populations could differ by activity type, EPCs were calculated separately by disturbance activity (i.e., separate EPCs were calculated for ATV riding, brush-clearing, mowing, and rotomilling).

Table 6-23 (Panel A) presents the calculated EPCs associated with disturbances of soil while driving on roads in Libby and Troy and in the OU8 ROWs.

6.9.4 Risk Estimates

Table 6-23 presents estimated cancer risks and non-cancer HQs from exposures to LA during soil disturbance activities along roadways and while driving based on RME (Panel B) and CTE (Panel C). As shown, these results indicate that, when these exposure scenarios are considered alone, estimated RME and CTE cancer risks are less than or equal to 1E-05 and non-cancer HQs are less than 1 for all exposure scenarios. The contribution of the OU8 soil disturbance exposure scenarios to cumulative risk is discussed in Section 9.

For the ROW outdoor ABS studies (ATV riding/brush-clearing/mowing), because ABS was only conducted on smaller segments of the ROWs in OU8, it was necessary to extrapolate ABS results to ROW segments that had not been sampled using ABS. This was achieved by assessing the degree to which soil results from un-sampled areas were similar to the soil results for the ABS areas. Because the segments selected for ABS were selected to be representative of the highest soil concentrations (see **Figure 6-15**), measured ABS concentrations are likely to represent "worst case" exposure conditions. Thus, it is expected that potential risks along the ROW in segments that were not evaluated as part of the ABS study are likely to be lower than those presented in **Table 6-23**.

6.10 Evaluation of Background LA Levels in Soil

EPA has performed extensive outdoor ABS investigations at the Site, seeking to characterize airborne levels of LA that occur in association with soil disturbance activities. In some cases, these studies have detected LA fibers in ABS air samples collected in locations where the soil is not expected to have mine-related contamination (EPA 2010d; CDM Smith 2014b). This raises the possibility that there is some "non-zero" level of LA in soils of the Kootenai Valley that is not attributable to anthropogenic releases from vermiculite mining and processing activities. Under Section 104(a)(3)(A) of CERCLA, EPA cannot clean up soils to a concentration lower than background; therefore, it is important for risk managers to understand the nature and magnitude of these naturally-occurring levels (EPA 2002b).

EPA has conducted several investigations at the Site to characterize LA in soil from areas that are thought to be representative of "background" conditions. The term "background" is used to refer to soils that are not expected to be affected by anthropogenic releases from vermiculite mining and processing activities. A detailed discussion and evaluation of the investigations that have been performed to characterize background levels of LA in soil is presented in the *Background Soil Summary Report* (CDM Smith 2014h).

6.10.1 LA Concentrations in Background Soil

In most of the background soil investigations, soil concentrations of LA were measured by TEM following preparation of the soil using a fluidized bed asbestos segregator (FBAS). FBAS is a technique for evaluating low level asbestos concentrations in soil. Following FBAS preparation, TEM soil analyses are able to achieve detection limits less than 0.005% by mass (Januch *et al.* 2013), which is approximately 100-times lower than the detection limits that are reliably achieved using other analytical methods (e.g., PLM).

The results of these background soil characterization studies show that LA structures have been consistently detected in background soils within the Kootenai Valley that are not thought to be affected by anthropogenic releases from vermiculite mining and processing activities. While background soil concentrations are variable (see **Figure 6-16**), in general, the average total LA concentration is about 5E+05 structures per gram of soil (s/g), which is estimated to be approximately 0.014% LA by mass (CDM Smith 2014h). This concentration is well below the reliable detection limit of traditional analytical methods for soil used at the Site (i.e., PLM-VE).

6.10.2 Outdoor Air Concentrations During Background Soil Disturbances

As discussed previously, the detection of LA in background soil does not necessarily indicate that human exposures to LA released to air during disturbances of background soil would result in unacceptable exposures or risks. Thus, several ABS studies were performed to measure LA concentrations in air during disturbances of background soils. In most of the background soil investigations, a digging ABS scenario was performed using soils collected and composited in a five-gallon container; hence, this ABS scenario is referred to as the "bucket of dirt" digging scenario. The five-gallon container was brought to a specified location where the ABS soil digging scenario was conducted. The digging activity was performed using a hand trowel, simulating a child digging and playing in the dirt (see **Figure 6-17**).

The results of the "bucket of dirt" digging ABS studies are summarized in **Table 6-24** (Panel A) and presented graphically in **Figure 6-18**. As indicated, measured LA concentrations in ABS air tend to be highly variable but concentrations released from background soils from Libby and Troy are generally similar and somewhat higher than concentrations for topsoil borrow sources within the Kootenai Valley.

The "bucket of dirt" digging ABS scenario is likely to represent the high-end of potential exposures and may not be a realistic estimate of exposures that could occur under authentic soil disturbance activities, such as raking, mowing, and digging activities in residential yards. In order to provide data on potential LA exposures from background soil under less vigorous disturbance scenarios that are more likely to be representative of scenarios that apply to residents, EPA conducted an outdoor ABS investigation at residential properties in OU4 where a "curb-to-curb" soil removal had occurred (i.e., the entire yard had been removed and replaced with topsoil fill material) (CDM Smith 2014b). A total of 11 residential properties were evaluated as part of the curb-to-curb outdoor ABS investigation. Three sampling events[22] were conducted at each property in the summer of 2011. For each sampling event, a single ABS air sample was collected from each property, representing a composite of three yard soil disturbance activities – mowing, raking, and digging. The mowing portion of the composite represented a one-pass mowing of the entire yard. The raking portion of the composite represented a one-pass raking of the entire yard. The digging portion of the composite simulated a sprinkler maintenance activity at each of two to six locations (i.e., digging a hole with a long shovel and trowel). **Table 6-24** (Panel A) summarizes the results of the curb-to-curb outdoor ABS study. These data are presented graphically in **Figure 6-18**.

6.10.3 Risk Estimates

Table 6-24 (Panel B) presents estimated RME cancer risks and non-cancer HQs for exposures to LA in outdoor ABS air for the "bucket of dirt" digging ABS scenarios and at curb-to-curb properties (i.e., during soil disturbances), assuming exposure parameters for residential yard soil disturbance (see **Table 6-1**). As shown, estimated RME and CTE cancer risks are less than 1E-05 and non-cancer HQs are less than 1 for all ABS datasets. For the curb-to-curb properties, the estimated RME cancer risk is 2E-06 and non-cancer HQ is 0.1. These estimated risks are the same those calculated for residential yards where the soil concentrations are non-detect by PLM-VE (Bin A) (see **Table 6-3a**). These results demonstrate that a portion of the total exposure from soil disturbances at the Site may be attributable to background levels of LA in soil.

6.11 Overall Risk Conclusions

In reviewing the risk calculation tables for exposures during soil disturbance activities, there are a number of general conclusions that can be drawn:

- Estimated cancer risks and non-cancer HQs span more than four orders of magnitude depending upon the exposure scenario.

[22] At one property, the resident agreed to participate in only one sampling event.

- For a given exposure scenario, non-cancer HQs can exceed 1 even when cancer risks are less than 1E-04, which indicates that non-cancer exposure is a more sensitive metric of potential concern. For example, exposures for a rockhound in the disturbed area of the mine yielded an estimated excess cancer risk of 4E-05 and a non-cancer HQ of 2 (based on RME) (see **Table 6-17**). (For LA, a non-cancer HQ of 1 is approximately equivalent to a cancer risk of 1E-05.)

- More than 80 different types of exposure scenarios during soil disturbances were evaluated, encompassing a wide range of disturbance activities, OUs, exposure locations, and soil concentrations. With one exception (outdoor worker exposures during yard soil disturbances with Bin B2/C concentrations), there were no individual soil disturbance exposure scenarios where CTE cancer risks exceeded 1E-04 or non-cancer HQs exceeded 1. However, there were four individual soil disturbance exposure scenarios where RME cancer risks exceeded 1E-04 and/or non-cancer HQs exceeded 1, including:

    - Residential exposures during disturbances of yard soils with detected LA at properties in OU4 and OU7 (see **Table 6-3a**)

    - Outdoor worker exposures during disturbances of yard soils with detected LA at residential and commercial properties in OU4 and OU7 (see **Table 6-3b**)

    - Outdoor worker exposures during disturbances of subsurface soils with residual LA contamination at residential and commercial properties in OU4 and OU7 (see **Table 6-5**)

    - Rockhound exposures in the disturbed area of the mine in OU3 (see **Table 6-17**)

- Quantitative risks were not calculated for potential exposures to workers exposed to residual LA in subsurface soils in OU1 and OU2; however, these exposure scenarios could result in potentially unacceptable exposures and risks because LA concentrations greater than 1% are present in subsurface soil beneath the cover fill in some areas.

- Exposure to LA in outdoor air during yard soil disturbances has the potential to be an important exposure scenario. Even when only trace levels of LA are present in the soil (i.e., PLM-VE Bin B1), this exposure scenario, when considered alone, could yield RME non-cancer HQs greater than 1, depending upon the spatial extent of the LA in soil and the frequency and intensity that these soils are disturbed.

- LA structures have been consistently detected in background soils within the Kootenai Valley that are not thought to be affected by anthropogenic releases from vermiculite mining and processing activities. ABS activities conducted on these background soils demonstrate LA can be released to air; however, estimated risks from background soil exposures appear to be low (i.e., cancer risk less than 1E-05 and non-cancer HQ less than 1).

- Estimated exposures and risks during yard soil disturbances when LA is not detected in soil (i.e., PLM-VE Bin A) are similar to those calculated for background soils.

There are several soil disturbance exposure scenarios where the ABS dataset was all non-detect (i.e., EPCs and estimated risks are zero) or the number of samples with detected PCME LA structures was limited. The uncertainty assessment (Section 10) provides additional information on risk estimates for datasets where all samples were non-detect or where the LA detection frequency was low.

Section 7

Risks from Exposures to Indoor Air

This section summarizes the results of studies performed at the Site to evaluate potential exposures to LA in indoor air, describes how these data are used to calculate exposures, and presents estimated cancer risks and non-cancer HQs for several potential exposure scenarios. This section is organized by receptor type and exposure location as follows:

- Section 7.1 - Residential and indoor worker exposures inside properties in OU4 and OU7
- Section 7.2 - Tradesperson exposures inside properties in OU4 and OU7
- Section 7.3 - Student and teacher exposures inside schools in OU4
- Section 7.4 - Worker exposures inside the David S. Thompson Search and Rescue building in OU1
- Section 7.5 - Worker exposures inside buildings in OU5

There have been several indoor ABS investigations to evaluate LA concentrations in air during various indoor disturbance scenarios. **Table 2-2** (Panel C) summarizes the types of indoor ABS investigations that have been conducted. The following sections summarize the indoor ABS datasets that provide information on each indoor exposure scenario. The following sections also present the selected RME and CTE exposure parameter values and calculated TWFs for each exposure scenario. Each section identifies the basis of the selected exposure parameters and notes if any Site-specific adjustments were applied. It is important to note that the exposure parameters and resulting TWFs are selected for the purposes of evaluating potential risks from each individual exposure scenario (i.e., the cumulative assessment may utilize different TWFs).

7.1 Residential/Commercial Exposures Inside Properties in OU4 and OU7

7.1.1 Exposure Populations and Parameters

There are two main exposure populations of interest for the purposes of evaluating potential exposures to LA inside properties in OU4 and OU7 – residents and indoor workers. As described previously in Section 2.1.2, indoor workers may include office administrative assistants, shop keepers, restaurant staff, etc. For both indoor workers and residents, there are a wide range of different activities that could occur inside properties. For the purposes of evaluating exposures in the risk assessment, parameters were determined separately for exposures under active and passive conditions. Active behaviors include indoor activities in which a person is moving about the building and potentially disturbing indoor sources; such activities have included walking from room to room, sitting down on upholstered chairs, sweeping, and vacuuming. Passive behaviors are minimally energetic actions, such as sitting and reading a book, watching television, and working at a desk, that will have low tendency to disturb any indoor source materials.

Table 7-1 presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential residential and indoor worker exposures inside properties in OU4 and OU7.

7.1.2 Investigation Summary

There have been four different indoor ABS investigations conducted in OU4 and one indoor ABS investigation in OU7. As part of these studies, indoor ABS air samples were collected under active and/or passive conditions. Each of these studies is described briefly below.

In 2001, indoor ABS was conducted as part of the Phase 2 investigation in OU4. During this ABS program, indoor ABS was performed during active cleaning and/or passive behaviors at 24 properties. Samples of indoor dust were also collected at each property. ABS air samples were originally analyzed in 2001; a subset of the samples underwent a supplemental TEM analysis as part of the OU4 SQAPP investigation (see below) to improve the achieved analytical sensitivity in 2005. The original Phase 2 indoor ABS results are summarized in EPA (2006d); supplemental analysis results are summarized in EPA (2007a).

In 2005, indoor ABS was conducted as part of the OU4 SQAPP investigation (EPA 2005b). Indoor ABS samples (both personal and stationary monitoring samples) were collected under routine (passive) living conditions over a period of about 8 hours. In addition to collecting indoor ABS air, samples of indoor dust were also collected at each property. Results of the OU4 SQAPP indoor ABS results are summarized in EPA (2007a).

The largest indoor ABS program in OU4 occurred from 2007-2008 (EPA 2007e). During this ABS program, indoor ABS was performed during active and passive behaviors at 81 properties. The properties evaluated included those where an outdoor soil removal had already been performed or where no outdoor soil removal was deemed necessary at that time with varying levels of LA in the outdoor soil, because it was hypothesized that outdoor soil concentrations of LA may be an important predictor of LA concentrations in indoor air. At each property, four rounds of ABS were conducted, such that the resulting data were representative of each season (summer, fall, winter, spring). Indoor dust samples were collected during each sampling event; outdoor soil samples were collected during the summer event for each property. Results of the 2007-2008 OU4 indoor ABS investigation are summarized in (EPA 2010d).

In 2013, two different indoor ABS scenarios were evaluated in OU4 (CDM Smith 2013h). During this ABS program, indoor ABS was performed during active and passive behaviors at 20 properties. In the first scenario, indoor ABS was conducted at 10 properties in OU4 where a "curb-to-curb" yard soil removal had been completed. Two rounds of ABS were conducted; one in the winter and one in the summer. In the second scenario, 10 of the 81 indoor ABS properties originally sampled in 2007-2008 were re-sampled in the summer of 2013. Results of the 2013 OU4 indoor ABS investigation are summarized in CDM Smith (2013i).

For OU7, an indoor ABS program was conducted in 2012 and 2013 to evaluate potential exposures during active and passive behaviors at 20 properties (Tetra Tech 2012b). The properties selected for evaluation included properties where removals had already been performed (an interior removal, an exterior removal, or both), as well as properties where no removal was deemed necessary at that time, with varying levels of LA in the outdoor soil. At each property, two rounds of ABS were conducted, such that the resulting data were representative of summer and winter conditions (collected in September 2012 and February/March 2013, respectively). Results of the OU7 indoor ABS investigation are summarized in Tetra Tech (2014).

7.1.2.1 Role of Source Material Information in Evaluating Indoor Risks

Because it is not feasible to evaluate risks by conducting indoor ABS at every property in OU4 and OU7, it is necessary to use the measured ABS data from the properties where ABS has been performed to draw risk conclusions about properties where ABS has not been performed. Recall that for outdoor ABS associated with disturbances of soil, this was done by grouping the outdoor ABS air results by LA concentrations in soil (i.e., PLM-VE bins). For indoor ABS, various strategies have been attempted to correlate indoor ABS air concentrations with LA levels in indoor dust and outdoor soil (EPA 2007a, 2010d). However, these attempts have had limited success.

A priori, it was expected that indoor dust would be the main source of LA in indoor air. However, no clear correlation could be detected. The reason for the lack of observable correlation between indoor dust and indoor ABS air is not certain. One possible explanation is that the relationship between dust levels and air levels is dependent on building-specific random variables, such as heating source, carpet age, number of pets, cleaning frequency, etc., which would result in extreme variability in the relationship. Another possible explanation is that the dust samples collected from horizontal surfaces and high traffic areas may not be the main source of LA in indoor air, and dust from other parts of the house (e.g., from upholstered furniture, air ducts) represents the main source (EPA 2007a).

There does appear to be a weak correlation between outdoor soil and indoor ABS air. However, regression analysis suggests that other sources besides outdoor soil are likely to be a larger contributor to indoor ABS air concentrations of LA (EPA 2010d).

Subsequent evaluations to determine if there are any trends or patterns in measured indoor ABS air concentrations as a function of various property characteristics (e.g., heating source, carpet age, number of pets, LA concentrations in outdoor soil, high-efficiency particulate air [HEPA] vacuum use) have demonstrated there is no single property characteristic that can be used to gauge the level of LA that may be present in indoor air. Rather, indoor air is affected by multiple property characteristics acting in combination (CDM Smith 2015f).

For these reasons, indoor ABS air data were not grouped based on either indoor dust or outdoor soil concentrations. Rather, data were grouped based on the interior removal status information (see below).

7.1.2.2 Role of Interior Removal Status Information in Evaluating Indoor Risks

Since 2000, nearly 1,000 interior removals have been completed at properties in OU4 and OU7 as part of the emergency response removals. The nature of the interior removal efforts performed depended upon the types of source materials present at the property, the levels of LA in these materials, as well as the presence of VV inside the property. For the purposes of grouping the indoor ABS data, ABS air samples for each property were classified into three removal status categories based on property conditions at the time of the ABS:

- **Pre-removal:** An interior removal was performed at this property; ABS data reflect property conditions prior to the removal being completed.
- **Post-removal:** An interior removal was performed at this property; ABS data reflect property conditions after the removal was completed.
- **No removal required:** This property was evaluated and no interior removal was deemed necessary at the time of the ABS.

7.1.2.3 Calculation of EPCs

7.1.2.3.1 Accounting for Seasonal Patterns

Figure 7-1 presents the average active and passive indoor ABS air concentrations by season as measured during the 2007-08 indoor ABS study in OU4. As shown, indoor ABS air concentrations of LA tend to vary temporally, with concentrations tending to be highest in summer and lowest in winter. This is perhaps due to the interaction between outdoor ambient air and indoor air (recall that a similar temporal pattern was seen for ambient air, see **Figure 5-6**). Because of this temporal variability, and because the sampling frequency has not been equal across seasons, for the purposes of calculating long-term average exposures over multiple years, the indoor ABS air EPC was calculated using the following approach:

$$EPC = \sum \bar{X}_i \cdot 1/S$$

where:

EPC = Long-term average indoor ABS air exposure point concentration (PCME LA s/cc)

$\bar{X}_i$ = Average indoor ABS air concentration for season '*i*' (PCME LA s/cc)

1/S = One season weighting factor, where '*S*' is the number of seasons represented in the dataset

For the purposes of this calculation, seasons were defined as follows:

- Spring: March, April, May
- Summer: June, July, August
- Fall: September, October, November
- Winter: December, January, February

Table 7-2 presents summary statistics of the measured TEM air concentrations for active and passive behaviors for each interior removal status category for OU4 and OU7.

7.1.2.3.2 Accounting for Different Indoor Disturbance Behaviors

Because it is expected that individuals may engage in a range of indoor behaviors (active and passive), to account for differences in behavior types in long-term exposure estimates, both EPC values were used in the risk estimates, but were time-weighted as follows:

$$Risk = (EPC_{active} \cdot TWF_{active} \cdot IUR_{LA}) + (EPC_{passive} \cdot TWF_{passive} \cdot IUR_{LA})$$

$$HQ = (EPC_{active} \cdot TWF_{active} / RfC_{LA}) + (EPC_{passive} \cdot TWF_{passive} / RfC_{LA})$$

where:

EPC_{active} = Exposure point concentration, during active behaviors (PCME LA s/cc)

TWF_{active} = Time-weighting factor for active behaviors (unitless)

$EPC_{passive}$ = Exposure point concentration, during passive behaviors (PCME LA s/cc)

$TWF_{passive}$ = Time-weighting factor for passive behaviors (unitless)

7.1.3 Risk Estimates

Table 7-3 presents the estimated cancer risks and non-cancer HQs for residential and indoor worker exposures to LA in indoor air in OU4 and OU7 based on RME (Panel A) and CTE (Panel B). As shown, with the exception of indoor exposures at "pre-removal" properties (discussed below), when these exposure scenarios are considered alone, estimated RME and CTE cancer risks are less than 1E-05 and non-cancer HQs are less than 1 for all exposure scenarios.

Non-cancer HQs are greater than 1 (based on RME) for both residential and commercial exposures to LA inside "pre-removal" properties in OU4 (properties where an interior removal was deemed necessary, but a removal had not been completed at the time of the ABS). Activities associated with active disturbance behaviors contributed most to total exposures, compared to passive disturbance behaviors (see **Table 7-3** Panel A). Non-cancer HQs are less than 1 based on CTE (see **Table 7-3** Panel B). Although no indoor ABS data are available for pre-removal properties in OU7, it is expected that the conclusions based on OU4 data would also apply to OU7.

Non-cancer HQs for "post-removal" properties are less than 1 based on RME (see **Table 7-3** Panel A). These results demonstrate that interior removals have been effective at mitigating sources of LA inside the property. Additionally, non-cancer HQs for "no removal required" properties are also less than 1 based on RME, which indicates that interior property assessments performed by the field teams are effective at identifying when removal efforts are not needed.

7.2 Tradesperson Exposures Inside Properties in OU4 and OU7

7.2.1 Exposure Populations and Parameters

Previous investigations conducted at the Site have demonstrated that LA may be present in VI and building materials in residential and commercial properties in OU4 and OU7. Thus, another population of interest for evaluating exposures to LA inside properties are local tradespeople (e.g., local contractors, electricians, carpet layers, plumbers), that may come into direct contact with LA-containing building materials (e.g., VI, asbestos-containing building materials, indoor dust) while engaging in occupational activities.

Table 7-1 presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential tradesperson exposures inside properties in OU4 and OU7.

7.2.2 Investigation Summary

In accordance with Occupational Safety and Health Administration (OSHA) requirements, during indoor removal activities, health and safety (H&S) monitoring of EPA-contracted workers is performed during various types of removal activities and samples are analyzed by PCM (see Section 2.3.2). A subset of the archived H&S air monitoring samples from properties in OU4 were re-analyzed by TEM in 2012 to support an evaluation of potential risks to local tradespeople from inhalation of LA during disturbances of indoor source materials (CDM Smith 2012b). These samples were selected to represent a range of indoor removal activities, including low intensity disturbances (e.g., wet-wiping and vacuuming living spaces using a HEPA vacuum, attic detailing) and high intensity disturbances (e.g., removal of bulk VI, wall demolition).

Detailed results from the H&S air sample re-analysis effort are presented in CDM Smith (2013j). **Table 7-4** presents summary statistics of the measured TEM PCME air concentrations for each type of indoor removal activity. The mean air concentration for each type of removal activity was used as the EPC in the risk calculations.

7.2.3 Risk Estimates

Table 7-5 presents the estimated cancer risks and non-cancer HQs for tradesperson exposures to LA in indoor air at residential and commercial properties in OU4 and OU7 based on RME (Panel A) and CTE (Panel B). As shown, exposures of local tradespeople have the potential to result in RME non-cancer HQs greater than 1 for every disturbance activity evaluated, with HQs ranging from 4 to 20, depending upon the activity. Estimated CTE non-cancer HQs also approached or exceeded 1 for all activities. In addition, estimated RME cancer risks also were greater than or equal to 1E-04 for most activities. Although not included in the LA exposure estimates, as shown in **Table 7-4**, other types of asbestos (chrysotile, amosite, crocidolite, and anthophyllite) were also detected in several collected air samples (CDM Smith 2013j).

These results indicate that local tradesperson exposures have the potential to be significant if appropriate personal protective measures are not employed to mitigate exposures during active disturbances of indoor source materials. It is important to note that, even for properties that have had an interior removal or where no interior removal has been deemed necessary, there is the potential for tradesperson exposures to occur if source materials have been left in place (e.g., VI may be left if place if it is well-contained within walls [EPA 2003a]). Although no tradesperson exposure data are available for properties in OU7, it is expected that the conclusions based on OU4 data would also apply to OU7.

Table 7-5 (Panel C) also provides information on potential exposures to residents that frequently perform their own home remodeling projects (i.e., the "weekend warrior" exposure scenario), using the tradesperson EPCs as surrogate exposure values, since they represent a range of disturbance activities. For the purposes of these risk estimates, it was assumed that a resident performs 10 remodeling projects in their lifetime, that each project requires 12 weekends of work (Saturday and Sunday), and remodeling activities are performed for 4 hours each workday. As illustrated, estimated cancer risks are less than or equal to 1E-05 and non-cancer HQs are less than 1, when this exposure scenario is considered alone. However, the non-cancer HQ approaches 1 when the remodeling activity included the removal of bulk VI.

7.3 Inside Schools in OU4

7.3.1 Exposure Parameters

There are two main receptor populations of interest for evaluating exposures inside schools – students and teachers. Because the student population differs by the type of school (i.e., younger children attend elementary school, older children attend high school), student exposure parameters were determined separately by school in OU4 and are based on information provided by school administrators. **Table 7-6** presents the selected exposure parameter values and calculated TWFs for indoor exposures at each school.

7.3.2 Investigation Summary

In December 2008, a study was conducted to evaluate indoor air concentrations of LA inside schools in OU4 (EPA 2008h). To minimize classroom disruption, samples were collected using stationary air monitors placed in multiple locations within each school building. Ten locations were selected per school building, generally including four classrooms, the lunch room/cafeteria, the gymnasium, and four hallways. To ensure that all samples were representative of average exposure conditions, each sample was collected over a period of two days. Sampling occurred only during the times that each location is typically used by students. That is, during extended periods when classroom or common areas (e.g., gymnasium, cafeteria) were vacant, sampling pumps were turned off until students returned. Hallways and other areas (e.g., library) that are used intermittently throughout the day were sampled for the entire school day. For each sampling location, the sampling cassette was placed at a level corresponding to the breathing zone of the students occupying the room. For example, in a classroom where students are usually seated at desks, the cassette was placed at the height of the face of a seated student. Conversely, in the gymnasium and hallways, the cassettes were placed at the height of a standing student. Detailed results of the indoor ABS at the OU4 schools are presented in (EPA 2010e).

Table 7-7 presents summary statistics of the measured TEM air concentrations by school. As shown, for several schools, all indoor ABS air samples collected were non-detect for PCME LA (mean achieved analytical sensitivity of about 0.0006 cc^{-1}). The mean air concentration (i.e., a concentration of zero) was used as the EPC in the risk calculations. The uncertainty assessment (Section 10) provides additional information on risk estimates for datasets where all samples are non-detect.

7.3.3 Risk Estimates

Table 7-8 presents the estimated cancer risks and non-cancer HQs for exposures to LA in indoor air in OU4 schools. As shown, these results indicate that, when these exposure scenarios are considered alone, estimated cancer risks are less than 1E-06 and non-cancer HQs are less than 0.1 for all exposure scenarios inside OU4 schools. Although there are no measured ABS data inside schools in OU7 (Troy), it is assumed that exposures and risks would be similar to those for OU4 since these schools were evaluated using procedures similar to OU4 and the OU4 indoor ABS exposure scenarios are representative of the types of activities that would occur inside OU7 schools. The contribution of these exposure scenarios to cumulative risk is discussed in Section 9.

7.4 Inside the Search and Rescue Building in OU1

As discussed previously, OU1 includes areas that were part of the former Export Plant (see **Figure 1-5**). The David S. Thompson Search and Rescue Building is the only building in OU1 that is regularly occupied. The Search and Rescue Building was constructed on the northwest portion of OU1 in 2004 (see **Figure 6-4**), and includes an office and a five-bay garage. The garage is used for storing search and rescue equipment and vehicles. Several other agencies, including local and state law enforcement, also hold meetings in the main office.

7.4.1 Exposure Populations and Parameters

Volunteer staff and individuals that attend meetings at the Search and Rescue Building may be exposed to LA in indoor air while inside the building. Exposure parameter data were obtained through a questionnaire administered in 2008 to individuals that use the building, including Search and Rescue volunteers. The detailed results of the survey are provided in **Appendix H**. **Table 7-9** presents the selected exposure parameter values and calculated TWFs for worker exposures inside the Search and Rescue Building in OU1.

7.4.2 Investigation Summary

An indoor ABS investigation was conducted inside the Search and Rescue Building in 2008. The results of this investigation were used in the *OU1 RI* (EPA 2009c) to evaluate potential risks to workers inside the Search and Rescue Building. At that time, it was concluded that risks from indoor exposures were within or below EPA's acceptable risk range (EPA 1991b). However, several additional remedial actions were conducted in OU1 since the indoor ABS investigation (CDM Smith 2013e). In accordance with the *OU1 ROD* (EPA 2010a), following implementation of the remedy, a post-construction risk assessment is needed to evaluate the effectiveness of the remedy for workers at the Search and Rescue Building. Thus, additional sampling data were deemed necessary to represent more recent conditions and evaluate post-ROD exposures.

Although there are no indoor ABS data that have been collected post-ROD inside the Search and Rescue Building, there are air clearance air samples that were collected in 2012 which provide data on indoor air concentrations of LA inside the building. In July 2012, a series of clearance air samples were collected in response to a citizen request. Clearance air samples were collected immediately following the use of a leaf blower inside the office and garage. The action of aggressively blowing dust from indoor surfaces effectively simulates a high-end exposure scenario. Following leaf blowing, fans were used to keep the air circulating and clearance air samples were collected using stationary air monitors. A total of five clearance air samples were collected; two samples from the office (meeting room and kitchen) and three samples from the garage. These samples were originally analyzed in 2012 and reported as non-detect (achieved analytical sensitivity of 0.009 cc^{-1}). The samples were re-analyzed in 2014 to achieve a better (lower) analytical sensitivity in support of their use in the risk assessment.

Table 7-10 (Panel A) presents summary statistics for the clearance air samples inside the Search and Rescue Building. The mean air concentration for each area (office, garage) was used as the EPC in the risk calculations.

7.4.3 Risk Estimates

Table 7-10 presents the estimated cancer risks and non-cancer HQs for exposures to LA inside the Search and Rescue Building in OU1 based on RME (Panel B) and CTE (Panel C). As shown, when this exposure scenario is considered alone, estimated RME and CTE cancer risks are less than 1E-05 and non-cancer HQs are less than or equal to 0.1 for both the office and garage under post-ROD conditions. These results support the risk conclusions of the earlier HHRA (EPA 2009c). The contribution of these exposure scenarios to cumulative risk is discussed in Section 9.

7.5 Inside Buildings in OU5

OU5 includes the former Stimson Lumber Mill and all properties owned by KBPID (see **Figure 1-5**). The majority of lumber production activities ceased in 2003, but there are still several buildings in OU5 (some vacant and some occupied) that are, or could be used in the future, for commercial/industrial purposes.

7.5.1 Exposure Populations and Parameters

The primary population of interest for the purposes of evaluating exposures inside OU5 buildings is commercial/industrial workers. Information on exposure parameters for indoor workers at OU5 was obtained through a questionnaire in the fall of 2007 for five of the eight occupied buildings at OU5. **Appendix H** summarizes the results of this survey. As shown, exposure information differed by building, with some buildings used frequently (e.g., the CDM Smith field office) and others used only occasionally (e.g., scale house). For vacant buildings where site-specific information on exposure was not available, exposure parameters were based on EPA default values for indoor workers.

Table 7-11 presents the selected exposure parameter values and calculated TWFs for worker exposures inside buildings in OU5.

7.5.2 Investigation Summary

In November/December 2007, EPA collected indoor ABS samples at 21 buildings in OU5 (CDM Smith 2007a). For the eight buildings that were occupied at the time of the study, an EPA contractor performed two types of indoor worker activity scenarios, including active behaviors (e.g., dust a desk or computer, sweeping or vacuuming a floor, walking from room to room) and passive behaviors (e.g., sitting at a desk working at a computer). Each activity was conducted for approximately two hours. For the 13 buildings that were vacant at the time of the study[23], five stationary air monitors were set up (one in the center of the building and one in each corner) and monitoring was performed following disturbance of the area with a leaf blower (i.e., a high-end active indoor disturbance scenario). Each stationary air sample was collected for a period of four hours following the disturbance.

Detailed results of the OU5 indoor ABS investigation are summarized in the *OU5 RI* (HDR 2013a). **Table 7-12** presents summary statistics of the measured TEM air concentrations for each building for each type of indoor disturbance activity. The mean air concentration for each building, stratified into active and passive behaviors, was used as the EPC in the risk calculations.

7.5.3 Risk Estimates

Table 7-13 presents the estimated cancer risks and non-cancer HQs for exposures to LA inside the buildings in OU5 based on RME (Panel A) and CTE (Panel B). As shown, with the exception of the Central Maintenance Building and the CDM Smith Libby field office (discussed below), estimated RME and CTE cancer risks are less than 1E-05 and non-cancer HQs are less than 1 for all buildings in OU5, when these indoor exposure scenarios are considered alone. The contribution of these exposure scenarios to cumulative risk is discussed in Section 9.

For the Central Maintenance Building, the RME non-cancer HQ is 1. Although an interior removal of VI was completed for at the Central Maintenance Building in 2005, residual indoor VI remained in wall cavities (HDR 2013a). Since the time of the ABS, additional response activities have been conducted at the Central Maintenance Building to remove asbestos-containing material from the roof (October 2010), to perform interior cleanings (November 2011), and to remove VI from walls (October 2012 and November 2013). Following these response actions, air clearance samples were collected to demonstrate that indoor air concentrations were non-detect.

The RME non-cancer HQ is also 1 for the CDM Smith Libby field office based on indoor ABS data collected in 2007. However, subsequent ongoing indoor air monitoring of the CDM Smith Libby field office shows that, of the more than 350 indoor air samples collected since the ABS study, LA structures have been detected in only 9 samples, with an overall average PCME LA air concentration of 0.000063 s/cc (about 20 times lower than the "active" ABS air concentrations).

This suggests that the 2007 indoor ABS datasets for the Central Maintenance Building and the CDM Smith Libby field office may be biased high relative to current exposure conditions. CTE cancer risks are less than 1E-05 and non-cancer HQs are less than 1 for both buildings.

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[23] Since this ABS study, two vacant buildings originally sampled have either burned (plywood plant) or been demolished (log yard pump house). In addition, one vacant building (boundary injection building) that was within the OU5 boundary at the time is now outside the current boundary of OU5.

7.6 Overall Risk Conclusions

In reviewing the risk calculation tables for indoor air exposures, there are a number of general conclusions that can be drawn:

- With the exception of indoor exposures at "pre-removal" residential/commercial properties and during tradesperson activities, estimated RME cancer risks are less than 1E-04 and non-cancer HQs are less than or equal to 1 for all indoor exposure scenarios.

- Residential and indoor worker exposures to LA have the potential to result in risks that are above a level of human health concern for properties in OU4/OU7 where it has determined that an interior removal is necessary, but no removal has been performed ("pre-removal"). Estimated RME HQs are less than 1 for properties where an interior removal has been completed ("post-removal") and where an interior removal is deemed not to be necessary ("no removal required"). These results demonstrate that interior property assessments have been effective at identifying when interior removals are not warranted and that interior removals, when performed, have been effective at mitigating sources of LA inside the property.

- Local tradesperson exposures have the potential to be significant and result in cancer risks greater than 1E-04 and non-cancer HQs greater than 1 (based on both RME and CTE) if appropriate personal protective measures are not employed to mitigate exposures during active disturbances of indoor source materials that contain LA. There is the potential for tradesperson exposures to occur, even for properties that have had an interior removal or where no interior removal has been deemed necessary, if source materials have been left in place (e.g., VI contained within walls).

Section 8

Risks from Exposures During Disturbances of Wood-Related Materials

Extensive data on LA levels on the bark surface of trees have been collected in the forested area near the mine (CDM Smith 2015a) and in the forested area near the current NPL boundary for the Site (CDM Smith 2013g). These data show that LA fibers are present on the outer bark surface of trees at the Site. Tree bark surface loading values of LA tend to be highest on trees closest to the mine (within about 3-4 miles), but LA was also detected on trees located even 13 miles from the mine (CDM Smith 2013g). LA has also been detected in other wood-related materials, including wood waste piles at Lincoln County landfills (Tetra Tech 2012c) and in woodchip/waste bark piles located in OU5 (CDM Smith 2007b,c).

If LA-containing trees or wood-related materials are disturbed, such as during wood harvesting activities or during gardening activities in landscaped areas covered by woodchips or mulch, people may become exposed to LA that is released to air from the wood. If LA-containing trees are used as a source of firewood (e.g., in a residential woodstove), studies have shown that LA fibers can become concentrated in the resulting ash (CDM Smith 2013k; Ward *et al.* 2009), which itself can become a source of potential LA exposure. Additionally, in the event of a wildfire, it is possible that LA may also be released to outdoor air when trees are burned in the fire. The various wood-related exposure media, exposure scenarios, and exposure populations are illustrated in **Figure 2-1** and **Table 2-1**.

There have been several ABS investigations to evaluate LA concentrations in air during various wood-related disturbance scenarios. **Table 2-2** (Panel B) summarizes the types of wood-related ABS investigations that have been conducted. As shown, these studies provide measured data on LA concentrations in air during a variety of wood-related disturbance exposure scenarios. The studies that have been performed for each exposure scenario are summarized briefly below. The following sections summarize the exposure scenarios by which receptors may be exposed to LA during disturbances of wood-related materials, identify the exposure populations for each scenario, present the selected RME and CTE exposure parameter values and calculated TWFs for each scenario. These sections also summarize the results of studies performed at the Site to evaluate wood-related exposures, describe how these data are used to calculate exposures, and present estimated cancer risks and non-cancer HQs for each exposure scenario.

8.1 Exposure Scenarios

8.1.1 Residential Wood Harvesting

8.1.1.1 Exposure Populations and Parameters

Local area residents may harvest/collect firewood from forested areas within the NPL boundary for use in residential fireplaces and woodstoves. Residential wood harvesting activities may include sawing, hauling, and stacking wood for personal use. During these activities, residents may be exposed to LA when fibers are released to air from the surface of the tree bark. **Table 8-1** presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential exposures during residential wood harvesting activities.

8.1.1.2 Investigation Summary

Outdoor ABS was conducted in the summer of 2010 at three locations in the forested area downwind (northeast) of the mine site (EPA 2010f). The three ABS areas (ABS-06'[24], ABS-07, ABS-02) were selected to represent locations at increasing distance from the mine site (i.e., approximately 2 miles [near], 4 miles [intermediate], and 8 miles [far] from the mine site) (see small red dots in **Figure 6-7**). The ABS activities included felling trees with a chainsaw, de-limbing and cutting felled trees to length, and stacking harvested wood. Activities were performed by Grace's contractors in accordance with an EPA-developed SAP (EPA 2010f). A total of five sampling events were conducted in each ABS area between July and August 2010. Detailed results from this ABS study are presented in CDM Smith (2015a). **Table 8-2** (Panel A) presents summary statistics of the wood harvesting results for each ABS area. The mean air concentration for each ABS area was used as the EPC in the risk calculations.

8.1.2 Commercial Logging

8.1.2.1 Exposure Populations and Parameters

Workers who are employed in commercial logging operations may harvest wood from forested areas within the NPL boundary. Logging operations may include a variety of activities performed manually or by machinery, including felling, skidding, de-limbing, sawing, stacking, and milling timber. During these activities, workers may be exposed to LA when fibers are released to air from the surface of the tree bark. Additionally, commercial logging workers may also be exposed to LA due to soil/duff disturbances (e.g., while dragging logs across the ground or during site restoration activities). Because potential exposures likely differ depending upon the type of logging activity, and different workers may perform different jobs at a logging parcel, exposures are evaluated separately by job type. **Table 8-1** presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential exposures during commercial logging activities.

8.1.2.2 Investigation Summaries

In September of 2012, ABS was conducted to evaluate the potential exposures to outdoor workers during commercial logging activities near the mine in OU3 (EPA 2012b). The selected tree harvesting area was located approximately one mile downwind (northeast) of the mine site in a location where higher concentrations of LA had been reported in tree bark and duff in earlier studies (see **Figure 8-1**). The ABS activities included hand-felling of trees with a chainsaw, "hooking and skidding" felled trees to a central landing area, mechanical de-limbing and cutting of timber, and site restoration of the landing area using a bulldozer. In addition, it also included a wood chipping scenario to simulate potential exposures during timber milling activities. Detailed results from the 2012 commercial logging ABS study are presented in SRC, Inc. (2013b).

In September of 2014, a second commercial logging ABS investigation (CDM Smith 2014i) was conducted in an area at a further distance from the mine, located approximately 4 miles downwind (northeast) of the mine site (see **Figure 8-1**). The ABS activities included the same types of commercial logging activities evaluated in 2012. Detailed results from the 2014 commercial logging ABS study are presented in CDM Smith (2015g).

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[24] Although the Phase IV, Part A study design was to perform ABS activities in area ABS-10, the location of the activities was modified at the time of collection to be located about 1 mile further downwind, closer to the Phase III ABS-06 area. Thus, to avoid potential confusion, the location of this area is referred to as ABS-06'.

Table 8-2 (Panel B) presents summary statistics of the commercial logging results for each type of logging activity for both the 2012 and 2014 investigations. The mean air concentration for each activity was used as the EPC in the risk calculations.

8.1.3 Wood Chipping

8.1.3.1 Exposure Populations and Parameters

Because local agencies have discouraged the burning of wood waste materials, wood waste generated from area residences and businesses has accumulated at the Lincoln County landfills. To reduce the volume of these wood waste piles, materials are regularly chipped. Because LA has been detected in the wood waste piles at both Lincoln County landfills (Tetra Tech 2012c), outdoor workers that perform these wood-chipping operations have the potential to be exposed to LA. **Table 8-1** presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential outdoor worker exposures during wood-chipping activities.

8.1.3.2 Investigation Summary

There have been two ABS studies conducted that provide information on potential exposures during wood-chipping activities. As discussed above (see Section 8.1.2), wood-chipping activities were conducted as part of the OU3 commercial logging study to simulate exposures during the milling process.

In addition, ABS was also performed in April of 2013 during wood-chipping of the wood waste pile at the Lincoln County landfill in Troy (OU7) (CDM Smith 2013l). This wood waste pile included both "raw" wood materials (e.g., large tree limbs, smaller branches and twigs, tree stumps) and manufactured wood materials (e.g., wood pallets, lumber, plywood). The ABS program included the collection of multiple personal air samples for the laborer operating the wood chipper, as well as the collection of stationary air samples for monitors located at varying distances downwind of the chipping activity. **Table 8-2** (Panel C) presents summary statistics of the wood-chipping results from the landfill. As shown, all ABS air samples collected as part of this sampling program were non-detect for PCME LA (mean achieved analytical sensitivity of 0.002 cc^{-1}). The mean air concentration (i.e., a concentration of zero) was used as the EPC in the risk calculations. The uncertainty assessment (Section 10) provides additional information on risk estimates for datasets where all samples were non-detect.

8.1.4 Forest Maintenance

8.1.4.1 Exposure Populations and Parameters

Outside of the Libby and Troy communities, most of the land within the current NPL boundary consists of forest, much of which is managed and maintained by USFS. USFS land management workers have the potential to be exposed to LA during forest maintenance activities. These activities may include tree stand examination and surveying, thinning vegetation and trimming trees, measuring trees, maintenance of roads and trails, etc. **Table 8-1** presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential exposures during forest maintenance activities.

8.1.4.2 Investigation Summary

In the summer of 2010, ABS was performed at three locations in the forested area downwind (northeast) of the mine site (EPA 2010f). The three ABS areas were co-located with the areas evaluated in the residential wood harvesting ABS study (see Section 8.1.1), and selected to represent locations at increasing distance from the mine site (see pink, orange, and green dots in **Figure 6-7**).

The ABS activities evaluated in this study were designed to simulate the types of activities routinely performed as part of the USFS land management worker responsibilities, including maintenance of roads and trails, thinning of trees and vegetation, and surveying trees. Activities were performed by Grace's contractors in accordance with an EPA-developed SAP (EPA 2010f). A total of five sampling events were conducted in each ABS area between July and August 2010. Detailed results from this ABS study are presented in CDM Smith (2015a). **Table 8-2** (Panel D) presents summary statistics of the USFS forest maintenance results for each ABS area. The mean air concentration for each ABS area is used as the EPC in the risk calculations. The uncertainty assessment (Section 10) provides additional information on risk estimates for datasets where all samples are non-detect.

8.1.5 Wood Chip/Mulch Disturbances

8.1.5.1 Exposure Populations and Parameters

Several woodchip and waste bark piles were left at OU5 from historical lumber processing activities. As noted above, sampling and analysis of these piles has shown LA is present in these wood materials. Woodchips from these piles have been sold and given away for use as landscaping mulch in gardens, flowerbeds, playgrounds, etc. There are two populations that were selected for the purposes of evaluating potential exposures to LA during woodchip/mulch disturbance activities – outdoor workers that disturb the piles in OU5 during occupational activities and residents that disturb woodchip/mulch landscaping materials. **Table 8-1** presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential exposures during woodchip/mulch disturbance activities.

8.1.5.2 Investigation Summary

In October of 2007, test pit excavations were performed at the woodchip and waste bark piles in OU5 to investigate whether disturbances of these piles was of potential concern to outdoor workers (CDM Smith 2007b). Excavations consisted of digging a pit into the side of the pile with an excavator (i.e., back hoe). Personal ABS air samples were collected for the excavator operator and the sampling personnel during the waste bark and woodchip pile test pit excavations.

In August of 2011, ABS was conducted to provide data on LA concentrations in air during woodchip disturbances, simulating activities that might be performed by a gardener (CDM Smith 2012b). During this ABS study, woodchips were collected from each of the two piles in OU5 and these materials were used to conduct ABS. The ABS activities included digging in the woodchips, using both a long shovel and a trowel, and raking the woodchips. Three sampling events were performed for each of five sets of collected woodchip materials.

Table 8-2 (Panel E) presents summary statistics of results for each woodchip disturbance investigation. All ABS air samples collected as part of these two sampling programs were non-detect for PCME LA. The mean air concentration (i.e., a concentration of zero) was used as the EPC in the risk calculations. The uncertainty assessment (Section 10) provides additional information on risk estimates for datasets where all samples are non-detect.

8.1.6 Ash Disturbances

8.1.6.1 Exposure Populations and Parameters

Trial burn experiments in woodstoves (Ward *et al.* 2009) and in test burn chambers (EPA 2012c) indicate that the majority of LA structures are retained in the ash when wood and duff materials are burned. Because the LA becomes concentrated in ash, this has the potential to be an important source media for LA exposures. If LA-containing firewood is burned in a residential woodstove, residents may be exposed to LA that is released to air from the resulting ash during removal of ash from the woodstove. **Table 8-1** presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential exposures during woodstove ash disturbance activities.

8.1.6.2 Investigation Summary

In 2012, EPA conducted an ABS study to measure LA concentrations in air during woodstove ash-removal activities (CDM Smith 2012f). For this study, firewood was collected from dead trees at three locations at varying distances from the mine site (see **Figure 8-2**) – near the mine (approximately one mile downwind of the mine site), near Flower Creek (approximately 2 miles south of Libby and 9 miles upwind of the mine), and near Bear Creek (approximately 10 miles south of Libby and outside the current NPL boundary). The firewood collected from each location was burned in a woodstove (tree bark was not removed prior to burning). The resulting ash was removed from the woodstove using a long-handled metal shovel and placed into a metal ash bucket (similar to what might be done by a resident). Detailed results from this ABS study are presented in CDM Smith (2013k). **Table 8-2** (Panel F) presents summary statistics of the measured ABS air concentrations for each firewood collection location. The mean air concentration for each location was used as the EPC in the risk calculations.

8.1.7 Fires

8.1.7.1 Exposure Populations and Parameters

A fire that occurs in an area of the forest where the trees and duff contain LA could result in the release of LA fibers into air, which has the potential to expose people to LA in areas near and downwind of the fire. There are several types of fires that could occur at the Site, including slash pile burns (e.g., when slash from logging or forest maintenance activities is consolidated into piles and burned), prescribed burns (e.g., when USFS forest workers perform understory burns to reduce fuel loads as part of wildfire mitigation practices), and authentic wildfires (e.g., fires that occur due to lightning strikes).

There are three populations of interest for the purposes of evaluating LA exposures during fires –USFS forest workers, responding firefighters, and local residents. Depending upon the size of the fire and location, there may be both ground-based and air-based responding firefighters. Because potential exposures likely differ for each, firefighter exposures are evaluated separately for ground-based and air-based responders. (Recall that exposures to ground-based USFS firefighters while simulating fireline cutting were evaluated in Section 6.6, as this type of exposure scenario is mainly associated with soil/duff disturbance activities [see **Table 6-17**].) Exposures during slash pile burns and understory burns are also evaluated separately because the nature of the LA releases and frequency of occurrence may differ for each type of burn. **Table 8-3** presents the selected RME and CTE exposure parameters values and calculated TWFs for evaluating potential exposures during fire-related activities.

8.1.7.2 Investigation Summary

8.1.7.2.1 Slash Pile and Understory Burns

In April 2015, two investigations were conducted in OU3 to provide information on potential exposures during fire-related activities, namely during the burning of slash piles (EPA 2015h) and during an understory burn (EPA 2015i). These two activities were selected because they are representative of the types of activities that might be performed by USFS forest workers and fire fighters as part of forest maintenance activities. Both investigations were conducted in an area located approximately one mile downwind (northeast) of the mine site in a location where higher concentrations of LA had been reported in tree bark and duff in earlier studies (this was the same location evaluated as part of the 2012 commercial logging investigation; see **Figure 8-1**).

During the slash pile burn, a slash pile, fuel break, and fire line were created, using heavy equipment (an excavator), and the resulting slash pile was burned. During the burn, ABS air samples were collected for two individuals monitoring the fire as well as from several perimeter air monitors placed around the fire approximately 50, 100, and 200 feet away from the edge of the fire line. After the slash pile was burned, the heavy equipment entered the burn area to address any remaining "hot spots" throughout burn area and simulate "mop-up" activities (i.e., mixing, stirring, and digging up the mineral soil using the bucket of the excavator). Two types of mop-up activities were performed, including include a "dry" mop-up scenario (i.e., where no water is applied during the mop-up activity) and a "wet" mop-up scenario (i.e., where water is applied during the mop-up activity).

During the understory burn, a 0.1-acre understory burn was conducted in basic accordance with the *Prescribed Fire Guidelines* established by the Montana Department of Natural Resources and Conservation (MDNRC 2007). Activities were performed by Grace's contractors in accordance with the EPA-developed QAPP (EPA 2015i). Similar to the slash pile burn, ABS air samples were collected for two individuals monitoring the fire as well as from several perimeter air monitors placed around the fire approximately 50, 100, and 200 feet away from the edge of the fire line. After the flames had been extinguished, two individuals entered the burn area to perform mop-up activities using hand tools (e.g., a Pulaski axe to mix, stir, and dig up the mineral soil) under both dry and wet mop-up conditions.

Results of the two ABS burn studies are summarized in CDM Smith (2015e).

Table 8-4 (Panel A and B, respectively) presents summary statistics of the measured air concentrations for each sample type collected during the slash pile burn and the understory burn. The mean air concentration for each sample type was used as the EPC in the risk calculations. For the purposes of estimating potential exposures to nearby residents, it was assumed that air concentrations in the community were equal to those measured at the perimeter monitor located 200 feet from the fire (a highly conservative assumption).

8.1.7.2.2 Souse Gulch Wildfire

In the event of an authentic wildfire that is in or near the current NPL boundary, there are sampling plans in place at the Site (EPA 2013a; CDM Smith 2013m) to collect opportunistic air samples, both at stationary monitors throughout the Libby community and near the wildfire (to evaluate exposures to firefighters). To date, air samples have only been collected during one wildfire event.

In late July 2013, a small (1.5 acre) wildfire occurred in the Souse Gulch day-use recreation area on Lake Koocanusa behind Libby Dam (approximately 2.5 miles southeast from the mine). During this fire, air samples were collected to provide data on LA exposures of responding firefighters (both to the ground crews and the aircraft support pilot) and downwind LA concentrations in air during the fire. **Table 8-4** (Panel C) presents summary statistics of the measured air concentrations for each sample type collected. The mean air concentration for each sample type was used as the EPC in the risk calculations.

8.2 Risk Estimates

8.2.1 Risks from Wood-Related Disturbances

Table 8-5 presents the estimated cancer risks and non-cancer HQs for exposures to LA during disturbances of wood-related materials based on RME (Panel A) and CTE (Panel B). These results indicate that, when these exposure scenarios are considered alone, RME and CTE cancer risks are less than 1E-04 and non-cancer HQs are less than 1 for most exposure scenarios. Non-cancer HQs for commercial logging activities and woodstove ash disturbance activities are greater than 1 based on RME when these activities are performed near the mine (about one mile from the mine). The following subsections provide further discussion of the estimated risks from commercial logging and woodstove ash disturbance activities. The contribution of these exposure scenarios to cumulative risk is discussed in Section 9.

8.2.1.1 Risks from Commercial Logging

When commercial logging activities were conducted near the mine (about one mile from the mine in an area with high concentrations of LA in bark and duff), non-cancer HQs based on RME are greater than 1 for skidding/hooking activities and site restoration activities (see **Table 8-5**). However, estimated RME and CTE cancer risks are less than 1E-05 and non-cancer HQs are less than 1 when commercial logging activities were performed in 2014 further from the mine (about four miles from the mine in an area where bark and duff LA levels were lower).

In reviewing the commercial logging ABS results near the mine, there are several general observations. First, LA concentrations in air during tree-felling tended to be lower than other logging activities and similar to measured ABS air concentrations during residential wood harvesting (see Panel A of **Table 8-2**). Second, air concentrations during hooking/skidding and site restoration activities, which included both disturbances of wood as well as soil and duff materials, tended to be about an order of magnitude higher than during felling activities, which was primarily a bark disturbance scenario (i.e., limited soil/duff disturbances). These data suggest that disturbances of soil/duff may be more important sources of LA exposure to commercial logging workers than tree bark.

8.2.1.2 Risks from Woodstove Ash Disturbances

Non-cancer HQs associated with the removal of ash from a woodstove differed depending on the source of the firewood that was burned (see **Table 8-5**). If firewood was collected from a location near the mine (about one mile from the mine where tree bark LA levels are highest), the RME HQ for LA exposures during ash removal activities is 2. However, if firewood was collected from locations far from the mine (2-10 miles south of Libby), RME HQs are less than 0.1. There are no ABS air data that provide information on potential exposures if firewood is collected at locations intermediate from the mine (i.e., between 2-4 miles from the mine in the downwind direction) (see **Figure 2-2**).

These risk estimates demonstrate that ash may be an important source medium, if the ash is derived from a wood source in close proximity to the mine. The LA present in the ash is likely to be derived from fibers on the outer bark surface; however, there are no data that provide information on differences in LA content of outer bark and “inner” wood. There are also no data on potential LA exposures from ash disturbances when the source firewood has had the outer bark removed prior to burning.

Although risk estimates were calculated for one type of ash disturbance scenario, there are several other potential ash disturbance scenarios for which measured ABS air data are not available, including residential exposures to ash in outdoor fire pits or recreational visitor exposures to ash from campfires. There are also no ABS air data that provide information on potential residential exposures if LA-containing ash is disposed in gardens or flowerbeds.

8.2.2 Risks from Fire-Related Activities

Table 8-6 presents the estimated cancer risks and non-cancer HQs for exposures to LA during fire-related activities based on RME (Panel A) and CTE (Panel B). These results indicate that, when these exposure scenarios are considered alone, RME and CTE cancer risks are less than 1E-04, but non-cancer HQs are greater than or equal to 1 for several exposure scenarios related to the slash pile and understory burns. The RME non-cancer HQ is 2 during slash pile building activities and the RME non-cancer HQ ranged from 1 to 5 during mop-up activities for the understory burn (when mop-up activities were conducted by hand), depending upon whether the mop-up was conducted under wet or dry conditions, respectively. These risks indicate that USFS worker and fire fighter exposures have the potential to be significant if appropriate personal protective measures are not employed to mitigate exposures while conducting activities near the mine (i.e., within about one mile of the mine).

As noted in Section 8.1.6, burn tests show that the majority of LA structures are retained in the ash when wood and duff materials are burned. Following the slash pile and understory burns, ash samples were collected from the burn areas. Total LA concentrations of about 1,000 million structures per gram of ash (Ms/g) were measured in these burn areas, which supports the conclusion that ash can be an important source medium for LA exposures within burn areas after the fire has been extinguished (CDM Smith 2015e).

There are only limited ABS air data that provide information on potential exposures from fire-related activities in areas further from the mine. As shown in **Table 8-6**, RME cancer risks are less than or equal to 1E-06 and non-cancer HQs are less than 0.1 during an authentic wildfire response (Souse Gulch fire). As noted above, this small wildfire occurred approximately 2.5 miles southeast from the mine and demonstrates that exposures during fire-related activities depend upon proximity to the mine (i.e., fire-related exposures activities further from the mine have much lower risks, presumably because LA concentrations in source fuels are lower).

Table 8-6 also demonstrates that residential exposures in and around Libby from smoke generated by fires in OU3, both during simulated burns and during an authentic wildfire, result in RME non-cancer HQs less than 0.1. However, available data are only representative of small-scale, low-intensity fires; it is possible LA releases during larger, higher-intensity fires could be greater.

8.2.2 Calculation of Area-Weighted Risks

As described previously in Section 6.6.4, it is not feasible to evaluate risks by conducting ABS in the forest at every location within OU3. Most ABS investigations for OU3 were conducted in locations downwind from the mine (i.e., to the northeast); it is assumed that the risks in locations that are crosswind and upwind from the mine are equal to or lower than those calculated in **Tables 8-5 and 8-6** (see Section 10.1.3 for additional discussion on the uncertainties of this assumption).

The wood-related risk estimates presented in **Table 8-5** assume the entire exposure time is spent within the EPC grouping location (e.g., near, intermediate, far from the mine). However, it is likely long-term receptor exposures could encompass multiple EPC grouping locations. Therefore, exposure and risk estimates were also calculated to provide an area-weighted estimate, adjusted based upon the frequency of each areas use. For the purposes of these calculations, the exposure frequency for each EPC grouping location in the forested areas was determined based on areal extent (i.e., acreage of the concentric circle) as well as the area accessibility (i.e., what proportion of the area is in proximity to forest service roads and trails). The total exposure frequency is the same as presented in **Table 8-5**, but is split across multiple exposure locations.

Appendix G.3 illustrates the area-weighted exposures and risks from exposures to LA during wood-related disturbance activities in forested areas within OU3 based on RME. As shown, with one exception, during hooking/skidding activities during commercial logging, RME cancer risks are less than or equal to 1E-06 and non-cancer HQs are less than 1 based on the area-weighted risk estimates. For exposures during hooking/skidding activities, even when risks are calculated using area-weighting, the non-cancer HQ is 2; nearly all (99%) of the total LA exposure for this scenario is due to activities conducted within one mile of the mine.

Section 9

Evaluation of Cumulative Risk

Most people who live or work in Libby or Troy are likely to be exposed to LA by a combination of the exposure scenarios described and evaluated separately in Section 5 through Section 8. Consequently, it is important to estimate the total (cumulative) risk to a receptor who is exposed by multiple scenarios over their lifetime. The calculation of cumulative risk is complicated by the fact that the exposure pattern of each individual at the Site may be unique. However, EPA does not typically perform risk calculations for specific individuals, but rather for generic classes of receptor populations with common exposure patterns. Thus, the goal of the cumulative risk assessment is to characterize how cumulative risk depends on different types of disturbance activities, LA levels in the source media, and exposure locations.

Traditionally, the term "cumulative risk" is applied when risks are summed across multiple contaminants. However, LA is the only contaminant of concern at the Site. (Risks from non-asbestos chemicals were evaluated for OU3, but results indicated that exposures to non-asbestos chemicals were not of significant health concern [EPA 2013b]). Thus, it is more appropriate to refer to the summation of risks for LA across multiple exposure scenarios as "aggregate risk" (EPA 2003b). However, because discussions with the community have typically utilized the term "cumulative risk", this terminology will be maintained to avoid potential confusion and to maintain consistency with other Site documents which have already been finalized that use this terminology.

9.1 Basic Approach

Cumulative risk from LA is expressed as the sum of the risks across various types of exposure scenarios, calculated as follows:

$$\text{Cumulative Cancer Risk} = \left(\sum EPC_s \cdot TWF_s\right) \cdot IUR_{LA}$$

$$\text{Cumulative Non-Cancer HI} = \left(\sum EPC_s \cdot TWF_s\right) / RfC_{LA}$$

where:

EPC_s = Exposure point concentration for exposure scenario 's' (PCME LA s/cc)

TWF_s = Time-weighting factor for exposure scenario 's'

IUR_{LA} = LA-specific inhalation unit risk $(\text{PCM f/cc})^{-1}$

RfC_{LA} = LA-specific reference concentration (PCM f/cc)

These equations help emphasize a basic principle – the risk from any one exposure scenario depends both on the exposure concentration in air (which depends on the concentration in the source medium and on the nature of the disturbance), and on the frequency and duration of the exposure (reflected in the TWF term). While high exposure concentrations tend to increase risk, a high exposure concentration alone will not necessarily result in excess risk if the TWF is small. Conversely, while lower exposure concentrations tend to decrease risk, a low concentration may not necessarily result in low risk if the TWF is large. Rather, both exposure concentration (EPC) and exposure time (TWF) influence the risk equally. Likewise, the relative risk contributed by any one scenario depends on both EPC and TWF, and cannot be inferred from either one alone.

In summing across multiple exposure scenarios, it is important to note that the underlying exposure assumptions, which form the basis of the risk estimates, do not yield a cumulative TWF that is greater than 1.0. This is because the value of each scenario-specific TWF term describes the fraction of a lifetime during which asbestos exposure occurs for that scenario. Consequently, the sum of the TWF terms across all exposure scenarios may not exceed 1.0 (100% of a lifetime). In other words, the total number of hours of asbestos exposure cannot be greater than the total number of hours in a lifetime, which is assumed to be 70 years (i.e., 24 hours/day · 365 days/year · 70 years = 613,200 hours).

To illustrate this, suppose the cumulative exposure for a receptor includes the following six exposure scenarios:

1. Outdoor air in OU4 under ambient conditions
2. Outdoor air while fishing along the Kootenai River
3. Indoor air in a OU4 residential property during active behaviors
4. Indoor air in a OU4 residential property during passive behaviors
5. Outdoor air at an OU4 residential property during yard work
6. Indoor air in the Central Maintenance Building in OU5

If the RME TWF values used in the previous risk calculations were selected for use in the cumulative assessment, the cumulative TWF across these six exposure scenarios would be greater than 1.0:

Exposure Scenario	RME TWF_s (Source)	Hours of exposure in a lifetime*
A-Outdoor air, OU4, ambient conditions	0.20 (Table 5-3)	122,640
B-Outdoor air, OU3, fishing along Kootenai River	0.041 (Table 6-15)	25,141
C-Indoor air, OU4, residential property, active	0.17 (Table 7-1)	104,244
D-Indoor air, OU4, residential property, passive	0.50 (Table 7-1)	306,600
E-Outdoor air, OU4, residential property, yard work	0.034 (Table 6-1)	20,849
F-Indoor air, OU5, Central Maintenance Building	0.11 (Table 7-11)	67,452
Cumulative:	**1.055**	**646,926**

*Calculated as RME TWF_s · 613,200 hours

Typically, RME estimates are based on a 95th percentile estimate (or another high-end statistic) of a population for any activity (EPA 1989). The cumulative impact of adding a series of 95th percentile estimates will result in a total exposure that is higher than physically possible. *Therefore, cumulative risk for various combinations of exposure scenarios cannot be calculated simply by summing the estimated risks presented in Section 5 through Section 8 without checking to be sure the total TWF does not exceed 1.0.*

Instead, exposure-specific TWF values for use in the cumulative assessment must be selected by specifying the fraction of the lifetime spent engaging in each exposure scenario, taking care to ensure that the cumulative TWF is equal to 1.0. This approach is illustrated in **Figure 9-1**. In this example, the cumulative exposure scenario includes the same set of six exposure scenarios described above, but the TWF values have been adjusted to ensure that the total number of hours of asbestos exposure does not exceed a 70-year lifetime of 613,200 hours (i.e., the cumulative TWF sums to 1.0).

TWF values for each exposure scenario used in the cumulative assessment were selected based primarily on professional judgment, taking into consideration the specified RME and CTE exposure parameters for each exposure scenario. In general, RME values were selected for a few of the exposure scenarios and the remaining pathways were selected to be more characteristic of CTE values.

9.2 Cumulative Risk Estimates

There are essentially an infinite number of possible exposure scenario combinations that could be evaluated in the cumulative risk assessment for the Site. The choice of which combinations to evaluate is a matter of judgment. For the purposes of this risk assessment, four alternate cumulative exposure scenario combinations were selected for evaluation. These were chosen to characterize the wide range of potential cumulative risks that may occur and to help identify which exposure scenarios tend to be the most substantial contributors to total risk. A detailed description of the cumulative exposure scenarios for each receptor example is provided in Section 9.2.1. Several additional cumulative examples are provided in Section 9.2.2 to illustrate how cumulative risk changes as a function of LA levels in source materials, interior removal status, and receptor behaviors.

9.2.1 Selected Cumulative Exposure Scenarios

The following sections describe the cumulative exposure scenarios for each of four receptor examples; showing the selected TWF for each exposure scenario and presenting graphical illustrations of the cumulative TWF and non-cancer HI. **Figures 9-2 to 9-5** present graphical illustrations of the cumulative assessment for each receptor example, respectively. In these figures, the upper panel illustrates the contribution of each exposure scenario to the total fraction of a lifetime as a pie chart, where the full pie represents the 613,200 hours that encompass a 70-year lifetime. The lower panel illustrates the contribution of each exposure scenario to the cumulative HI as a stacked bar graph. The table below the figures provides a tabular presentation of the information shown in the two figures. (Note: These figures only present cumulative HIs as the non-cancer endpoint appears to be the more sensitive metric of potential risk. The fractional contribution of each exposure scenario to total cancer risk is the same as for the non-cancer HI.)

9.2.1.1 Receptor Example #1

Example #1 illustrates the potential cumulative exposure and risk to a receptor that lives in Libby at residence where a curb-to-curb soil removal has been completed (i.e., a full yard soil removal was performed) and an interior removal effort has been completed (i.e., a "post-removal" residence). **Figure 9-2a** illustrates this simplistic "baseline" residential exposure, meaning the exposure is attributed only to those pathways associated with the residential property (i.e., ambient air, indoor air inside the residence, and outdoor air within residential property line). The majority (75%) of the lifetime of this receptor is spent at the Site (i.e., 25% of the lifetime is spent offsite; meaning about 52 years of the 70-year lifetime). As illustrated in **Figure 9-2a**, the "baseline" residential exposure scenario yields a cumulative HI less than 1; the cumulative cancer risk is also less than 1E-05 (i.e., within EPA's acceptable risk range). However, this cumulative exposure scenario does not account for potential exposures outside the residential property. Thus, this cumulative exposure scenario was made more realistic by adding in additional pathways outside the residence.

In addition to the "baseline" residential exposure, the following exposure scenarios were added:

- This receptor attends school (elementary through high school) in Libby.
- This receptor works in a commercial building in Libby where an interior removal effort was deemed not to be necessary (i.e., conditions inside the building did not trigger an interior removal).
- This receptor drives on roads in Libby.
- This receptor also engages in a variety of recreational activities, such as bicycling in OU4, motorcycle riding at the MotoX Park in OU5, ATV riding in LUAs where soil concentrations are Bin A (non-detect), hiking in the forested areas far (>6 miles) from the mine site, fishing along the Kootenai River, and playing disc golf at the course in Troy (OU7).

This exposure scenario is likely to represent a "low-end" cumulative exposure scenario, since potential exposures tend to occur at properties and locations with lower levels of LA, and this receptor does not engage in activities that would be expected to increase potential LA exposures (e.g., disturbances of soils with detected LA or disturbances of LA-containing VI).

As illustrated in **Figure 9-2b**, even after adding in multiple exposure scenarios to the "baseline" residential exposure, the cumulative exposure scenario for Receptor Example #1 yields a cumulative HI less than 1; the cumulative cancer risk (1E-05) is also within EPA's acceptable risk range. This example shows that receptors who are predominantly exposed at properties and in locations where steps have been taken to limit potential exposures to LA (e.g., exterior and interior removals have been completed or deemed not to be necessary), even when the cumulative scenario includes many different exposure activities across multiple OUs, are likely to have cumulative risks that are below a level of concern.

9.2.1.2 Receptor Example #2

Example #2 illustrates the potential cumulative exposure and risk to a receptor that lives in Libby at a residence where yard soil concentrations are Bin B2 and an interior removal effort is deemed necessary, but has not yet been completed (i.e., a "pre-removal" residential property). This receptor attends school (elementary through high school) and drives on roads in Libby. This receptor also works in a commercial building in Libby at which an interior removal effort is deemed necessary, but has not yet been completed (i.e., a "pre-removal" commercial property). This receptor engages in a variety of outdoor activities, such as hiking along Rainy Creek in OU3, riding ATVs along ROWs in OU8, and harvesting firewood from the forested areas intermediate (2-6 miles) from the mine (OU3). In addition, this receptor burns the firewood that was harvested in a woodstove, and is exposed to LA during ash removal activities. The majority (75%) of the lifetime of this receptor is spent at the Site.

This exposure scenario is likely to represent a "high-end" exposure scenario, as the exposure scenarios selected for inclusion all tend to occur at properties and locations with higher levels of expected LA, and this receptor tends to engage in multiple activities that would be expected to increase potential LA exposures.

As illustrated in **Figure 9-3**, the cumulative exposure scenario for Receptor Example #2 yields a cumulative HI of 10; cumulative cancer risks are also greater than 1E-04. This example shows that cumulative exposures have the potential to become significant if the majority of the receptor lifetime is spent at properties and in locations where LA is present and engaging in source disturbance activities that have a high potential for LA releases.

This example also illustrates that those exposure scenarios which contribute most to the total lifetime exposure time do not necessarily contribute most to the cumulative HI. For example, exposure from ambient air (exposure scenario "A") comprises 15% of the total lifetime exposure time (TWF_s of 0.15), but contributes only 0.1% to the cumulative HI. Conversely, some exposure scenarios that contribute a small amount to the total lifetime exposure time contribute significantly to the cumulative HI. For example, exposure during disturbances of residential yard soil (exposure scenarios "D" and "E") contributes about 3% to the total lifetime exposure time (TWF_s of 0.034), but comprises 70% of the cumulative HI.

9.2.1.3 Receptor Example #3

Example #3 illustrates the potential cumulative exposure and risk to a receptor that lives in Libby at a residence where yard soil concentrations are non-detect for LA (i.e., Bin A) and an interior removal effort has been completed (i.e., a "post-removal" residential property). This receptor attends school (elementary through high school) and drives on roads in Libby. This receptor works in a commercial building in Libby at which an interior removal effort was deemed not to be necessary (i.e., conditions inside the building did not trigger an interior removal) and at the Central Maintenance Building in OU5. This receptor participates in a variety of outdoor activities, such as hiking in forested areas at an intermediate (4-8 miles) distance from the mine, bicycling on paths in OU5, and playing in parks in Troy (OU7). The majority (75%) of the lifetime of this receptor is spent at the Site.

The cumulative exposure scenario for Receptor Example #3 is presented in **Figure 9-4**. As shown, although the HQ values for each individual exposure scenario are less than 1, the cumulative HI is greater than 1. This example illustrates the importance of evaluating potential exposure scenarios as part of a cumulative assessment and not just individually. However, calculations based on individual exposure scenarios provide useful information on potential "risk drivers" that can be used to guide risk managers in determining future remedial levels and/or institutional controls. (A "risk driver" is an individual exposure scenario that contributes a substantial fraction of the cumulative risk.)

It is important to note that a cumulative HI greater than 1 does not necessarily mean that adverse non-cancer effects will occur. As noted previously (see Section 3.3.2), there is a margin of safety built into the RfC, as the derivation of the RfC_{LA} included a UF of 300 (EPA 2014c). Thus, a cumulative HI that only moderately exceeds 1 has a relatively small likelihood of actually causing an adverse effect. However, the probability of an adverse effect tends to increase as the cumulative HI increases.

9.2.1.4 Receptor Example #4

Example #4 illustrates the potential cumulative exposure and risk to a receptor that lives in Libby at a residence where a curb-to-curb yard soil removal has been performed and an interior removal effort has been completed (i.e., a "post-removal" residential property). This receptor attends school (elementary through high school) and driving on roads in Libby. This receptor participates in recreational activities in OU3, including hiking and building/burning campfires near the mine site. This receptor has also had several types of worker exposures over the course of a lifetime, including working in a commercial building in Libby at which an interior removal effort was deemed not to be necessary (i.e., conditions inside the building did not trigger an interior removal), working as a commercial logger (felling/skidding timber) in forested areas near the mine site (OU3), and working as a USFS worker performing various forest maintenance and firefighting activities in the forested areas in OU3. The majority (75%) of the lifetime of this receptor is spent at the Site.

As illustrated in **Figure 9-5**, the cumulative exposure scenario for Receptor Example #4 yields a cumulative HI greater than 1. This example demonstrates that, even though the total time spent in OU3 (exposure scenarios "J" to "Q") contributes only about 6% to the total lifetime exposure time, these exposures contribute about 80% of the cumulative HI. Additionally, about 70% of the cumulative HI is due to a single exposure scenario, performing skidding as part of commercial logging operations near the mine (exposure scenario "O"). The TWF_S for this individual exposure scenario is 0.002, which is the equivalent of working as a skidder for approximately two summers for 8 hours per day, 5 days per week, for 15 weeks per summer. This example illustrates that, if commercial logging operations are performed near the mine, these activities have the potential to contribute significantly to the cumulative HI of the person doing the logging, even when the exposure time is limited. This example also illustrates that, with the exception of the skidding scenario, exposures from occupational and recreational activities in OU3 contribute less to the cumulative HI than exposures in OU4.

9.2.2 Determinants of Cumulative Risk

As noted above, the following examples are provided to specifically illustrate how cumulative risk depends on LA levels in source materials, interior removal status, and receptor behaviors.

9.2.2.1 LA Levels in Source Materials

It is important to understand that the cumulative HI depends not only on which exposure scenarios are included, but also on the nature of the source materials where those exposures occur. Soil disturbance activities performed in a yard where LA is non-detect (Bin A) by PLM-VE will contribute less risk than the same type of activities performed in a yard where LA soil concentrations are reported as 1% (PLM-VE Bin C). **Figure 9-6** illustrates the importance of LA concentration in soil to the cumulative HI. In this example, the exposure scenarios are identical (i.e., the TWF pie chart is unchanged), but the EPC utilized in the risk calculation has been adjusted from representing a Bin C yard soil concentration to a Bin A concentration. As shown, the cumulative HI decreases from 8 to 1 when the yard soil that is disturbed is changed from Bin B2/C to non-detect (Bin A).

The same is true for potential exposures from indoor air during woodstove ash removal activities and from commercial logging activities. **Figure 9-7** (Panel A) presents a cumulative HI example that includes exposures from woodstove ash. This figure illustrates the cumulative HI if the ash is derived from firewood collected near the mine site and far from the mine site. In this example, the exposure scenario is identical; only the source of the firewood used in the woodstove is different. As shown, the cumulative HI decreases from 1 to 0.6 when the firewood source is changed from near the mine to far from the mine. **Figure 9-7** (Panel B) illustrates the cumulative HI if commercial logging activities (felling, skidding trees) are conducted near the mine site (within one mile) and intermediate from the mine site (about 4 miles from the mine). As shown, the cumulative HI decreases from 6 to 0.5 when the commercial logging location is changed to be further from the mine.

These examples demonstrate how cumulative exposures and risks can decrease, without altering activity behavior patterns, by lowering LA levels in source media where disturbance activities are performed (e.g., removing yard soils with 1% LA and replacing with non-detect soil) and/or by changing the locations where these disturbance activities are performed (e.g., collecting firewood and performing logging in areas further from the mine site versus near the mine site).

9.2.2.2 Interior Removal Status

The same is also true for indoor exposure scenarios; it is possible to change cumulative exposures and risks, without altering activity behavior patterns, by addressing LA source materials inside properties.

Figure 9-8 illustrates how the cumulative HI decreases when indoor residential and workplace exposures occur at properties where LA-containing indoor source materials have not been addressed ("pre-removal") to properties where these materials have been addressed ("post-removal") or where no removal has been deemed necessary ("no removal required"). In this example, the exposure scenario is identical; only the type of property is different. As shown, indoor air exposures have the potential to contribute significantly to cumulative exposures and risks if the majority of time is spent inside residences and workplaces where a removal has been deemed necessary, but has not been performed. However, the cumulative HI is reduced from 3 to 0.4 once these indoor sources have been addressed.

Currently, there are three criteria that are evaluated to determine the need for an interior removal (EPA 2003a):

1) The presence of open, uncontained, or migrating VI in attics/walls

2) The presence of VV in the indoor living space (e.g., VI that has migrated from the attic or walls into the main living spaces)

3) Measured indoor dust levels above 5,000 total LA structures per square centimeter (s/cm^2)

As illustrated in **Figure 9-8,** these criteria are effective in determining when interior removals are not needed, as evidenced by the fact that cumulative HIs are generally similar for exposures at "post-removal" (0.4) and "no removal required" (0.5) properties.

9.2.2.3 Addressing Risk Drivers

As noted above, of the numerous exposure scenarios that may be included in the cumulative assessment, those exposure scenarios where LA-contaminated source materials are disturbed tend to be important risk drivers in cumulative HI estimates.

As illustrated in **Figure 9-9**, for this exposure scenario, two exposure scenarios contribute more than half of the cumulative HI for this example receptor – hiking along lower Rainy Creek near the mine site and disturbing VI during tradesperson demolition activities. **Figure 9-9** demonstrates how elimination of these two risk drivers affects the cumulative HI. As shown, if this receptor were to hike along the Kootenai River (in OU2), instead of along lower Rainy Creek (in OU3), the cumulative HI is reduced from 3 to 2. If this receptor were to also utilize personal protective equipment (e.g., respirator) and employ appropriate dust mitigation measures while performing VI-disturbing activities, which would effectively change the EPC to zero, the cumulative HI is reduced to 0.4.

This example demonstrates that it is not necessary to address every single exposure scenario to significantly lower the cumulative risk. Addressing exposures for a small subset of the potential exposure scenarios, focusing on risk drivers, will have the greatest impact in lowering cumulative exposures and risks. In this regard, the cancer risk and non-cancer HQ summary tables presented in Section 5 through Section 8 provide useful information on the individual exposure scenarios that have the potential to be important cumulative risk drivers.

9.3 Cumulative Risk Conclusions

In reviewing these cumulative HI examples, several general conclusions can be made:

- Cumulative HI estimates are less than 1 if exposures tend to occur at properties and locations with lower levels of LA. However, cumulative HI estimates have the potential to be much greater than 1 if exposures occur at properties and locations with higher levels of expected LA.
- When cumulative exposure includes exposure scenarios where LA-contaminated source materials are disturbed, such as hiking along lower Rainy Creek near the mine, riding ATVs in the disturbed area of the mine, disturbing yard soils with detected LA, performing timber skidding operations near the mine site, or disturbing VI during tradesperson activities, these pathways are important risk drivers for cumulative HI estimates.
- Those exposure scenarios that contribute most to the total lifetime exposure time do not necessarily contribute most to the cumulative HI. In some cases, exposure scenarios that contribute little to the total lifetime exposure time can contribute significantly to the cumulative HI.
- It is possible to reduce cumulative exposure and risk, without altering activity behavior patterns, by lowering LA levels in source media where disturbance activities are performed (e.g., removing yard soil with LA) and/or by changing the locations where the activities are performed (e.g., collecting firewood from areas far from the mine site).
- It is not necessary to address every single exposure scenario to significantly lower cumulative HIs. Addressing exposures for risk drivers will have the greatest impact in lowering cumulative exposures and risks.
- It is possible for individual exposure scenario HQs to be less than 1, but the cumulative HI across all exposure scenarios to be greater than 1. Thus, risk managers should consider both cumulative risks and individual exposure scenario risks to identify potential risk drivers to guide decisions on future remedial action levels and/or institutional controls.

Section 10

Uncertainty Assessment

As with all HHRAs, uncertainties exist due to limitations in the exposure and toxicity assessments and our ability to accurately determine cumulative exposure and risk from multiple sources over a lifetime. This risk assessment has used the best available science to evaluate potential human health exposures and risks from LA at the Site. However, there are number of sources of uncertainty that affect the risk estimates that must be considered when making risk management decisions. The most important of these uncertainties are discussed below.

Because of these uncertainties, the cancer risks and non-cancer HQs for individual exposure scenarios are uncertain, and consequently all estimates of cumulative cancer risks and non-cancer HI values presented in this HHRA are also uncertain, and should be considered to be approximate. Actual risks may be either higher or lower than estimated.

10.1 Exposure Assessment Uncertainties

10.1.1 Uncertainty in True Long-Term Average LA Concentrations in Air

Concentrations of LA in air (especially ABS air) are inherently variable, so estimates of mean exposure concentrations are subject to uncertainty arising from random variation between individual samples ("sampling uncertainty"). The magnitude of the uncertainty due to sampling variability depends on the number of samples collected and the variability between individual samples, with uncertainty tending to decrease as sample number increases, and increasing as between-sample variability increases. In general, large data sets (e.g., with 10-20 or more samples) are likely to capture most of the effect of sampling uncertainty, while data sets that are substantially smaller will be more uncertain.

This sampling uncertainty is further compounded by the effect of analytical measurement error. If it were possible to actually examine the entire air filter by TEM, it would be possible to count exactly the number of LA structures present on the filter and the true concentration in the air that passed through the filter would be known with certainty. However, due to time and cost constraints, the TEM analysis examines only a small portion of the total filter. For example, a typical ABS air filter has an area of about 385 mm^2, yet a TEM analysis of 100 grid openings will only examine about 1 mm^2 (only about 0.25% of the total filter area). For the purposes of reporting the air concentration for the sample, it is assumed to be equal to the concentration as determined based on the small portion of the filter area examined.

For each air filter analyzed, the number of asbestos structures observed during the analysis is a random variable that is characterized by the Poisson distribution:

$$\text{Count}_{\text{observed}} \sim \text{POISSON}(\lambda)$$

where:

$\text{Count}_{\text{observed}}$ = Number of asbestos structures observed during the analysis λ = Expected average count, calculated as:

$$\text{Concentration}_{\text{true}}\ (\text{s/cc}) \cdot \text{Volume of Air Analyzed (cc)}$$

For example, if λ were 3.72 structures, then the probability of observing a specified number of structure counts during the TEM analysis is shown in **Table 10-1** (Panel A). This is referred to as Poisson uncertainty. The magnitude of Poisson uncertainty depends mainly on the number of asbestos structures counted during the analysis. In general, the relative magnitude of the uncertainty due to Poisson variation tends to be largest for small structure counts, and decreases as count increases (see **Appendix B** for details). This concept is illustrated in **Figure 10-1**. As shown, above about 25 structures, there is little change in the relative uncertainty.

The 90% confidence interval around a count of *N* structures is given by:

$$LB = ½ \cdot \text{CHISQ.INV}[0.05, 2N+1]$$

$$UB = ½ \cdot \text{CHISQ.INV}[0.95, 2N+1]$$

where:

LB = Lower bound count on the 90% confidence interval on *N*

UB = Upper bound count on the 90% confidence interval on *N*

CHISQ.INV = Inverse Chi-squared cumulative distribution function

N = Number of asbestos structures observed

Two examples of this calculation are shown in **Table 10-1** (Panel B).

The overall uncertainty in a measured concentration is the combination of the sampling uncertainty and the Poisson uncertainty, depending in a very complex way on the number of samples collected, between-sample variability, number of structures counted, and volume of air passing through the area of filter examined. In risk assessments for non-asbestos contaminants, EPA recommends that risk calculations be based on the 95UCL of the sample mean to minimize the chances of underestimating the true level of exposure and risk (EPA 1992). However, at present, there is no EPA-approved method for calculating the 95UCL for asbestos datasets, which adequately accounts for both sampling and Poisson uncertainty. Therefore, in accordance with EPA guidance (EPA 2008a), all risk calculations presented in the risk characterization (Section 5 through Section 9) utilize the sample mean. The sample mean is an unbiased estimate of the true concentration (see **Appendix B**), but the true concentration may be either higher or lower.

10.1.2 Uncertainty in the EPC Due to Non-Detects

When calculating the EPC, the sample mean is computed simply by averaging the concentrations across all samples, treating "non-detects" (samples with a count of zero) as having a concentration of zero (EPA 2008a). For the purposes of this discussion, this EPC is referred to as the "best estimate" of the mean (BE). However, as the number of non-detects in a data set becomes large, the uncertainty (due to Poisson uncertainty) around the BE tends to increase. Therefore, in order to provide information on the magnitude of the Poisson uncertainty, risk estimates were evaluated for several datasets using an alternate EPC metric.

This alternate EPC metric is determined by assuming the concentration of each non-detect is equal to 1 PCME structure times the achieved analytical sensitivity of that sample, and then computing the mean across all samples. For example, if the achieved analytical sensitivity for a non-detect sample were 0.001 cc^{-1}, the concentration for that sample would be evaluated as 0.001 PCME LA s/cc, rather than zero. Although not statistically rigorous, assuming the data set contains an adequate number of samples to capture sampling variability, this alternate EPC metric may reasonably be thought of as an "upper-bound" on the mean (UB). As illustrated in **Figure 10-2**, when a dataset has a high frequency of detects, the UB will approach the BE; but when a dataset has a low frequency of detects, the UB will approach the mean achieved sensitivity. Use of the UB in calculating risk estimates is considered to be conservative, especially when many or all of the samples in a dataset are non-detect.

Appendix I summarizes the estimated cancer risks and non-cancer HQs (based on RME) for each dataset using the UB. **Table 10-2** presents several examples of the UB risk calculations. As shown, for those datasets where the LA detection frequency was high (e.g., **Table 10-2**, Panel A, exposures during disturbances of yard soils with Bin B2/C concentrations of LA), estimated risks based on the UB are similar or equal to those based on the BE. Even for many datasets where all samples were non-detect (e.g., **Table 10-2**, Panel B, exposures during disturbances of soils in OU2) or LA detection frequency was low, use of the UB does not alter overall risk conclusions (i.e., cancer risk estimates and non-cancer HQs are below a level of concern regardless of the EPC metric). This is because the target analytical sensitivity requirements were specified such that the target sensitivity was lower than a scenario-specific risk-based level of potential concern.

For a few datasets (**Table 10-2**, Panel C), such as hiking in the forest or driving on roads in OU3, estimated non-cancer HQs exceed 1 based on the UB, but do not based on the BE. For these datasets, the achieved analytical sensitivity was not adequate to support decisions based on the non-cancer endpoint. Typically, this occurs in earlier (pre-2011) ABS datasets. This is because earlier ABS programs were conducted prior to the development of the RFC_{LA} and target analytical sensitivity requirements were derived to be protective of the cancer endpoint (which is not the most sensitive endpoint).

It is possible to improve (lower) the achieved analytical sensitivity by performing a supplemental TEM analysis (i.e., examine additional grid openings) for the previously collected air filters that are in the project archive. As noted previously, supplemental analyses have been performed for several ABS air datasets (e.g., see Section 6.1.2 and 6.2.2). **Table 10-3** illustrates the outcome of one of the supplemental analysis efforts performed for OU3 ABS air samples. During the supplemental analysis, more than 6,600 additional grid openings were examined for 48 filters[25] representing four different exposure scenarios (hiking in the forest, driving on forest roads, residential wood gathering, and fire line cutting using a Pulaski tool). **Table 10-3** presents the RME non-cancer HQs (for both the BE and the UB) based on the results from the original analysis and after the supplemental analysis. As shown, there was little change in the estimated non-cancer HQs based on the BE, but the HQs based on the UB decreased because the achieved analytical sensitivity decreased (improved). Thus, the supplemental analysis effort did not alter the risk conclusions for these scenarios, but it did reduce the uncertainty.

[25] Supplemental analysis was only performed for a subset of the filters for each scenario. Table 10-3 only present EPCs and HQs as derived from this subset of filters for the purposes of illustration, whereas Table 10-2 presents EPCs and HQs based on all the filters.

As illustrated, it is possible to reduce the level of uncertainty in these datasets through additional analysis if necessary to support risk management decision-making.

10.1.3 Uncertainty Due to Air Filter Preparation Methods

As discussed in Section 2.3.4, collected air filters are examined at the laboratory prior to analysis to determine the estimated particulate loading on the filter. If an air filter is not deemed to be overloaded by particulates and there is no loose material in the cowl, the filter is directly prepared for analysis by TEM. If an air filter is deemed to be overloaded or if loose material is noted in the air cassette or adhering to the cowl, the filter is prepared indirectly (usually with ashing) in accordance with the indirect filter preparation procedures in Site-specific SOP EPA-LIBBY-08. For chrysotile asbestos, indirect preparation tends to increase structure counts due to dispersion of bundles and clusters; however, the effects of indirect preparation on amphibole asbestos are generally much smaller, usually only increasing concentrations by a factor of 2-3 (Goldade and O'Brien 2014).

In order to ensure that air concentrations used in the risk assessment were not biased high due to filter preparation methods, concentrations for all air samples that were indirectly prepared were adjusted (decreased) by a factor of 2.5. This factor was based on Libby-specific studies of the potential effect of indirect preparation on air samples (see **Appendix D**). However, the actual effect of indirect preparation will likely depend upon the nature of the LA structures present on the filter, which could differ depending upon the source material (e.g., soil, tree bark, VI), the sampling location (e.g., at the mine site in OU3, inside an attic at an OU4 residence), and the type of disturbance activity. Hence, the estimated air concentration calculated using an adjustment factor of 2.5 may be higher or lower than the true concentration.

A further source of uncertainty is between-laboratory variations in the determination of which filters require indirect preparation. This is because the decision to use an indirect preparation is inherently subjective. Laboratories with a lower tolerance for loose/adhering materials will tend to perform indirect preparations more frequently, and these results would require adjustment (as described above) to account for potential high bias due to indirect preparation methods. Laboratories with a higher tolerance for loose/adhering materials will tend to perform a direct preparation, even when it is possible that an indirect preparation may have been warranted. In this case, results may be biased low because the preparation did not include potential asbestos structures that may have been present in the loose/adhered materials. It is not possible to quantify the potential bias or adjust concentrations due to differences in filter preparation method preferences between TEM laboratories.

10.1.4 Uncertainty Due to Analytical Methods

As discussed in Section 6.1.6.3, unlike traditional chemistry methods, where analytical results are based solely on the output of a laboratory instrument, analytical results for asbestos are dependent upon subjective analyst interpretations. Thus, high data quality is ensured through the use of laboratories and analysts that are well-trained in asbestos analysis, and specifically trained in the analysis of LA.

All analytical laboratories participating in the analysis of samples for the Site are accredited by the National Institute of Standards and Technology (NIST) National Voluntary Laboratory Accreditation Program (NVLAP) for the analysis of asbestos by TEM and/or PLM. This accreditation process includes the analysis of NIST/NVLAP standard reference materials, or other verified quantitative standards, and successful participation in two rounds of proficiency testing per year each of bulk asbestos by PLM and airborne asbestos by TEM as supplied by NIST/NVLAP. In addition, each laboratory working for the Site is also required to pass an onsite EPA laboratory audit, participate in ongoing analytical discussions with other project laboratories, and meet Site-specific data reporting requirements.

Even with these quality assurance (QA) procedures, due to the subjective nature of both TEM and PLM analyses, results can differ between analysts and laboratories. Because of this, the analytical QC program for the Site performs regular evaluations of both within- and between-laboratory variability in asbestos results for both analytical methods. A detailed evaluation of the QA procedures and QC analysis results is presented in CDM Smith (2012c, 2014d) and summarized in **Appendix E**. The following sections summarize some of the method-specific uncertainties of the data utilized in the risk assessment.

10.1.4.1 TEM

When analyzing an air filter for asbestos, the TEM analyst visually scans prepared grids for potential asbestos fibers. When a structure is observed, the distinction between asbestos/non-asbestos and asbestos type (e.g., chrysotile, actinolite, amosite) is determined based on a visual assessment of the structure-specific selective area electron diffraction (SAED) pattern and energy dispersive spectra (EDS) spectra, comparing them to a spectral library of known asbestos types. Interpretation of the EDS spectra with respect to LA determination requires significant training, as LA is inclusive of a range of asbestos mineral types (EPA 2008i). EDS interpretation is further complicated by the fact that spectra can differ between TEM instruments, chemical composition can differ within an asbestos structure (e.g., the EDS obtained at the end of a fiber may differ from the EDS at the center point of the same fiber), and spectra can be influenced by surrounding matrix particles.

Results of the TEM laboratory QC analyses show that there are differences in structure counting and recording methods within and between the analytical laboratories, with within-laboratory precision being better than between-laboratory (CDM Smith 2012c, 2014d). Grid opening re-examination (recount) results show there were some differences noted in the number of LA structures counted and in the differentiation of LA structures from non-asbestos material structures with EDS that are similar to LA (e.g., pyroxene). Yet, despite these differences, the number of LA structures counted usually only differed by one structure. For air samples, the between-laboratory differences in structure counting and recording methods are not likely to be a large source of uncertainty in reported air concentrations.

10.1.4.2 PLM

For the purposes of most exposure scenarios evaluated in the risk assessment, uncertainties in the PLM method are not likely to alter risk management decisions, because soil data were not considered in the risk characterization. However, for other exposure scenarios (e.g., residential properties in OU4 and OU7 without measured outdoor ABS data during soil disturbances), potential risks were extrapolated based on LA soil concentrations as determined by PLM-VE.

Most of the PLM methods currently available for the analysis of asbestos in solid media were developed for the analysis of building materials containing relatively high asbestos levels and are not generally intended for assessing low-level (<1%) asbestos contamination in soil. Indeed, even the Site-specific PLM-VE method is not able to reliably detect the levels of LA in soil below about 0.2% by mass (EPA 2008j). When performing a PLM-VE analysis, the analyst utilizes visual estimation techniques (e.g., standard area projections, photographs, drawings, or trained experience) to estimate the LA content of the soil and results are reported semi-quantitatively based on visual comparisons to LA-specific reference materials. The “detection limit”[26] is dependent upon the ability of the analyst, but is typically about 0.2% to 0.3% LA (by mass) (EPA 2008j). This means that soil LA concentrations below about 0.2%, may not be reliably identified by PLM-VE, and some soils ranked as Bin A (non-detect) by PLM-VE likely contain low levels of LA that cannot be reliably quantified. Thus, the difference between Bin A (non-detect) and Bin B1 (trace LA present at concentrations less than 0.2%) is not always distinct. As such, result reproducibility is especially difficult for Bin A and Bin B1. Because risk conclusions differ for exposures to yard soils that are Bin A versus Bin B1 (see **Table 6-3a** and **Table 6-3b**), the distinction between these two bins is important.

Although within-laboratory reproducibility is generally good for PLM-VE, inter-laboratory results show that there are differences between the analytical laboratories (CB&I 2012; CDM Smith 2012c, 2014d). In particular, the ESATR8 laboratory has demonstrated proficiency in detecting the presence of “trace” levels (Bin B1) of LA in soil compared to other laboratories (CDM Smith 2014d). In general, the majority of soil samples used to group the outdoor ABS air data were analyzed by the ESATR8 laboratory. Thus, there is less uncertainty in the PLM-VE results for samples used in the risk assessment. However, the ESATR8 laboratory did not begin performing PLM-VE analyses until about 2008; thus, soil samples collected prior to this would have been analyzed by non-ESATR8 laboratories. Any extrapolation of the risk characterization results to OU4 and OU7 properties without outdoor ABS must consider which PLM laboratory performed the soil analyses. Even for PLM analyses performed by the ESATR8 laboratory, all soil sample results are uncertain due to the inherent variability in the analytical method.

10.1.5 Uncertainty Due to Field Collection Methods

10.1.5.1 Air

There have been few changes to the basic air sampling methodology at the Site. A known volume of air is drawn through a filter that is inside an air sampling cassette which is either affixed to a stationary monitor, such as is done for the collection of ambient air samples, or to an individual, such as during the various ABS programs. While the sampling durations, pump flow rates, and ABS scripts varied depending upon the objectives of the investigation, the underlying air sample collection methods remain consistent. Even so, measurements of LA in air, especially under source disturbance conditions, are inherently variable. For example, measured outdoor ABS air concentrations during disturbances of yard soils ranked as Bin B1 (trace) span more than four orders of magnitude (EPA 2010d). This is not unexpected since the release of LA from soil to air can depend not only on LA concentration, but also upon multiple other factors, such as soil moisture content, vegetation coverage and condition, humidity, and intensity of the disturbance activity. This is not an inherent limitation of the ABS methodology; in fact, it is desirable for the collected data to span the range of air concentrations that may result during source disturbances under a variety of conditions, such that the resulting EPCs are representative of long-term exposures. Recognizing the variability in asbestos air concentrations, the air sampling programs employed at the Site typically included multiple sampling events at each sampling location to better capture the range of sampling variability due to changing environmental and meteorological conditions.

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[26] For this discussion, the “detection limit” is defined as the concentration that must be present in a sample such that the method will be able to detect LA 95% of the time.

Because airborne releases of LA are expected to depend upon environmental conditions, in order to maximize potential releases during disturbance activities, sampling was usually conducted in the dry, summer months. Additionally, activities were not performed if significant precipitation events occurred in the preceding day or if there was standing water present. For OU3, activities were also targeted in areas located downwind of the mine, where exposures were likely to highest. The risk assessment assumes that potential exposure and risks in areas upwind/crosswind of the mine are equal to or lower than estimated in the downwind areas. As illustrated in **Figure 10-3**, spatial patterns of LA levels in tree bark and duff show contamination is centered on the mine and extends beyond four miles from the mine, but tends to be highest within two miles of the mine. LA levels tree bark and duff from crosswind areas (i.e., northwest and southeast) tend to be lower than levels in upwind and downwind areas. This supports the conclusion that potential exposures and risks in the crosswind areas are likely to be lower than what has been calculated in the risk assessment. Similarly, for OU8, ABS activities were performed in locations where LA soil concentrations tended to be highest. Thus, resulting ABS air concentrations are more likely to overestimate potential exposures, rather than underestimate.

Another potential limitation of the air datasets is their limited sampling duration relative to the long-term exposure scenarios evaluated in the risk assessment. It is not feasible to collect samples, particularly ABS air samples, for long sampling durations due to the potential for filter overloading with particulates. Therefore, ABS investigations collect short-term samples that are assumed to be representative of the long-term exposure scenario. However, the actual long-term exposure levels have the potential to be higher or lower than the measured filter concentrations.

As noted previously, more than 3,100 ABS air samples and 1,500 ambient air samples have been collected at the Site. Despite the issues noted above, these datasets provide the most comprehensive evaluation of airborne asbestos exposures ever collected at an asbestos-contaminated Superfund site.

10.1.5.2 Soil

As noted previously in Section 6.1.6.3, soil sampling methodologies at the Site have changed over time. Prior to 2007, soil samples collected at the Site were usually collected as five-point composite samples. The number of samples collected at the property varied, depending upon the types of use areas identified (e.g., yards, driveways) and the size of the use area. In 2007, the sampling methodology was changed to collect 30-point composite samples and the property evaluation methods were revised to better characterize each potential use area (CDM Smith 2013n). Because a 30-point composite is more likely to provide an accurate representation of the true average concentration in soil over a study area than a five-point composite, soil concentration estimates based on five-point composites are more uncertain than those based on 30-point composites.

Recognizing this limitation, EPA has determined that properties evaluated prior to 2007 where no removal was conducted and where previously collected soil samples show detected LA is present (Bin B1, Bin B2) will be re-evaluated using current sampling protocols (CDM Smith 2014j). EPA is also conducting a pilot study to determine if a re-evaluation is necessary for properties evaluated prior to 2007 where no removal was conducted and where previously collected soil samples show no detected LA is present (Bin A) (EPA 2014f).

10.1.6 Uncertainty in Human Exposure Patterns

10.1.6.1 Differences Between Individuals

For every exposure scenario of potential concern, it is expected that there will be differences between different individuals in the level of exposure due to differences in exposure time, exposure frequency, and exposure duration. Thus, there is normally a wide range of average daily exposures between different individuals of an exposed population. In this risk assessment, two types of exposures are estimated – CTE, which represents "average" exposures, and RME, which represents exposures near the upper end of the range. The true exposure for any individual within a given population may be either higher or lower than the exposure parameters selected in the risk assessment, so risks to individuals may vary from the values presented in this report. In accordance with EPA (1991b), risk managers generally focus on RME risk estimates for the purposes of supporting risk management decision-making, which ensures that decisions are sufficiently protective of the general population.

10.1.6.2 Exposure Parameter Assumptions

Risk calculations require knowledge of the exposure time, duration, and frequency for a variety of exposure scenarios. However, limited or no Site-specific data were available on these exposure parameters; thus, exposure parameters for each receptor population and exposure scenario were selected based mainly on professional judgment, taking into consideration EPA default values and Site-specific factors. For example, EPA's RME default value for residential exposure frequency is 350 days/year (EPA 1993a). The exposure frequency for residential exposures to LA during driveway soil disturbances was adjusted to 225 days/year to reflect Site conditions and account for days when releases due to soil disturbance activities were unlikely, either due to snow cover or high soil moisture content (from November through March) (see **Table 6-1**).

In some cases, exposure data were assumed based on professional judgment. For example, there is no information available on the fraction of yard soil disturbance time that is spent in "high-intensity" disturbance activities. For the purposes of this risk assessment, it was assumed that 5% of the total yard disturbance time is spent performing high-intensity disturbance activities (see Section 6.1.4.1.1). **Table 10-4** illustrates the change in estimated residential RME cancer risks and non-cancer HQs from yard soil disturbances if this assumption were changed from 5% (Panel A) to 20% (Panel B). As shown, although the absolute risk values increase, there is no change in the overall risk conclusions for this exposure scenario. Even if the assumed fraction of time spent in high-intensity disturbances were 20%, estimated RME cancer risks are less than 1E-04 and non-cancer HQs are less than 1 for soils where LA is not detected (Bin A) and above a level of potential concern for soils where LA is detected (Bin B1, Bin B2/C). Indeed, even if it were assumed that 70% of the yard disturbance time were spent in high-intensity disturbances (calculations not shown), the estimated RME cancer risks and non-cancer HQs would continue to be below a level of potential concern for Bin A (non-detect) soil concentrations.

In general, when exposure data were limited or absent, exposure parameters were chosen in a way that was intended to be conservative. Therefore, the values selected are thought to be more likely to overestimate than underestimate actual exposure and risk.

10.2 Toxicity Assessment Uncertainties

The toxicity factors for LA (IUR_{LA}, RfC_{LA}) are derived from the best available epidemiological studies in humans (EPA 2014c). However, there are a number of sources of uncertainty inherent in these values, including the following:

- *Uncertainty in exposure estimates.* Estimates of worker exposure to LA are based on a limited set of industrial hygiene measures performed in the workplace. Because there is variability between locations and over time, these measurements may or may not fully capture the true exposure levels in the workplace. In addition, because the measurements are generally based on stationary monitors, rather than personal monitors, the exposures experienced by individual workers may differ from those captured by the stationary monitors. Finally, each worker has a unique job history, and variations due to days off, sick time, shifts in job duties, etc., may or may not be fully captured in the calculations.

- *Uncertainty in exposure-response relationships.* As described in EPA (2014c), there is uncertainty in the best exposure-response model to use to describe both cancer and non-cancer effects in workers. This includes both the mathematical form of the models, as well as the best set of explanatory variables. In both cases (cancer and non-cancer), EPA investigated a range of alternative models and exposure matrices, and selected the combination that is judged to be most reliable. Although model choice can yield different values, as demonstrated in EPA (2014c), all models evaluated resulted in RfC_{LA} values that were within one order of magnitude.

- *Uncertainty in Age-Dependence.* Exposure-response models developed previously by EPA for evaluating cancer risks from inhalation of asbestos indicated that cancer risk depended on the age at first exposure as well as the duration of exposure (EPA 1986). That is, predicted cancer risk from a specified exposure concentration and duration (e.g., 0.001 f/cc for 10 years) is highest when exposure occurs early in life and tends to decrease as age at first exposure increases. For this reason, EPA (2008a) developed a table of IUR values applicable to a wide range of differing age at first exposures and exposure durations. In contrast, neither the LA-specific IUR nor the RfC were developed using models where age at first exposure was an explanatory variable. If age at first exposure does influence the risk of adverse effect, then the toxicity factors for LA might tend to underestimate risks from exposure scenarios that occur early in life. EPA (2014c) includes a review of studies that provide information on the age-dependence of the adverse effects of LA, and finds that the data are too limited to draw strong conclusions.

- *Statistical uncertainty in model fit.* Given the preferred model and exposure metrics for cancer and non-cancer effects, there is statistical uncertainty in the best fit of the model to the epidemiological data. To account for this, EPA derived toxicity factors not only based on the best fit, but also factors that characterizes the upper-bound on the toxicity per unit exposure. These conservative estimates of the toxicity factors were used in the derivation of the IUR_{LA} and RfC_{LA}, which helps ensure that risks are more likely to be overestimated than underestimated.

- *Database Uncertainty.* In the derivation of the RfC_{LA}, a composite UF of 300 was applied to account for data deficiencies in the available health effects literature (UF = 3), human variability and potentially susceptible individuals (UF = 10), and a data-informed subchronic-to-chronic factor to address uncertainty due to increasing risk of LPT over the course of a lifetime (UF = 10) (EPA 2014c).

In summary, the quantitative toxicity values for LA are derived in a way that is intended to be conservative, and are more likely to overestimate than underestimate true risks.

10.3 Cumulative Risk Characterization Uncertainties

Individuals that reside, work, or visit the Site will have exposures to LA from numerous potential source materials, locations, and activities. It is not possible to evaluate every possible cumulative exposure scenario combination. In addition, TWF values for each exposure scenario used in the cumulative assessment were selected based primarily on professional judgment, setting some exposure scenarios to high-end values and others to more typical values.

The cumulative risk assessment presents estimated exposure and risks for a limited number of examples, with the goal of demonstrating the range of potential risks that could be present at the Site, as well as how risk depends on different types of disturbance activities, LA levels in the source media, and exposure locations to guide future risk management decision-making.

Section 11

Risk Assessment Conclusions

This Site-wide risk assessment characterizes risks to people from exposure to LA at the Site to help risk managers determine if past removal actions have been sufficient to mitigate risk, if additional remedial actions are necessary to address risks, and if so, which exposure scenarios would need to be addressed in future remedial actions. Results of this risk assessment are intended to help inform Site managers and the public about the magnitude of potential risks attributable to LA and to guide the selection of final remedial actions for the Site.

The primary exposure route of concern for LA is inhalation. This risk assessment evaluates risks from potential inhalation exposures to LA in outdoor ambient air, in outdoor air during soil disturbance activities, in indoor air (under both active and passive disturbance activities), and air during wood-related disturbance activities. Because people may be exposed by multiple exposure scenarios, often across multiple OUs, potential cumulative exposures and risks were evaluated on a Site-wide basis for a wide range of multi-activity exposure scenarios. The risk assessment conclusions based on the exposure scenario-specific risk estimates and the cumulative risk estimates are discussed below.

11.1 Exposure Scenario-Specific Risks

In total, more than 150 different exposure scenarios were evaluated in the risk assessment in Section 5 through Section 8. The RME and CTE non-cancer HQs for every exposure scenario evaluated in the risk assessment are depicted in **Figures 11-1 to 11-5**. Note that these figures only depict non-cancer HQs and not cancer risks, because non-cancer hazard is the more sensitive metric of potential health risk. **Figure 11-1** presents HQs for exposures to outdoor ambient air, **Figure 11-2** presents HQs for exposures to outdoor air during soil disturbance activities, **Figure 11-3** presents HQs for exposures to indoor air (under both active and passive disturbance activities), **Figure 11-4** presents HQs for exposures to air during wood-related disturbance activities and **Figure 11-5** presents HQs for exposures to air during fire-related activities. As seen, there were very few exposure scenarios that, when considered alone, yield RME non-cancer HQs that exceed 1. These exposure scenarios include (listed from highest to lowest HQ below):

- Tradesperson exposures during active source disturbance activities, such as VI removal or demolition, inside residential and commercial properties in Libby and Troy
- Outdoor worker exposures during disturbances of subsurface soils with LA contamination (Bin B2/C)
- Residential and outdoor worker exposures during disturbances of surface soils with detectable LA concentrations (e.g., Bin B2/C)
- Outdoor worker exposures during commercial logging activities in OU3 near the mine (within about one mile), especially those logging activities that disturb soil and duff material (e.g., skidding, site restoration)
- Firefighter exposures while performing dry mop-up activities after an understory burn that occurs near the mine (within about one mile)

- Residential and indoor commercial worker exposures to indoor air during active source disturbance activities inside properties where one or more interior removal triggers are present (i.e., at "pre-removal" properties)

- Forest worker exposures while building slash piles near the mine (within about one mile)

- Rockhound exposures in the disturbed area of the mine in OU3

- Residential exposures during woodstove ash disturbances (i.e., while emptying ash from the woodstove) when firewood is collected from near the mine (within about one mile)

In addition to the above exposure scenarios, although quantitative risk estimates were not calculated, it is expected that non-cancer HQs also have the potential to be above a level of concern if individuals disturb subsurface soils in OU1 and OU2 where LA contamination has been left at depth following soil remediation.

There were also several exposure scenarios that, when considered alone, yielded RME non-cancer HQs that approached 1 (e.g., hiking along Rainy Creek in OU3, brush-hogging along road ROWs in OU8, residential exposures while digging in subsurface soil with LA concentrations of Bin B2/C). Although these exposure scenarios alone do not result in unacceptable risks, they have the potential to be important contributors to cumulative risk.

11.2 Cumulative Risk

The calculation of cumulative risk is complicated by the fact that the exposure pattern of each individual at the Site may be unique. However, EPA does not typically perform risk calculations for specific individuals, but rather for generic classes of receptor populations with common exposure patterns. Thus, the goal of the cumulative risk assessment is to illustrate how risk depends on different types of disturbance activities, LA levels in the source media, and exposure locations. The cumulative risk calculations demonstrate:

- People who are predominantly exposed at properties and in locations where steps have been taken to limit potential exposures to LA (e.g., exterior soil removals and interior VI removal and cleanings have been completed or deemed not to be necessary), are likely to have cumulative risks that are below a level of concern, even when the cumulative scenario includes many different exposure activities across multiple OUs.

- Cumulative exposure has the potential to become significant if the majority of the receptor lifetime is spent at properties and in locations where LA is present and engaging in source disturbance activities that have a high potential for LA releases.

- When cumulative exposure includes scenarios where LA-contaminated source materials are disturbed, such as trespassing on the disturbed area of the mine site, disturbing surface soils with Bin B2/C concentrations, performing commercial logging operations near the mine site, disturbing VI during tradesperson activities, or disturbing subsurface soils with residual LA contamination, these exposures are important risk drivers for cumulative risk estimates.

- Addressing exposures for the risk drivers (i.e., those exposure scenarios that have HQs that approach or exceed 1), will have the greatest impact in lowering cumulative exposures and risks.

Section 12

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FIGURES

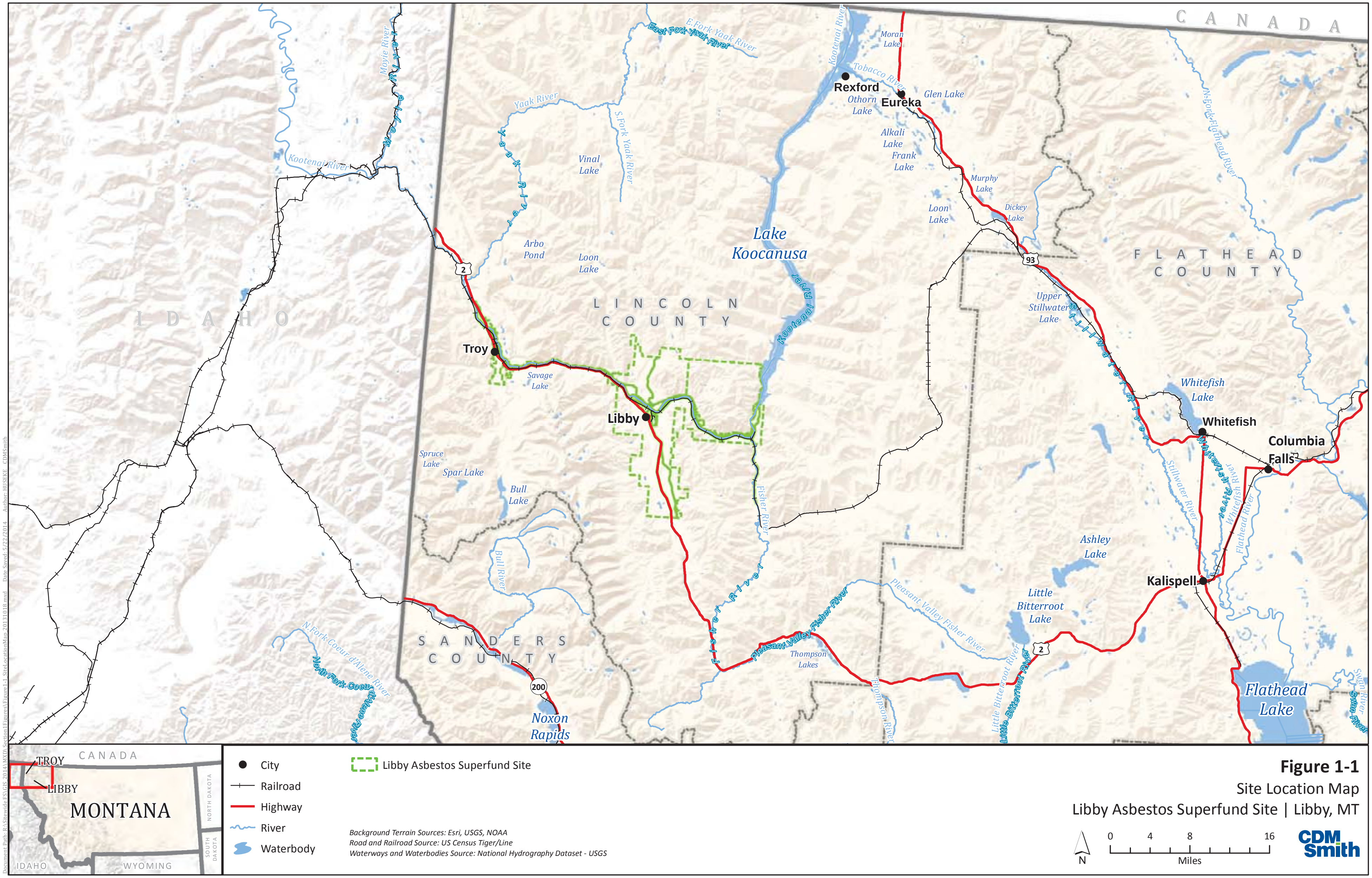


Figure 1-1
Site Location Map
Libby Asbestos Superfund Site | Libby, MT

Vermiculite ore

Unexpanded (“unexfoliated”) vermiculite

Expanded (“exfoliated”) vermiculite

Zonolite products

Amphibole asbestos fibers

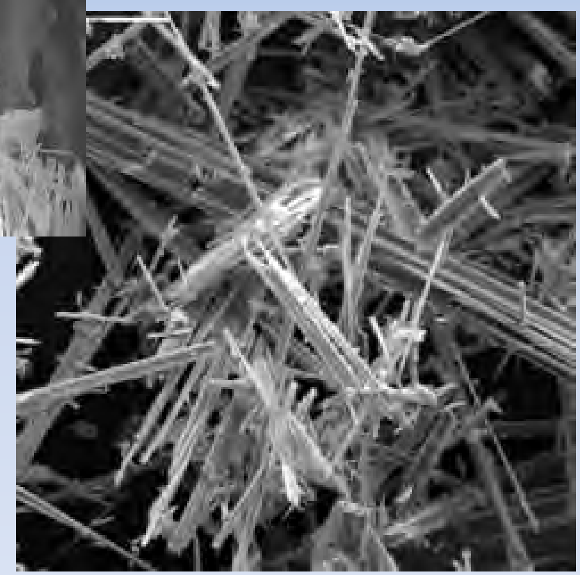
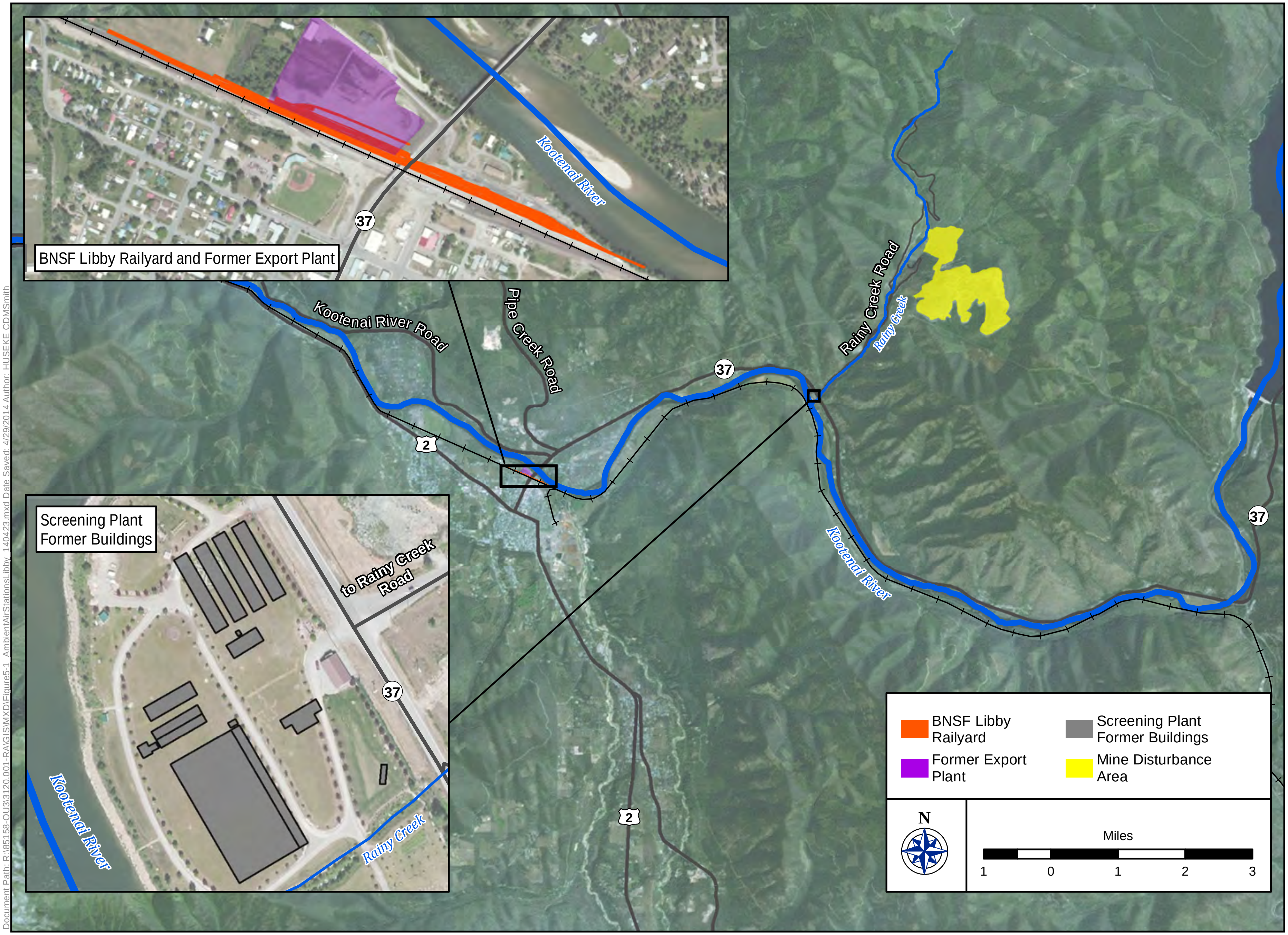


Figure 1-2. Photographs of Vermiculite and Asbestos

Libby Asbestos Superfund Site



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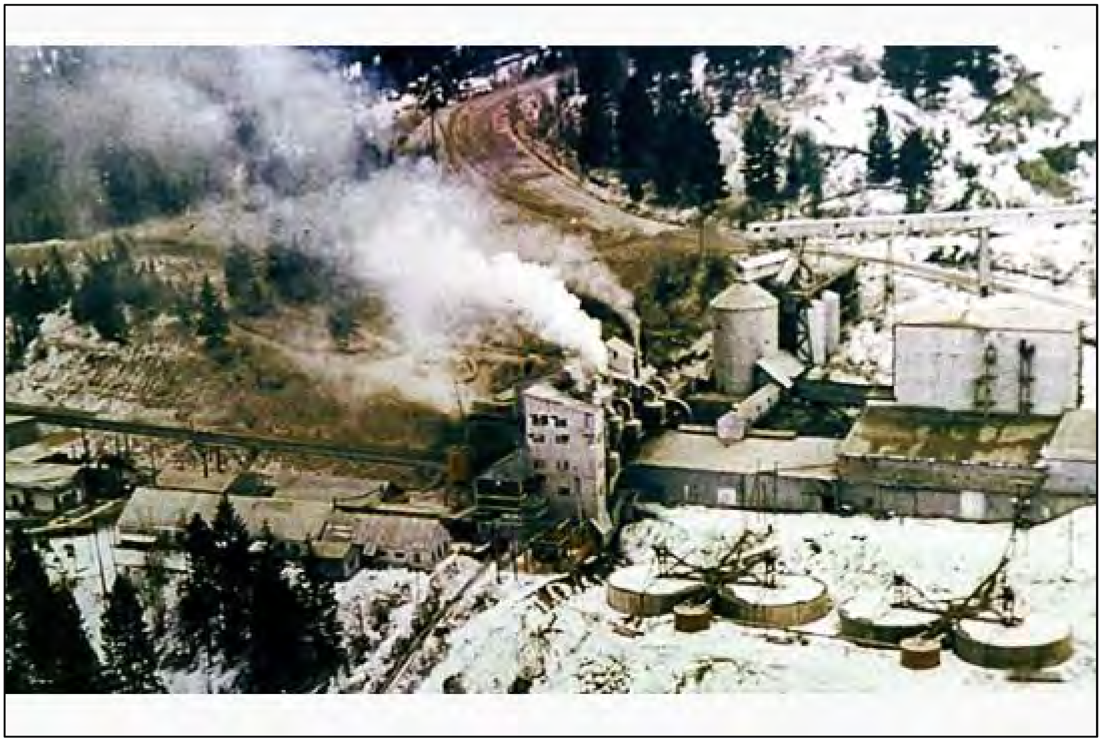
CDM Smith

Mining - Related
Site Features

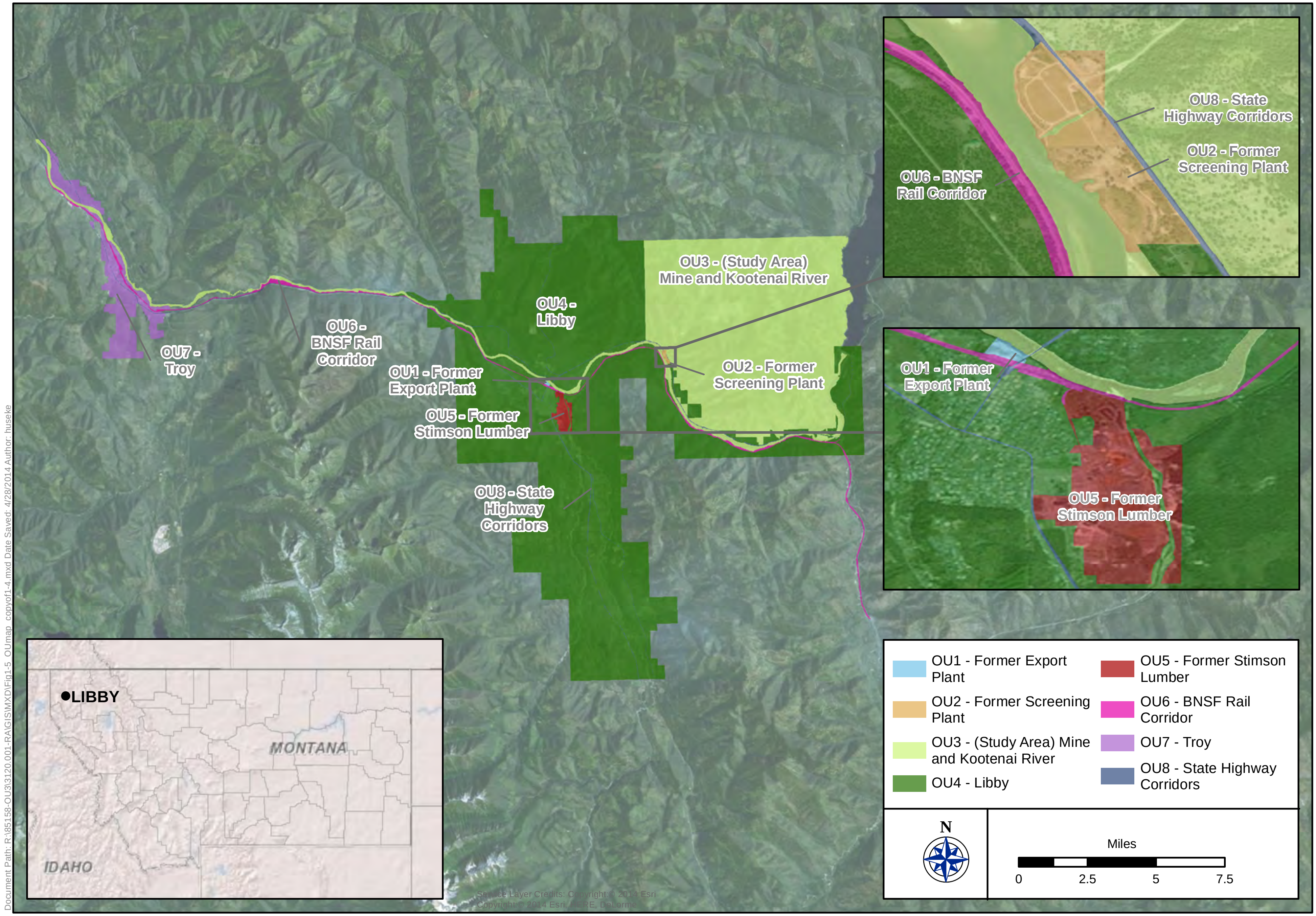
FIGURE 1-3

FIGURE 1-4

PHOTOGRAPH OF THE MILL AT THE VERMICULITE MINE IN LIBBY



SOURCE: LINCOLN COUNTY DISTRICT COURT / AP FILE PHOTO



Libby Asbestos Superfund Site | Operable Units
Lincoln County, Montana

FIGURE 1-5

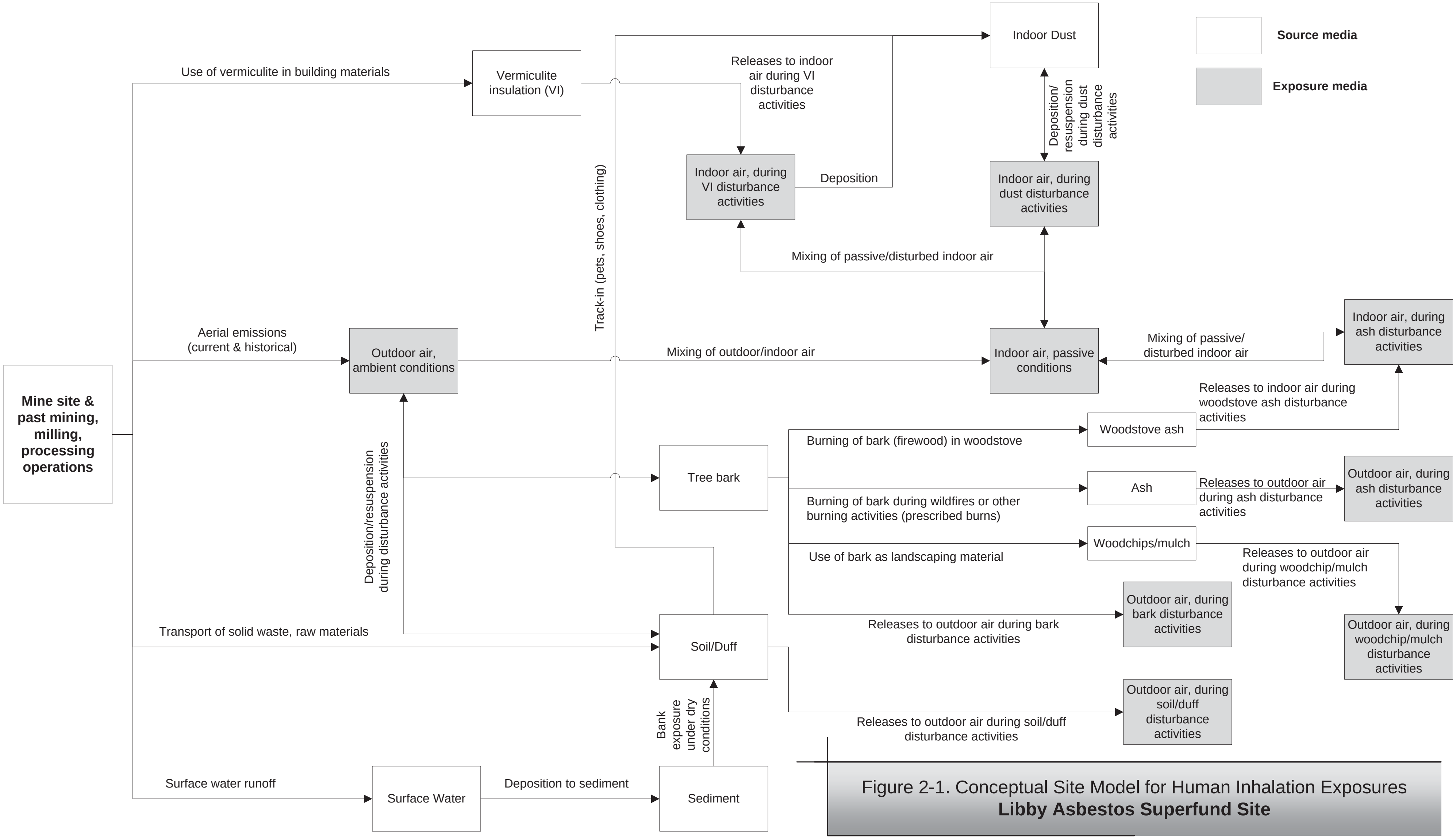
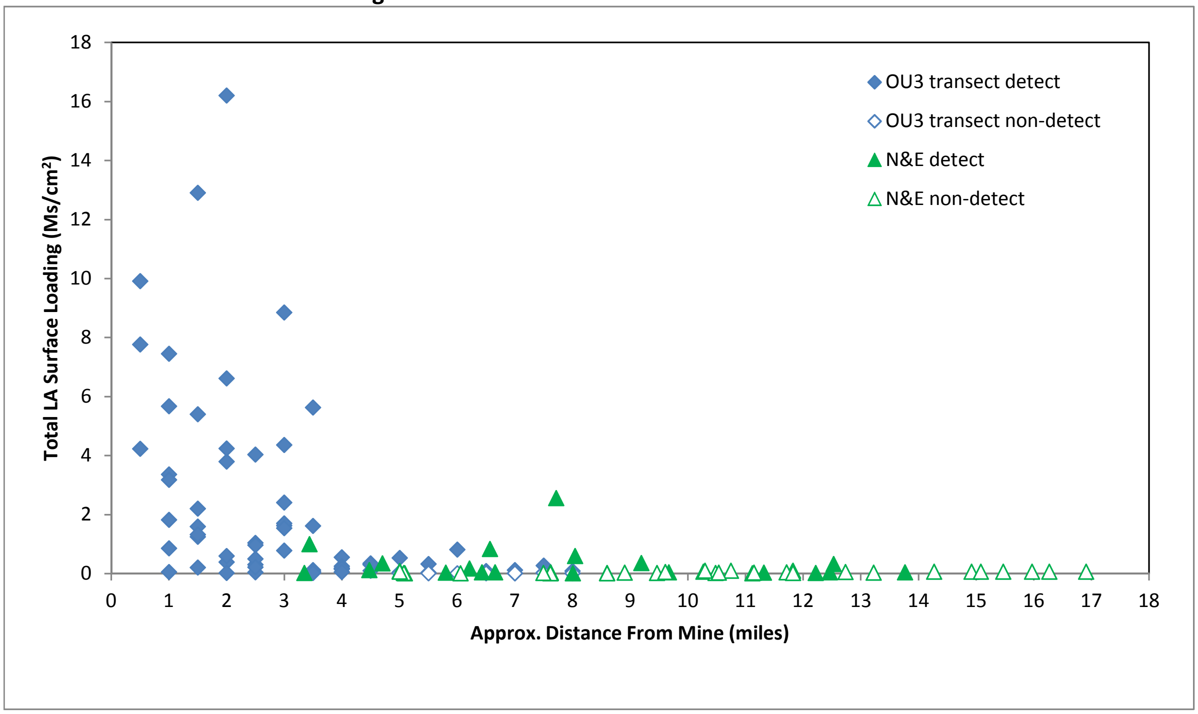


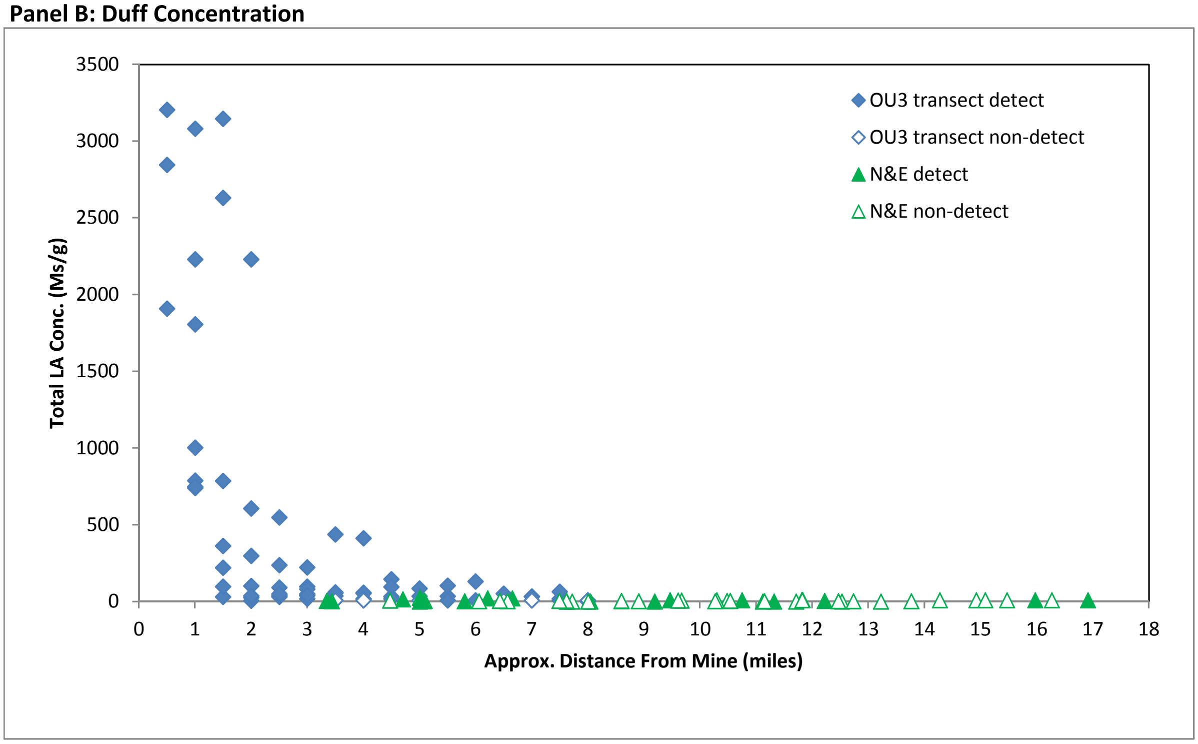
Figure 2-1. Conceptual Site Model for Human Inhalation Exposures
Libby Asbestos Superfund Site

FIGURE 2-2
Tree Bark and Duff Levels of LA as a Function of Distance from the Mine

Panel A: Tree Bark Surficial Loading



Panel B: Duff Concentration



LA = Libby amphibole
MS/cm^2 = million structures per square centimeter of tree bark
Ms/g = million structures per gram of duff
N&E = Nature & Extent Forest Study
OU3 = Operable Unit 3 Phase I Study

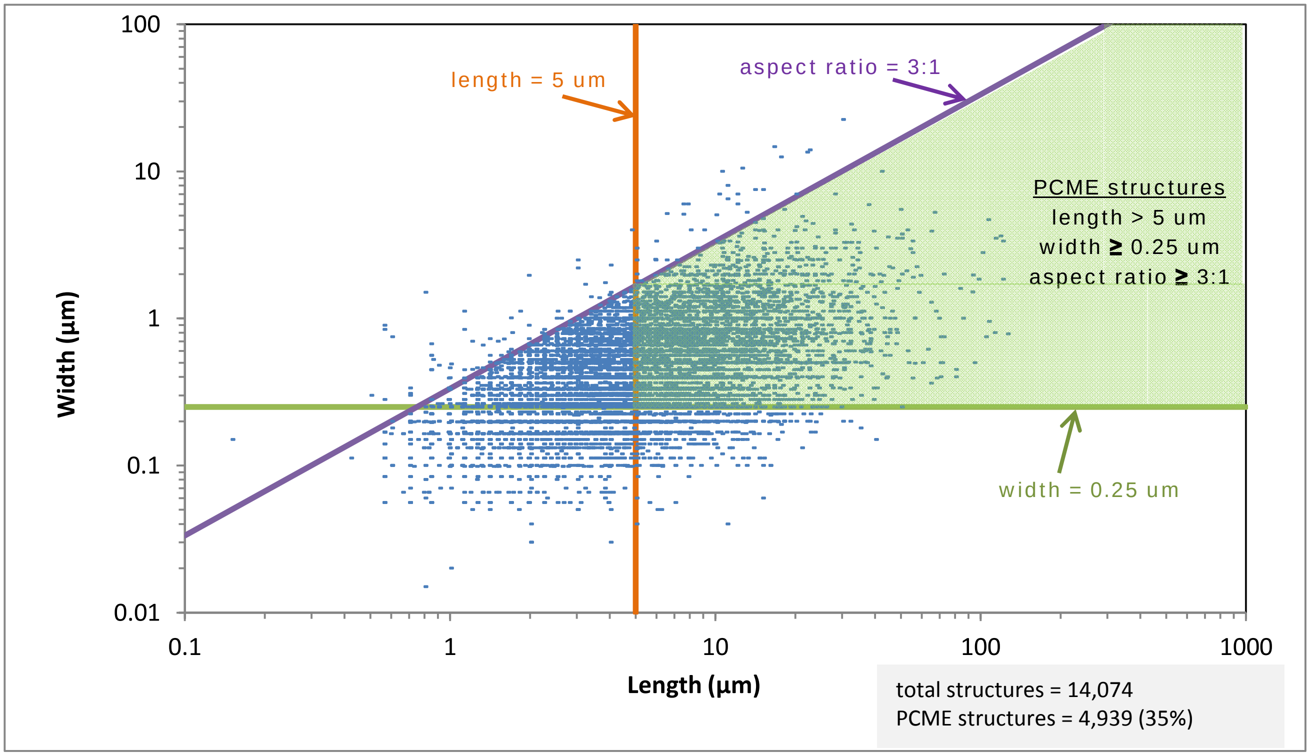
FIGURE 2-3. EXAMPLE PHOTOGRAPHS OF ABS ACTIVITIES

[A] Mowing lawn in a yard
[B] Biking along road in Libby
[C] Tricycling on unpaved driveway
[D] Raking leaves in a yard
[E] Sweeping floor inside a residence
[F] Digging in a yard

FIGURE 2-3. EXAMPLE PHOTOGRAPHS OF ABS ACTIVITIES (cont.)

[G] Playing frisbee
[H] Mowing lawn on a riding mower
[I] Playing on playground equipment
[J] Weed trimming
[K] Riding ATVs in unmaintained fields
[L] Riding motorcycles at the MotoX Park

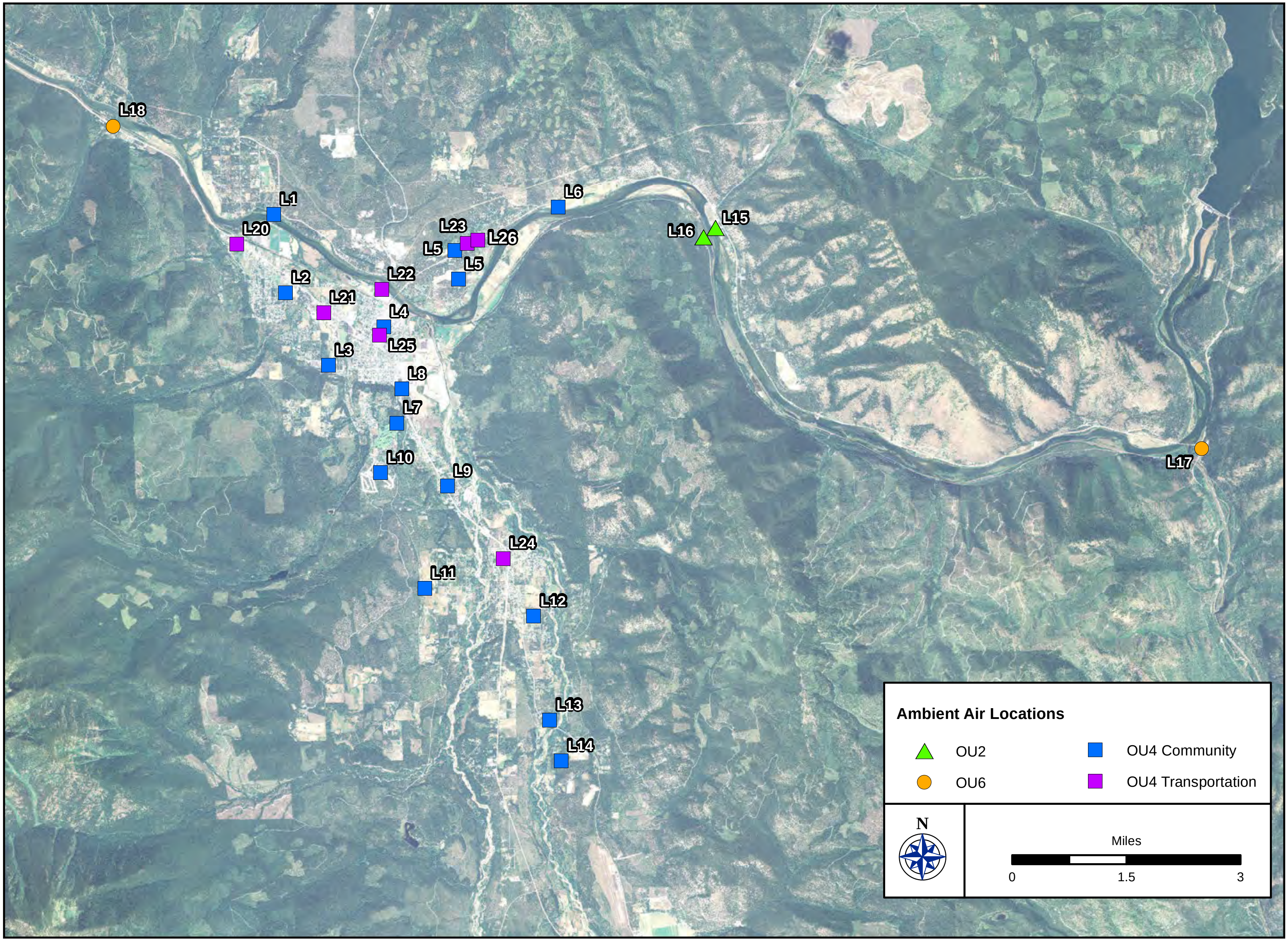
FIGURE 2-4. ILLUSTRATION OF PCME STRUCTURES



Notes:

µm = micrometer

PCME = phase-contrast microscopy - equivalent



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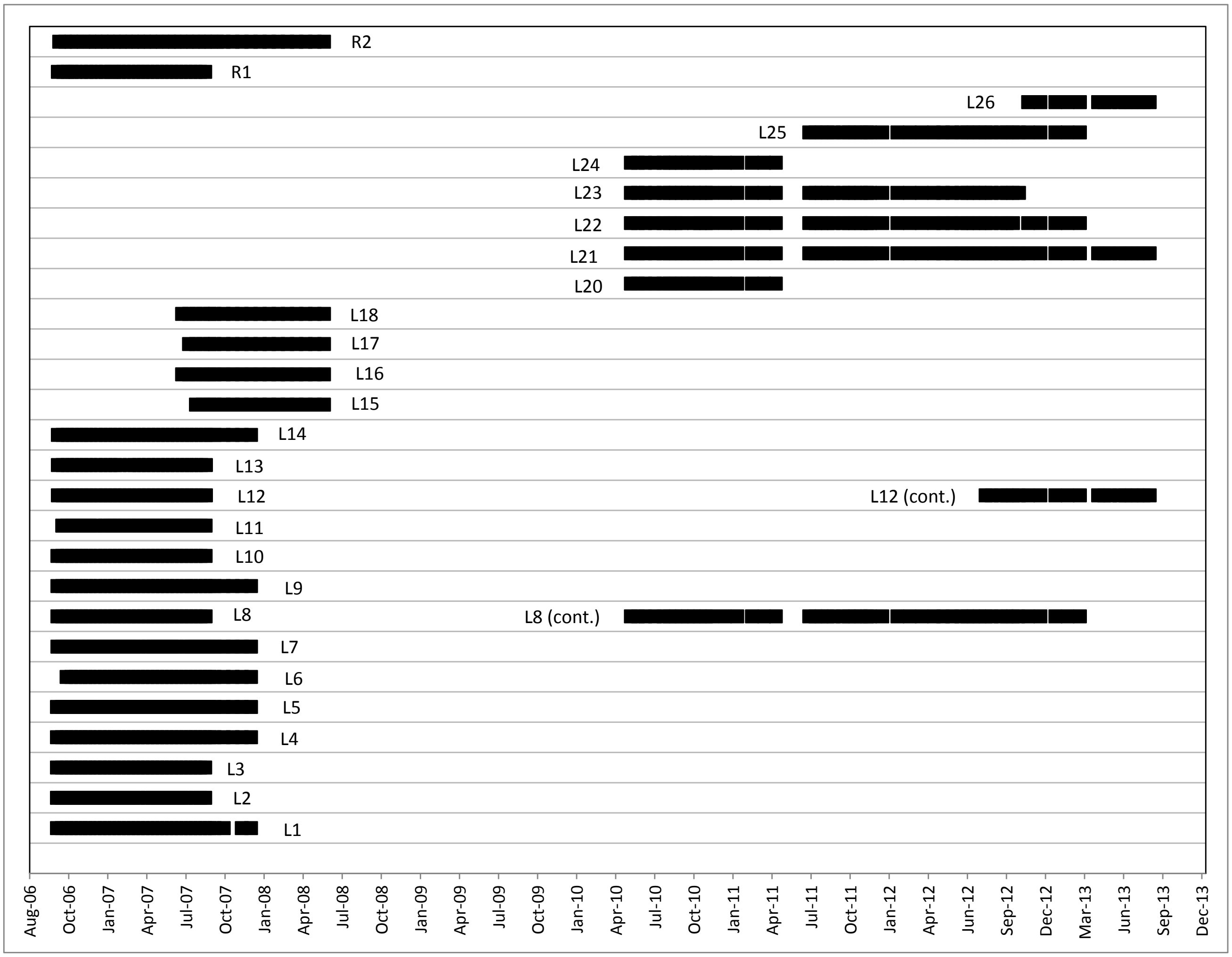
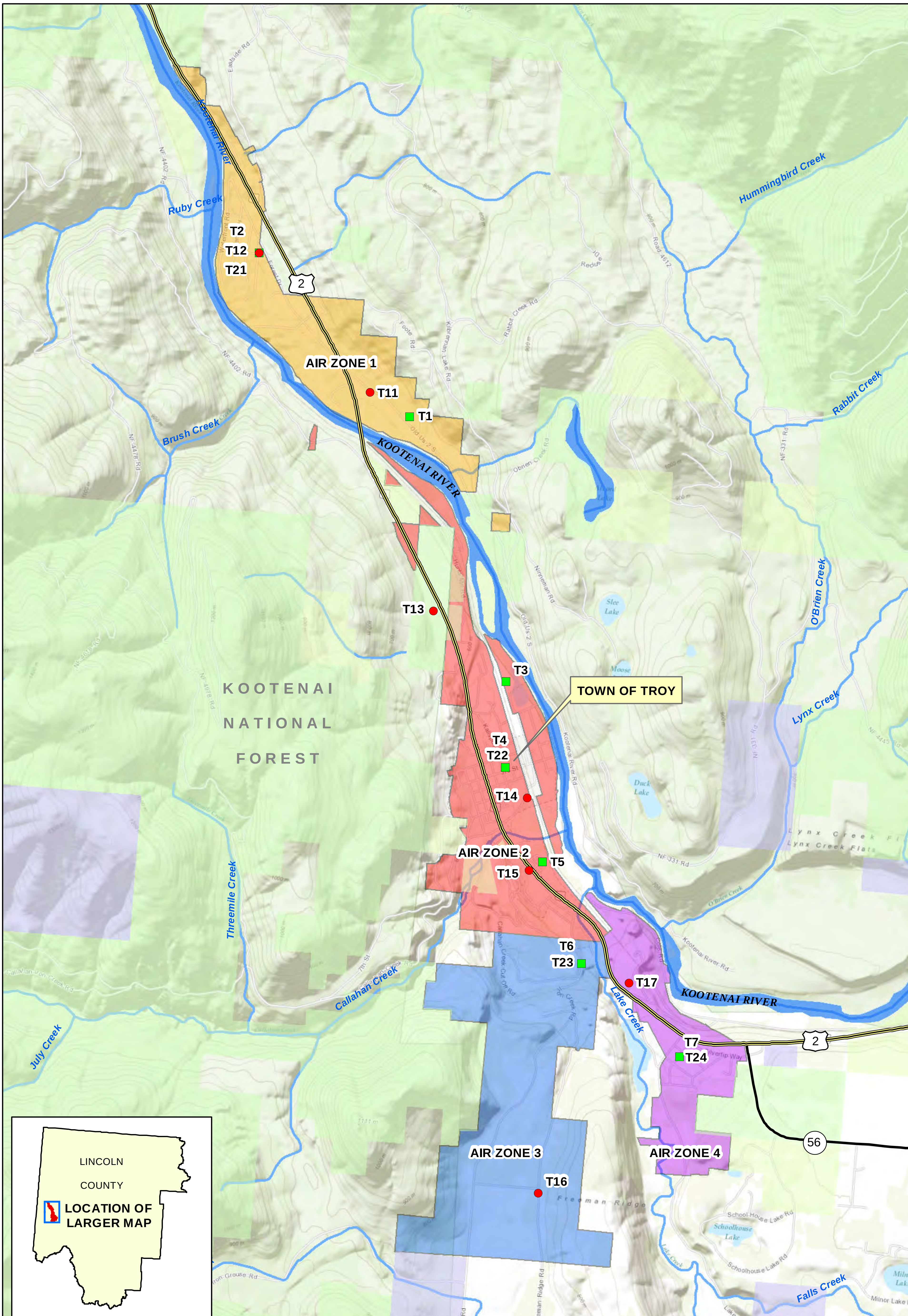
Ambient Air Monitoring
Stations in Libby

FIGURE 5-1

FIGURE 5-2
AMBIENT AIR SAMPLING DURATIONS FOR LIBBY, EUREKA, AND HELENA MONITORING STATIONS
Libby Asbestos Superfund Site, Libby, Montana



Monitor Location	Station ID	N Events	Station Description	Sampling Date Range
Libby (community)	L1	37	1915 Kootenai River Rd	Oct-2006 to Dec-2007
	L2	30	247 Indian Head Rd	Oct-2006 to Sep-2007
	L3	32	101 Ski Rd	Oct-2006 to Sep-2007
	L4	38	501 Mineral Ave	Oct-2006 to Dec-2007
	L5	38	1427 Highway 37 N	Oct-2006 to Dec-2007
	L6	36	3088 Highway 37 N	Oct-2006 to Dec-2007
	L7	36	378 Cabinet View Rd	Oct-2006 to Dec-2007
	L8	83	OU5, 60 Port Blvd	Oct-2006 to Aug-2007; May-2010 to Mar-2013
	L9	38	2261 Highway 2 S	Oct-2006 to Dec-2007
	L10	32	378 Cabinet View Rd	Oct-2006 to Sep-2007
	L11	30	Snowshoe Dr & Woodland Heights	Oct-2006 to Sep-2007
	L12	52	899 Farm to Market Rd	Oct-2006 to Aug-2007; Aug-2012 to Mar-2013
	L13	31	119 Evans Rd	Oct-2006 to Dec-2007
	L14	38	475 Fish Hatchery Rd	Oct-2006 to Dec-2007
	L15	16	OU2, 5002 Highway 37 N	Aug-2007 to Jun-2008
	L16	18	OU2, 4500 Highway 2 W	Jul-2007 to Jun-2008
	L17	17	OU6, Fisher River Bridge, Milepost 0.25	Aug-2007 to Jun-2008
	L18	18	OU6, 3501 Haul Rd	Jul-2007 to Jun-2008
Libby (transportation corridors)	L20	18	30414 US Highway 2	May-2010 to Apr-2011
	L21	60	32000 US Highway 2	May-2010 to Aug-2013
	L22	49	303 W Thomas St	May-2010 to Mar-2013
	L23	46	1675 MT Highway 37	May-2010 to Oct-2012
	L24	18	36304 US Highway 2	May-2010 to Apr-2011
	L25	33	Lincoln Blvd & Mineral Ave	Nov-2012 to Aug-2013
	L26	14	1799 MT Highway 37	May-2010 to Apr-2011
Eureka	R1	32	101 Iowa Flats Rd	Oct-2006 to Sep-2007
Helena	R2	39	1735 Missoula Ave	Oct-2006 to Jun-2008



Legend

- 2010 (Year 1) AMBIENT AIR SAMPLE STATION
- 2011 (Year 2) AMBIENT AIR SAMPLE STATION

AMBIENT AIR ZONES

- ZONE 1
- ZONE 2
- ZONE 3
- ZONE 4

0 1 Miles

N

TETRA TECH EM INC.

LIBBY ASBESTOS SUPERFUND SITE

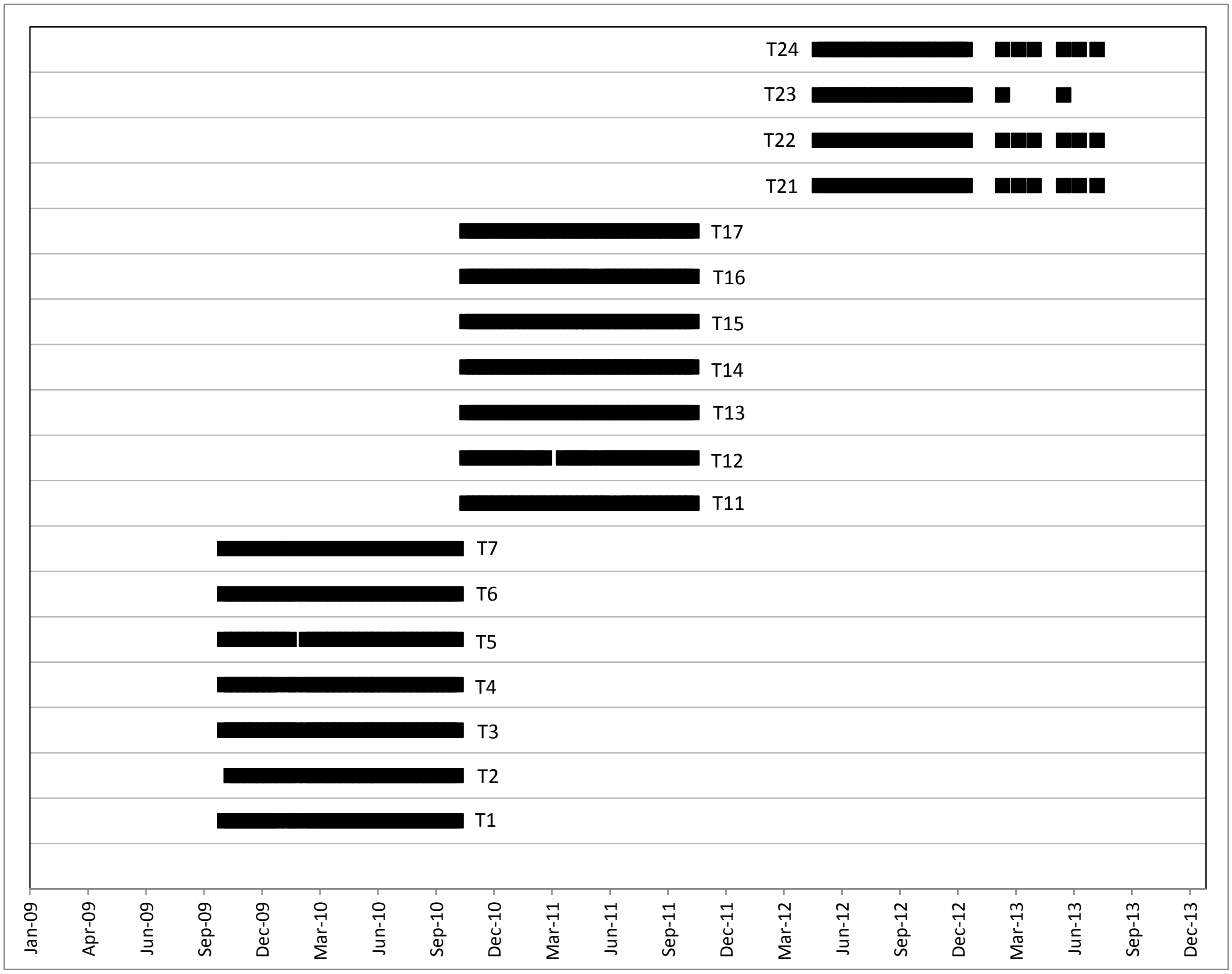
FIGURE 5-3
OPERABLE UNIT 7
OUTDOOR AMBIENT AIR
STATION LOCATIONS

GIS map by Ed Madej TTEMI-HE
FIG3-1_OU7RI_AMBIENT_AIR_122612.mxd

FIGURE 5-4

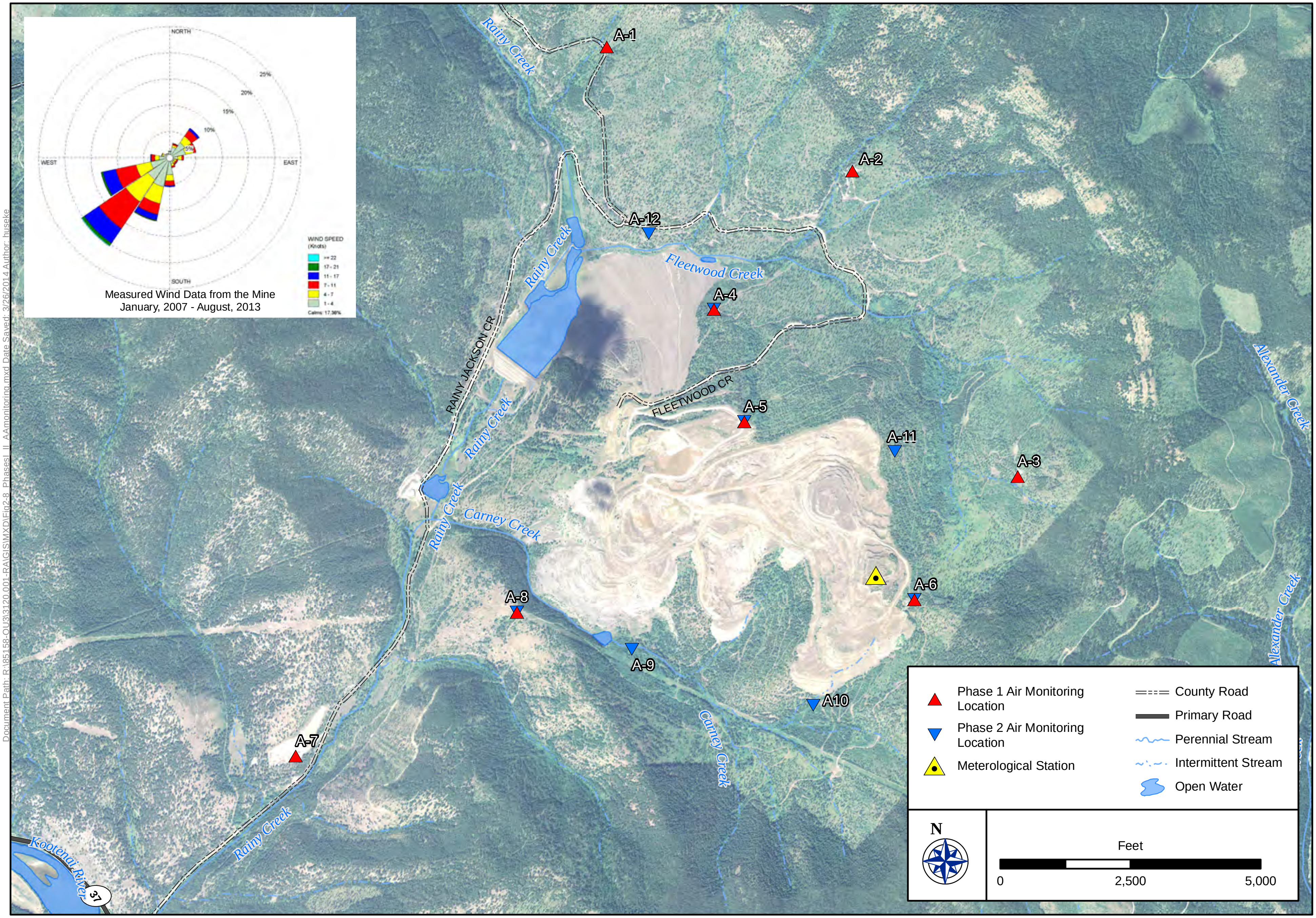
AMBIENT AIR SAMPLING DURATIONS FOR TROY MONITORING STATIONS

Libby Asbestos Superfund Site, Libby, Montana



Station ID	N Events	Station Description	Sampling Date Range
T1	35	Residential Property, North River Road	Oct-2009 to Oct-2010
T2	35	Fire Station in Kootenair Vista	Oct-2009 to Oct-2010
T3	36	Water Treatment Station, Roosevelt Park	Oct-2009 to Oct-2010
T4	35	MDEQ Troy Information Center	Oct-2009 to Oct-2010
T5	35	County Shops at Hwy 2-Sunset Road	Oct-2009 to Oct-2010
T6	36	Water Tower at Iron Creek Road	Oct-2009 to Oct-2010
T7	35	Residential Property, Wilderness Plateau	Oct-2009 to Oct-2010
T11	35	Community area NE of Kootenai River	Nov-2010 to Oct-2011
T12	32	Near northwest border of OU7 boundary	Nov-2010 to Oct-2011
T13	36	City of Troy, northern site	Nov-2010 to Oct-2011
T14	36	City of Troy, population center	Nov-2010 to Oct-2011
T15	36	City of Troy, southern site	Nov-2010 to Oct-2011
T16	35	Southwest OU7 boundary	Nov-2010 to Oct-2011
T17	36	Southeast OU7 boundary	Nov-2010 to Oct-2011
T21	30	North OU7 boundary	May-2012 to Dec-2012, Feb-2013 to Jul-2013*
T22	30	City of Troy, population center	May-2012 to Dec-2012, Feb-2013 to Jul-2013*
T23	26	City of Troy, southern site	May-2012 to Dec-2012, Feb-2013 to Jul-2013*
T24	30	Southeast OU7 boundary	May-2012 to Dec-2012, Feb-2013 to Jul-2013*

*Approximately one sample per month

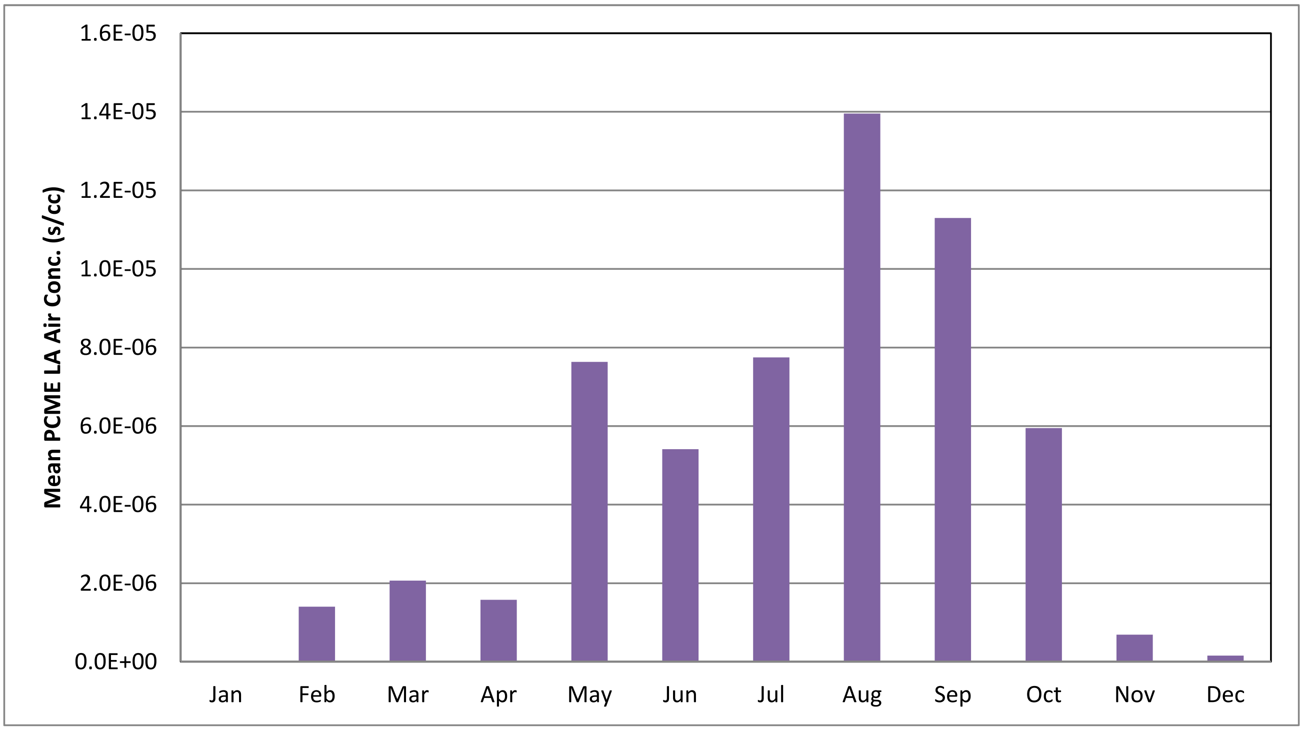


Ambient Air Monitoring Locations
Phases I and II

CDM Smith

FIGURE 5-5

FIGURE 5-6
Temporal Evaluation of Mean Ambient Air Concentrations in Libby
Libby Asbestos Superfund Site, Libby, Montana



Based on monitoring stations in Libby (L1-L18)

s/cc - structures per cubic centimeter
PCME - phase contrast microscopy-equivalent
LA - Libby amphibole

FIGURE 6-1
Example of Exposure Area Spatial-Weighting Approach

Panel A: Exposure Area Soil Concentrations

Soil Sample #1:
Bin A

Soil Sample #2:
Bin B1

Soil Sample #3:
Bin C

Panel B: Estimated HQs* for Each Subarea

Bin A
Soil Concentration HQ = 0.1

Bin B1
Soil Concentration HQ = 2

Bin C
Soil Concentration HQ = 7

Panel C: Estimated Average HQ for the Entire Exposure Area

Exposure Area HQ =
$(0.1 \cdot 0.5)$ +
$(2 \cdot 0.25)$ +
$(7 \cdot 0.25)$
= **2**

*Based on OU4 Yard Soil Disturbance ABS Residential RME HQs (see **Table 6-3a**)

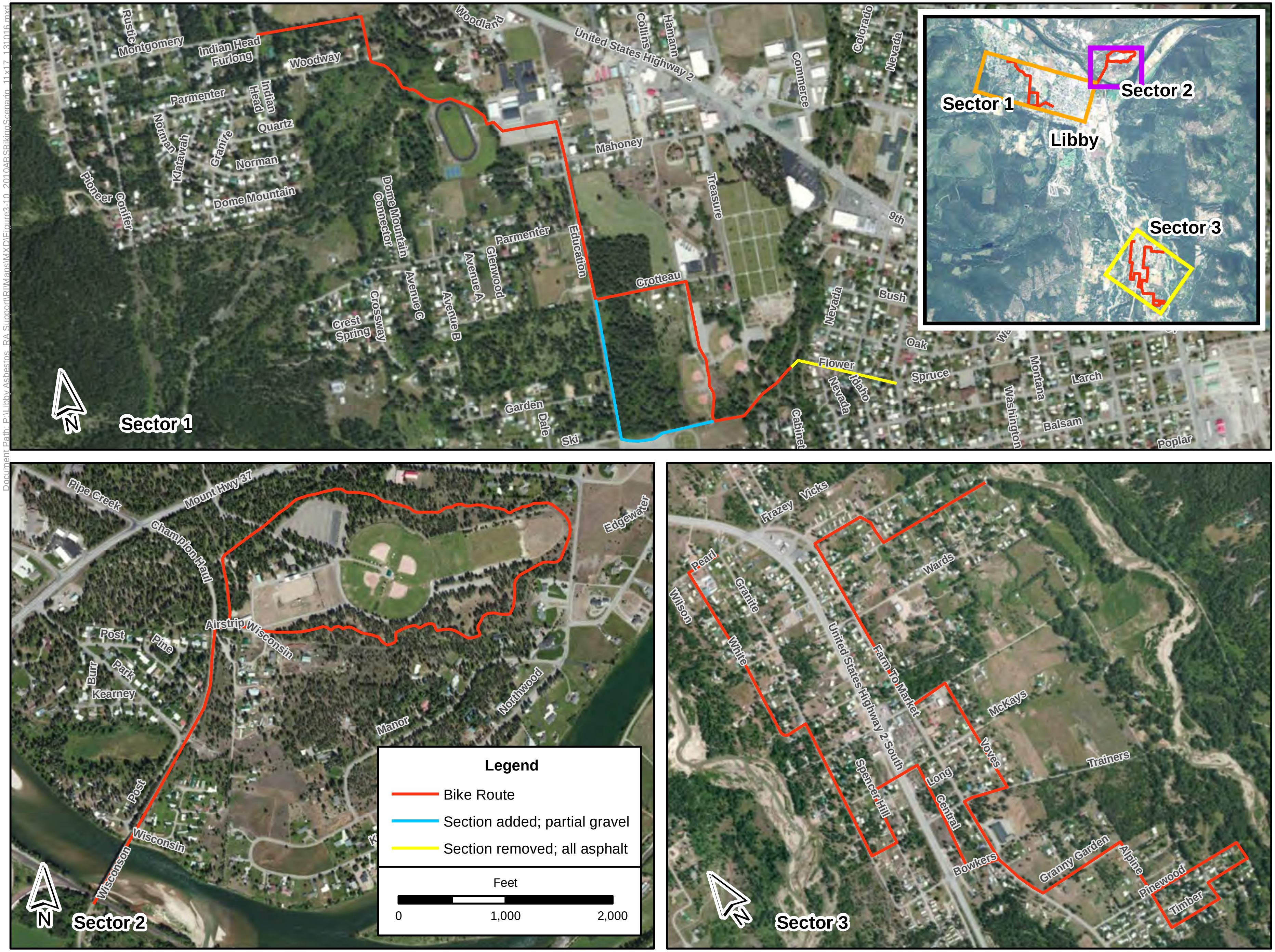


Figure 6-2
Libby Bicycle Routes

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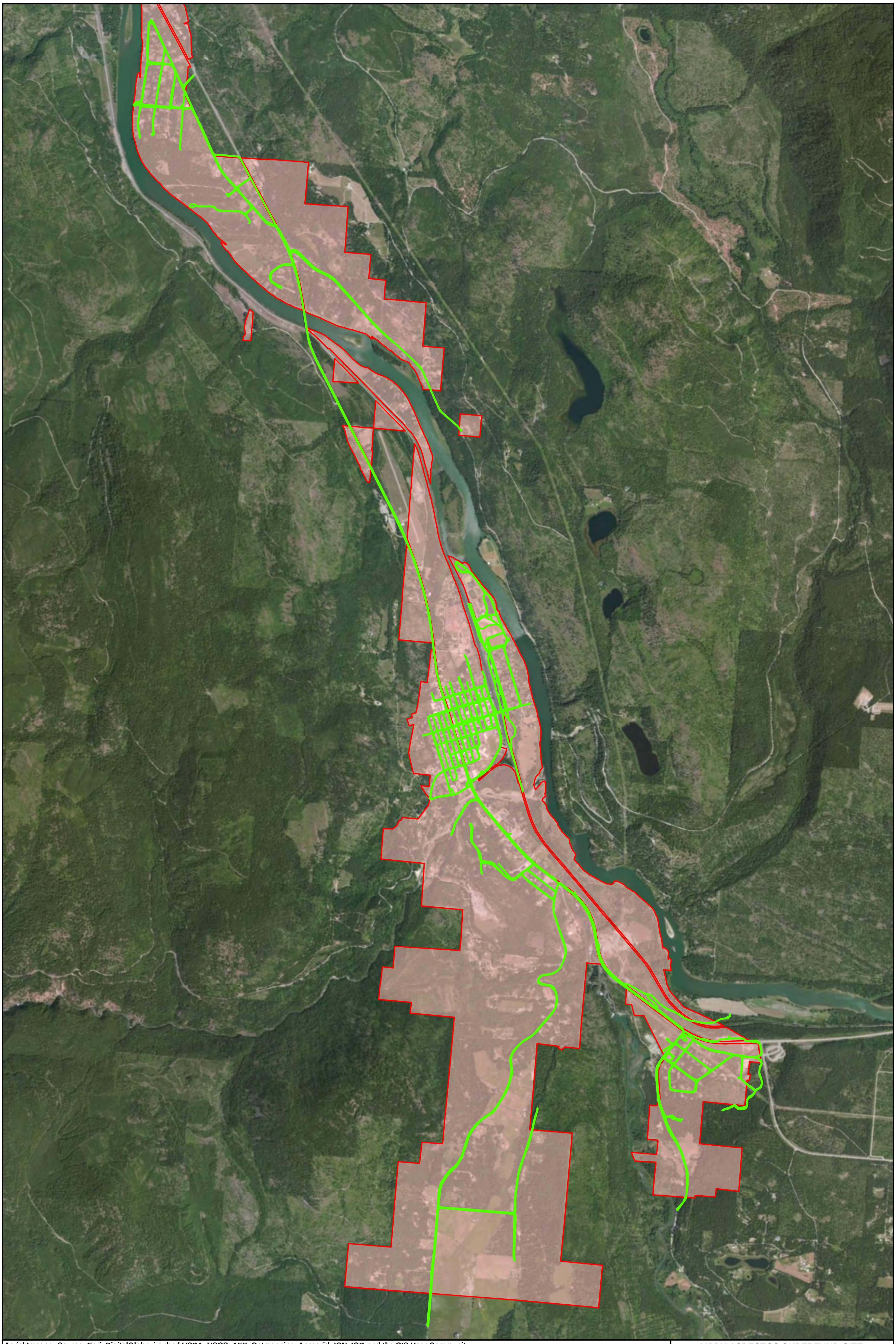


Aerial Imagery Source: Esri, DigitalGlobe, i-cubed,USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

LEGEND

ABS BIKE ROUTE - 2011

OPERABLE UNIT 7 AREA

N

0 1 Miles

LIBBY ASBESTOS SUPERFUND SITE
LIBBY, MONTANA

FIGURE 6-3
2011 TROY ABS BIKE ROUTE COVERAGE

TETRA TECH EM INC.

Bike_Track_Base_Map_021414.mxd - DWH - TTEMI HELENA

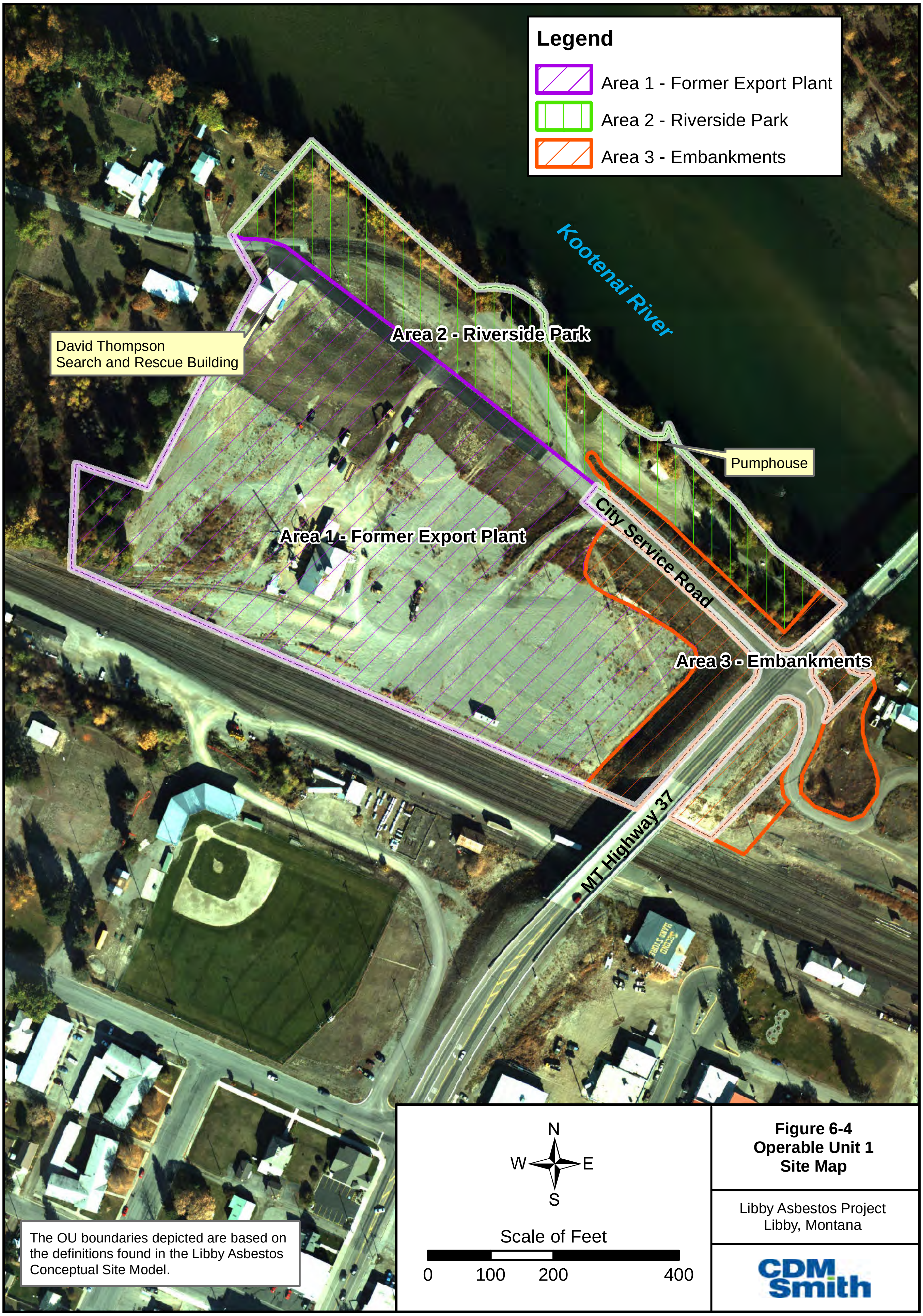
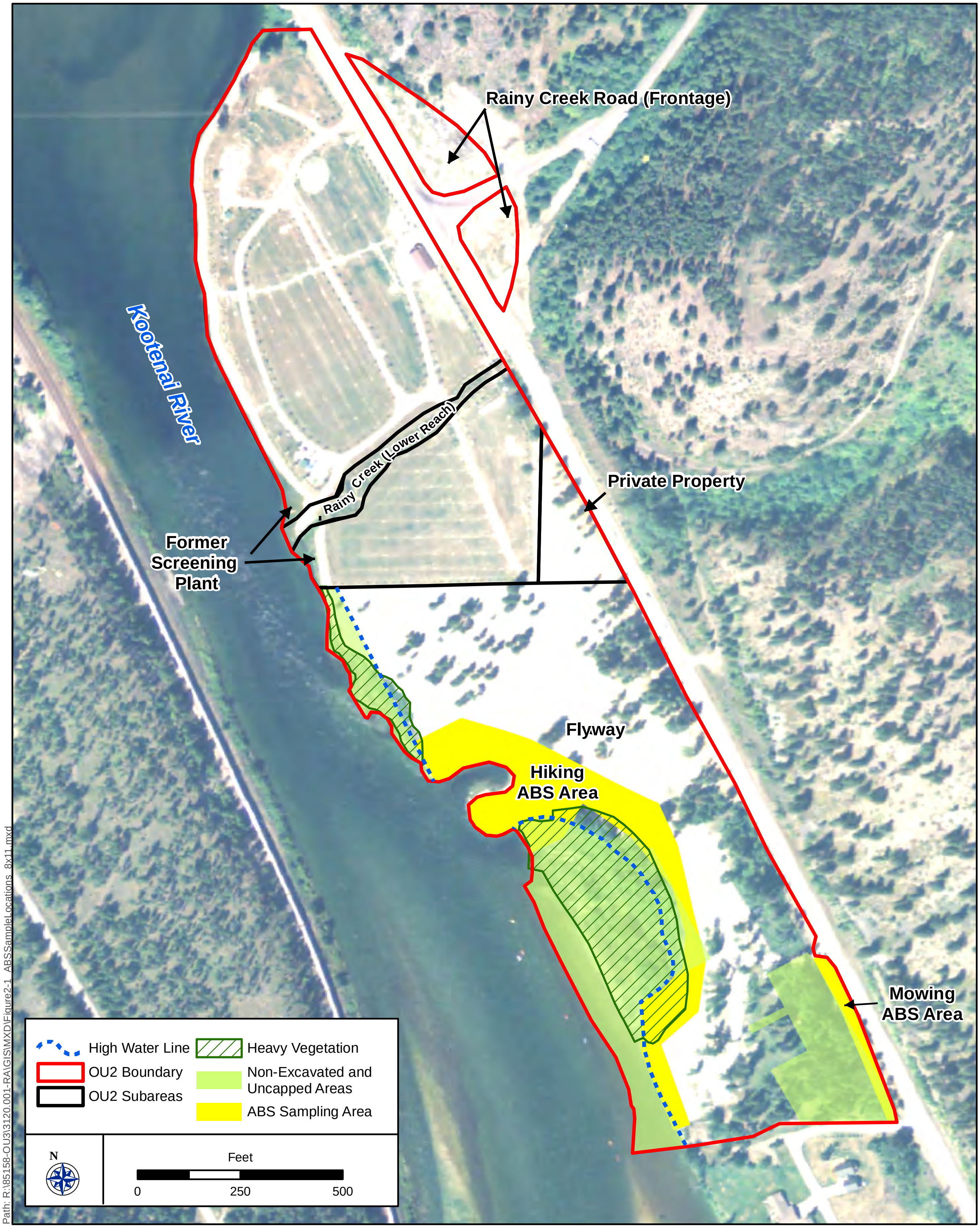


Figure 6-4
Operable Unit 1
Site Map

Libby Asbestos Project
Libby, Montana



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OU2 ABS
Sampling Areas

FIGURE 6-5

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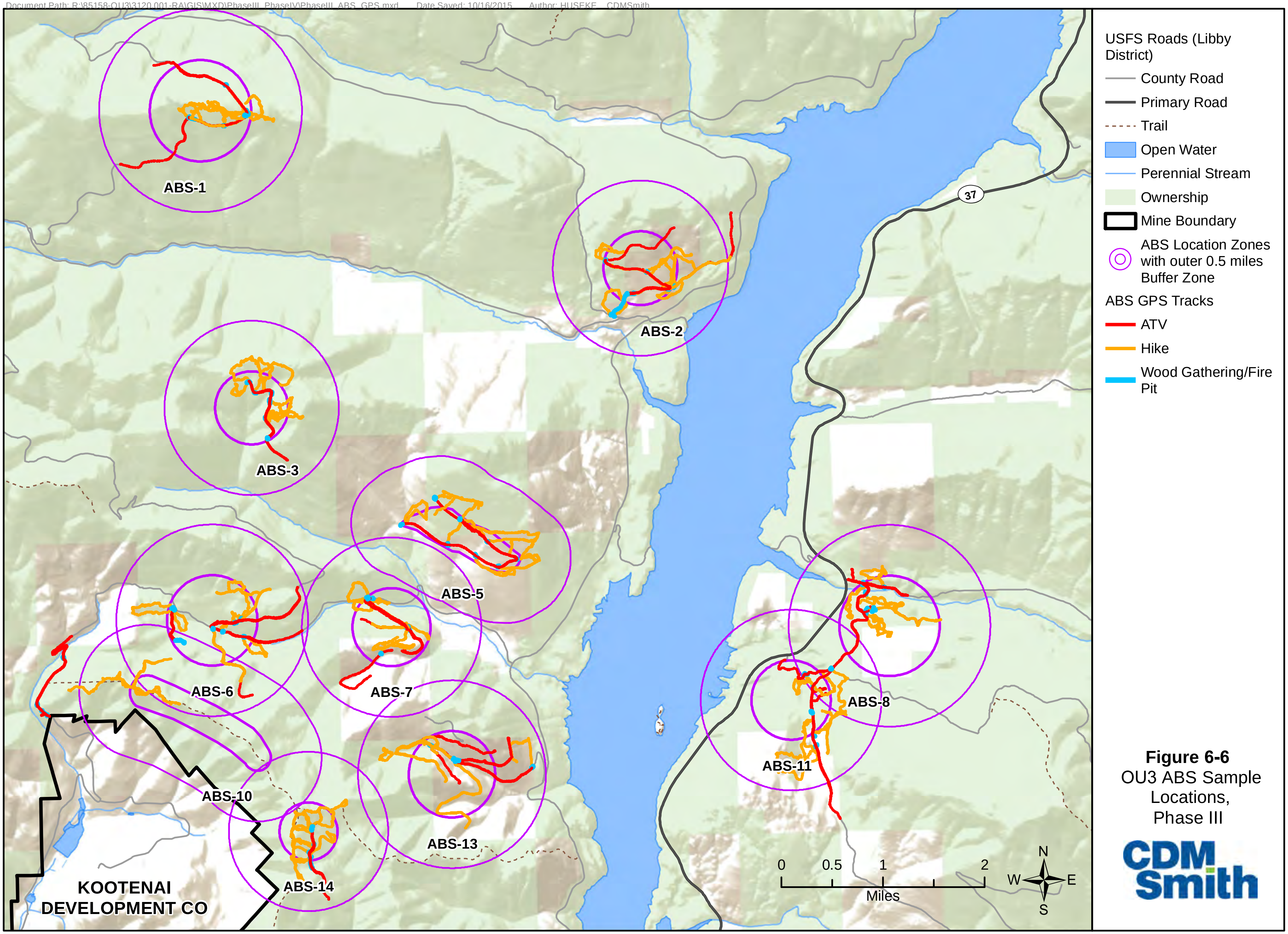

Figure 6-6
OU3 ABS Sample Locations, Phase III

CDM Smith

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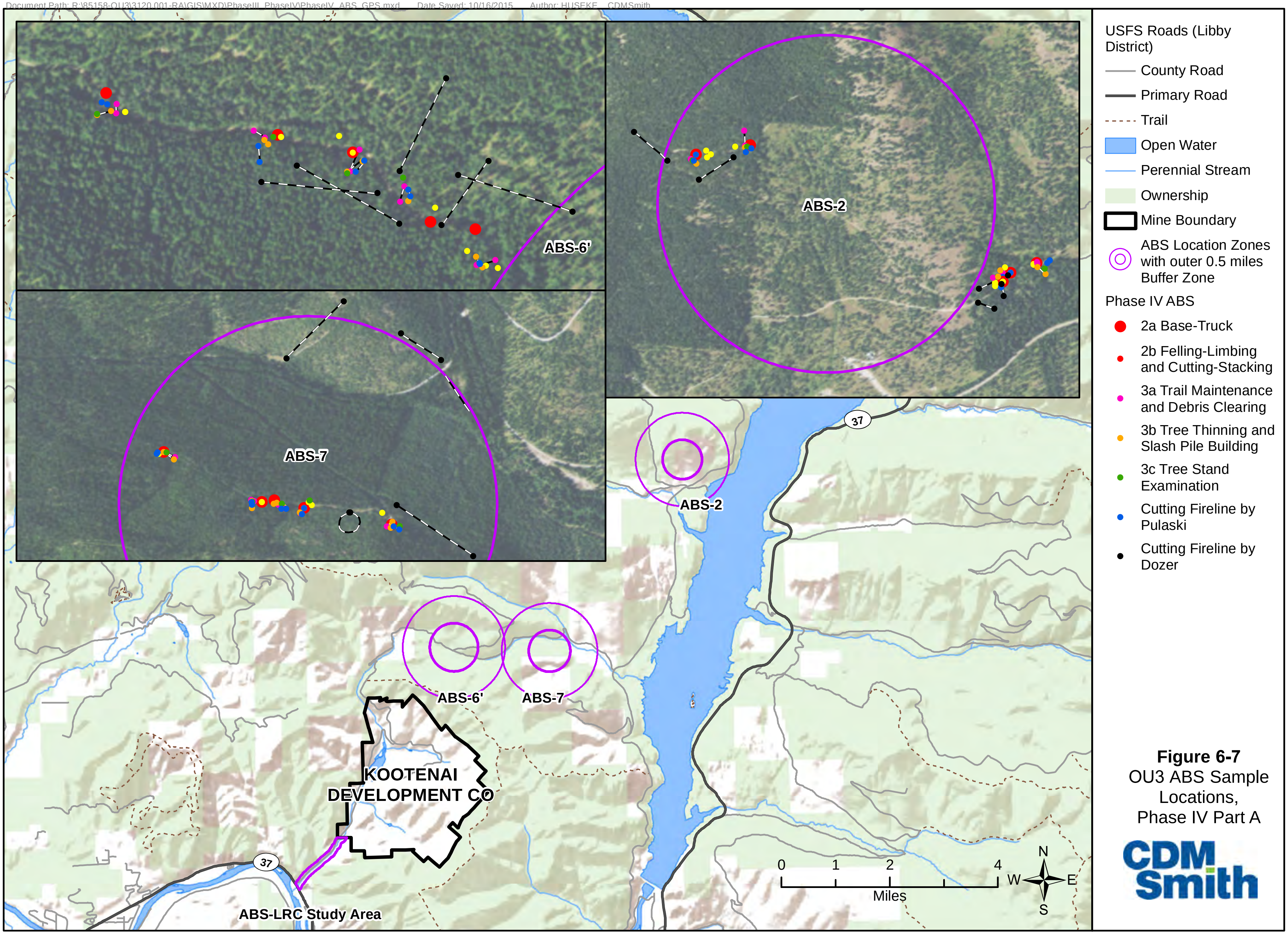
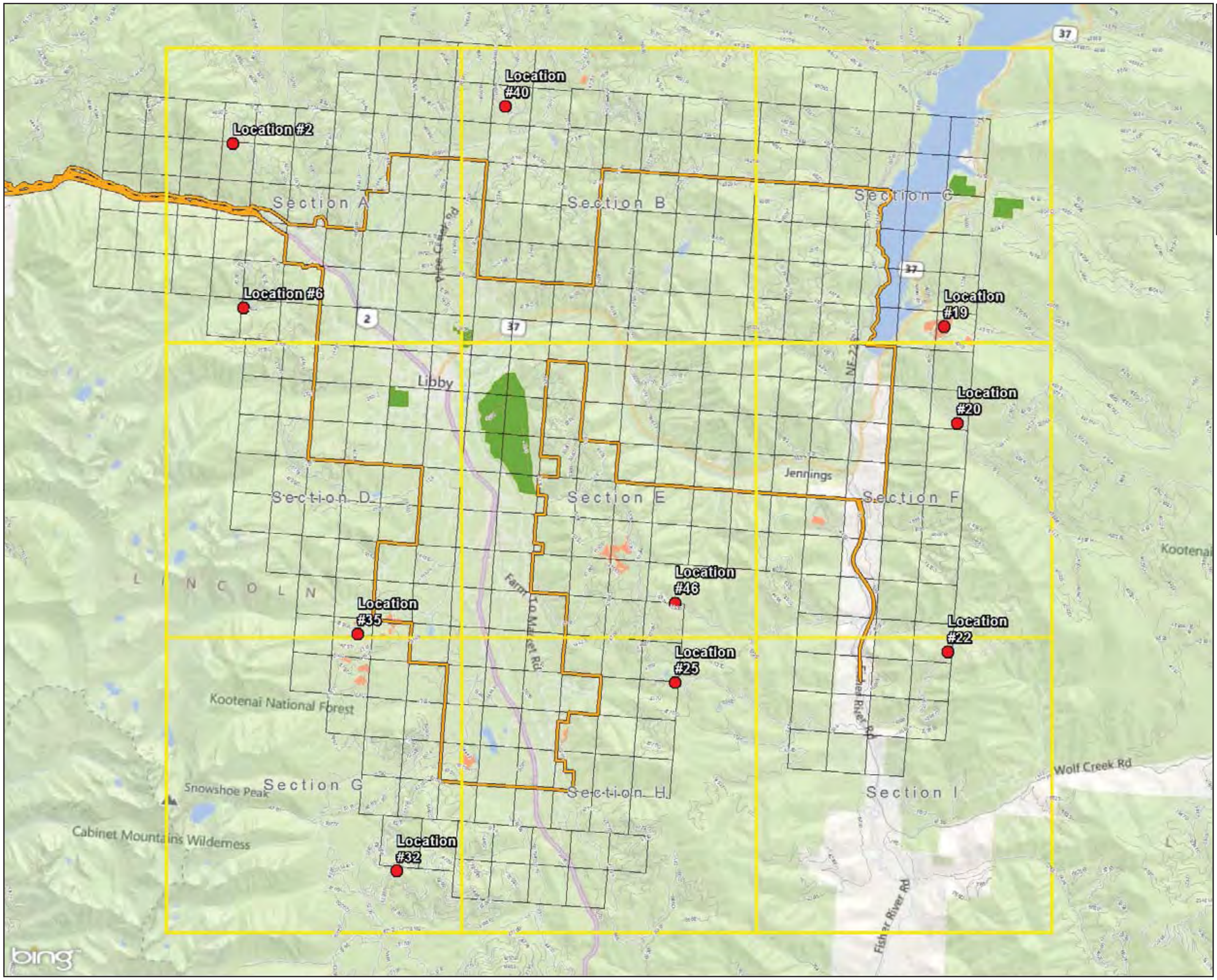


Figure 6-7
OU3 ABS Sample Locations, Phase IV Part A



Legend

- Sampling Locations
- Forest Service Roads
- Libby Asbestos NPL Boundary
- Two Mile Buffer Along the NPL Boundary
- DNRC Timber Sales
- DNRC Precommercial Tree Thinning
- Detailed Map Index

* See Appendix C for Detailed Maps

N W E S

Miles

0 1.25 2.5 5

1 inch = 2.424579 miles

Data Sources:
NPL Boundary - U.S. EPA Region 8 (2011);
Timber Sales and Precommercial Tree Thinning - MT DNRC (2011);
Base - Microsoft Bing (2011)

For Official Use Only

Figure 6-8

Nature and Extent
Forest Pulaski ABS
Locations

CDM Smith

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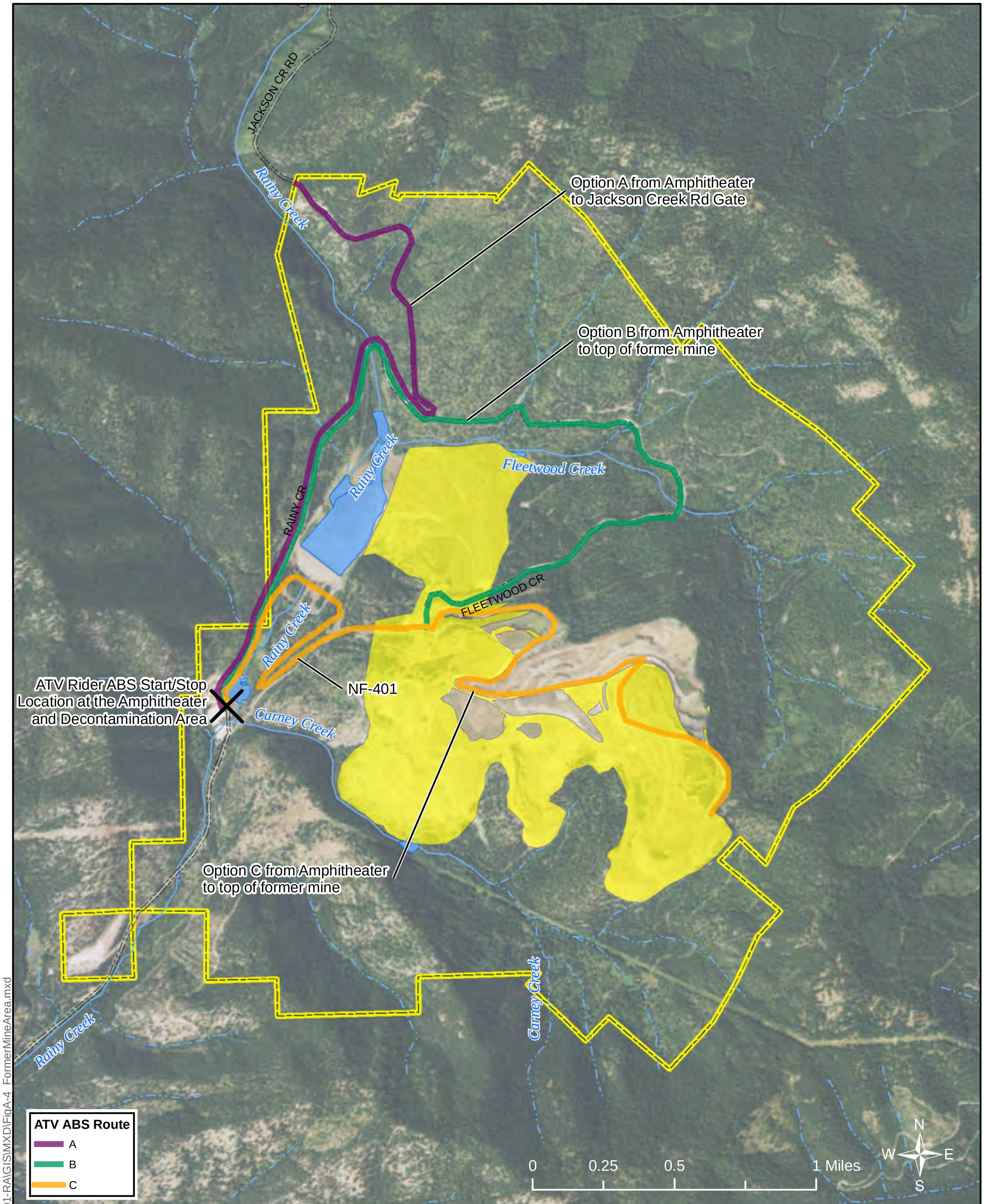

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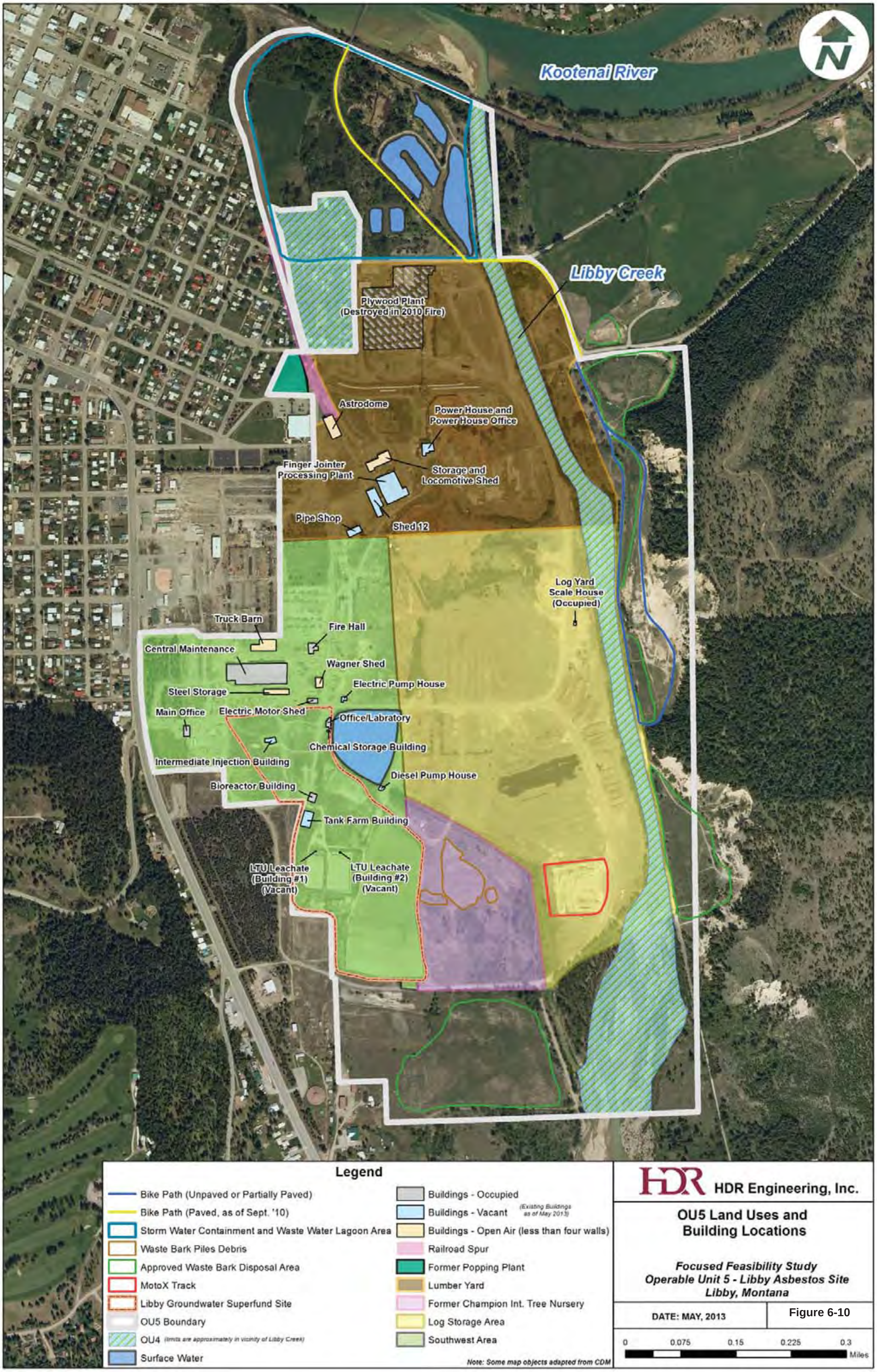
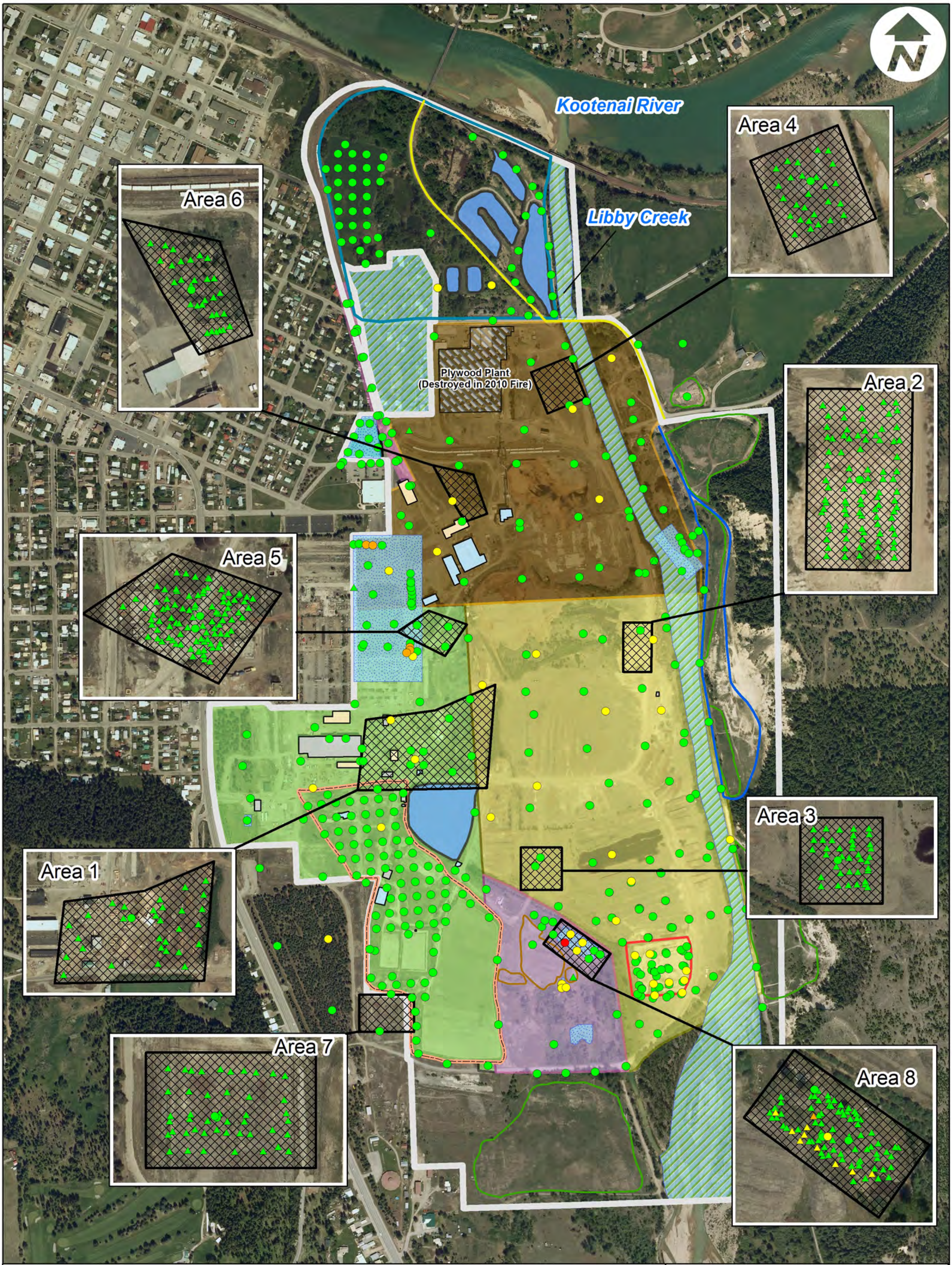
CDM Smith

ABS Area
County Road
Primary Road
Perennial Stream
Intermittent Stream
Open Water
Former Mine Property

Figure 6-9
Trespasser ABS Areas


Kootenai River
N
Libby Creek
Plywood Plant (Destroyed in 2010 Fire)
Astrodome
Power House and Power House Office
Finger Jointer Processing Plant
Storage and Locomotive Shed
Pipe Shop
Shed 12
Log Yard Scale House (Occupied)
Truck Barn
Fire Hall
Central Maintenance
Wagner Shed
Electric Pump House
Steel Storage
Main Office
Electric Motor Shed
Office/Labratory
Chemical Storage Building
Intermediate Injection Building
Diesel Pump House
Bioreactor Building
Tank Farm Building
LTU Leachate (Building #1) (Vacant)
LTU Leachate (Building #2) (Vacant)
Legend
Bike Path (Unpaved or Partially Paved)
Bike Path (Paved, as of Sept. '10)
Storm Water Containment and Waste Water Lagoon Area
Waste Bark Piles Debris
Approved Waste Bark Disposal Area
MotoX Track
Libby Groundwater Superfund Site
OU5 Boundary
OU4 (limits are approximately in vicinity of Libby Creek)
Surface Water
Buildings - Occupied
Buildings - Vacant
(Existing Buildings as of May 2013)
Buildings - Open Air (less than four walls)
Railroad Spur
Former Popping Plant
Lumber Yard
Former Champion Int. Tree Nursery
Log Storage Area
Southwest Area
Note: Some map objects adapted from CDM
HDR HDR Engineering, Inc.
OU5 Land Uses and Building Locations
Focused Feasibility Study
Operable Unit 5 - Libby Asbestos Site
Libby, Montana
DATE: MAY, 2013
Figure 6-10
0 0.075 0.15 0.225 0.3
Miles



LA Results

Grab Samples
- < 1%
- Trace
- Non-Detect

Composite Samples
- >= 1%
- < 1%
- Trace
- Non-Detect

- Bike Path (Unpaved or Partially Paved)
- Bike Path (Paved, as of Sept. '10)
- Storm Water Containment and Waste Water Lagoon Area
- Waste Bark Piles Debris
- Approved Waste Bark Disposal Area
- MotoX Track
- Libby Groundwater Superfund Site
- Worker ABS Areas
- OU5 Boundary
- OU4 (limits are approximately in vicinity of Libby Creek)
- Abatement Reponse Action Areas[1]

- Buildings - Occupied
- Buildings - Vacant (Existing Buildings as of May 2013)
- Buildings - Open Air (less than four walls)
- Surface Water
- Railroad Spur
- Former Popping Plant
- Lumber Yard
- Former Champion Int. Tree Nursery
- Log Storage Area
- Southwest Area

[1]Results shown on Figure reflect testing done before abatement actions. See Figure 1-4 & Table 1-1 for details on response actions taken at OU5.

HDR Engineering, Inc.

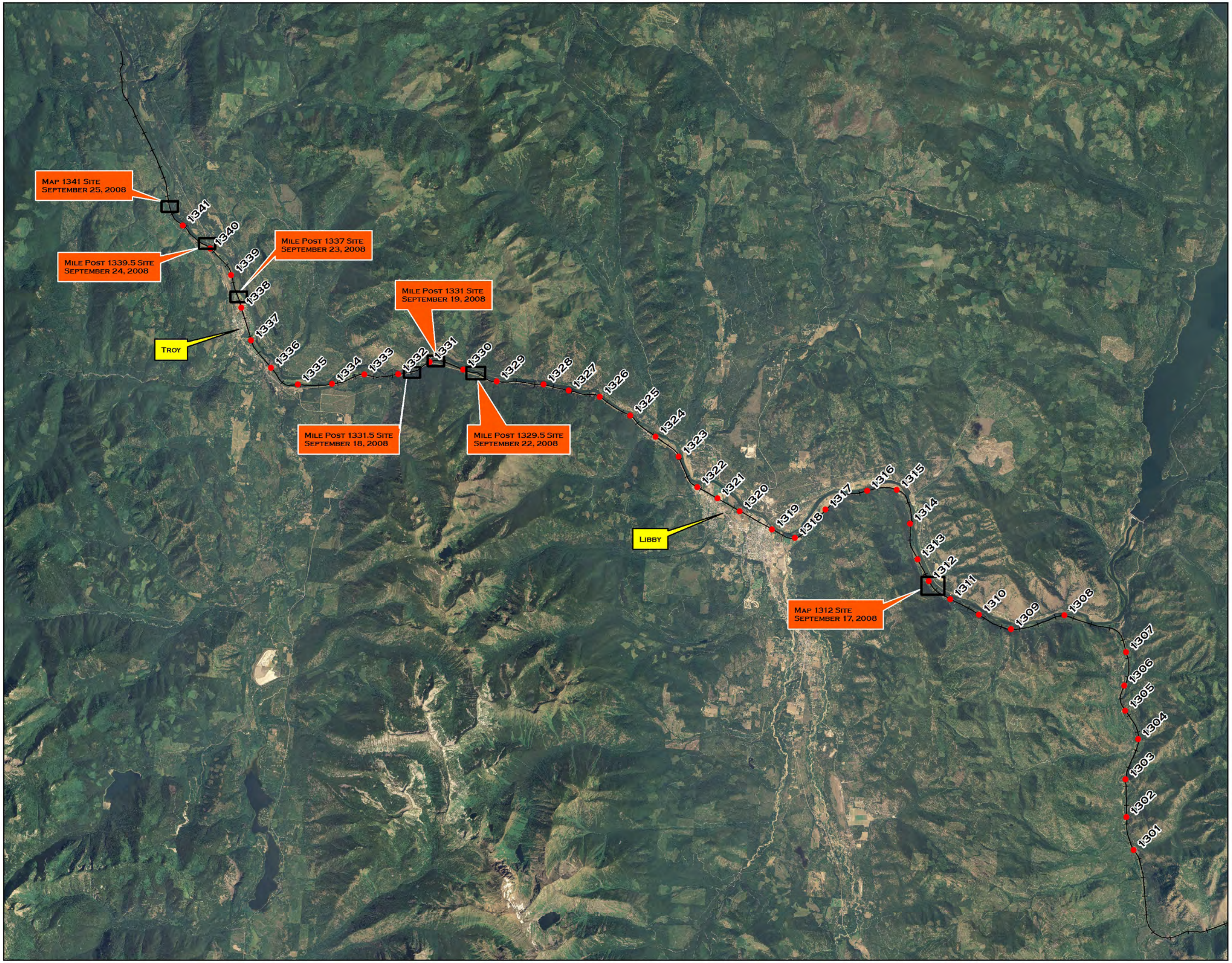
OU5 Outdoor ABS Areas

Remedial Investigation
Operable Unit 5 - Libby Asbestos Site
Libby, Montana

DATE: MAY, 2013

Figure 6-11

0 0.08 0.16 0.24 0.32 Miles



N
W E
S

Figure 6-12
OU6 Outdoor ABS Locations

Activity Based Sampling
Summary Report
--
Worker Receptors

BNSF Kootenai River Sub
Libby, Montana

Legend

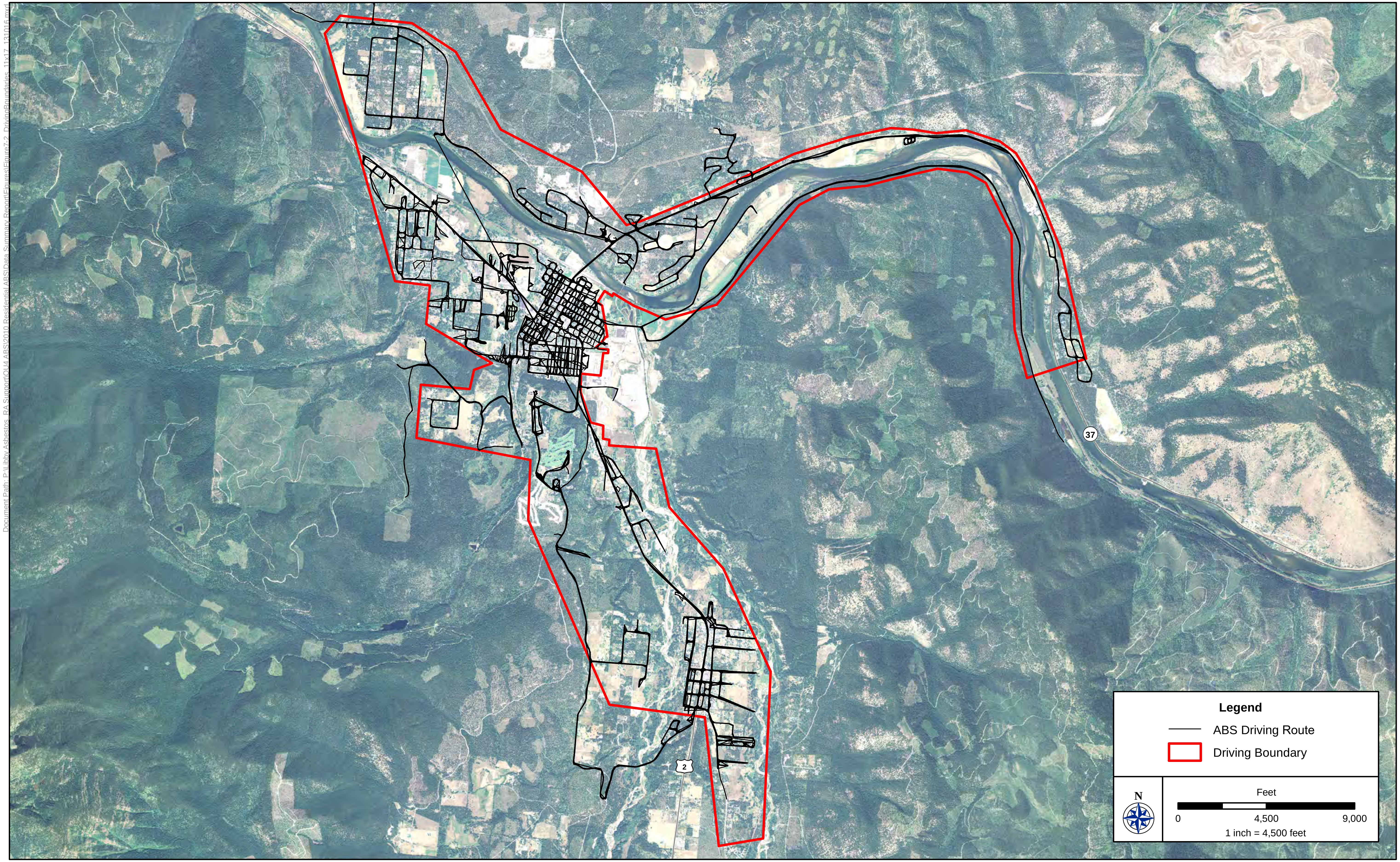
- Approximate Milepost Locations
- BNSF Railway

0 7,000 14,000 28,000
Scale In Feet

0 2 4
Scale In Miles

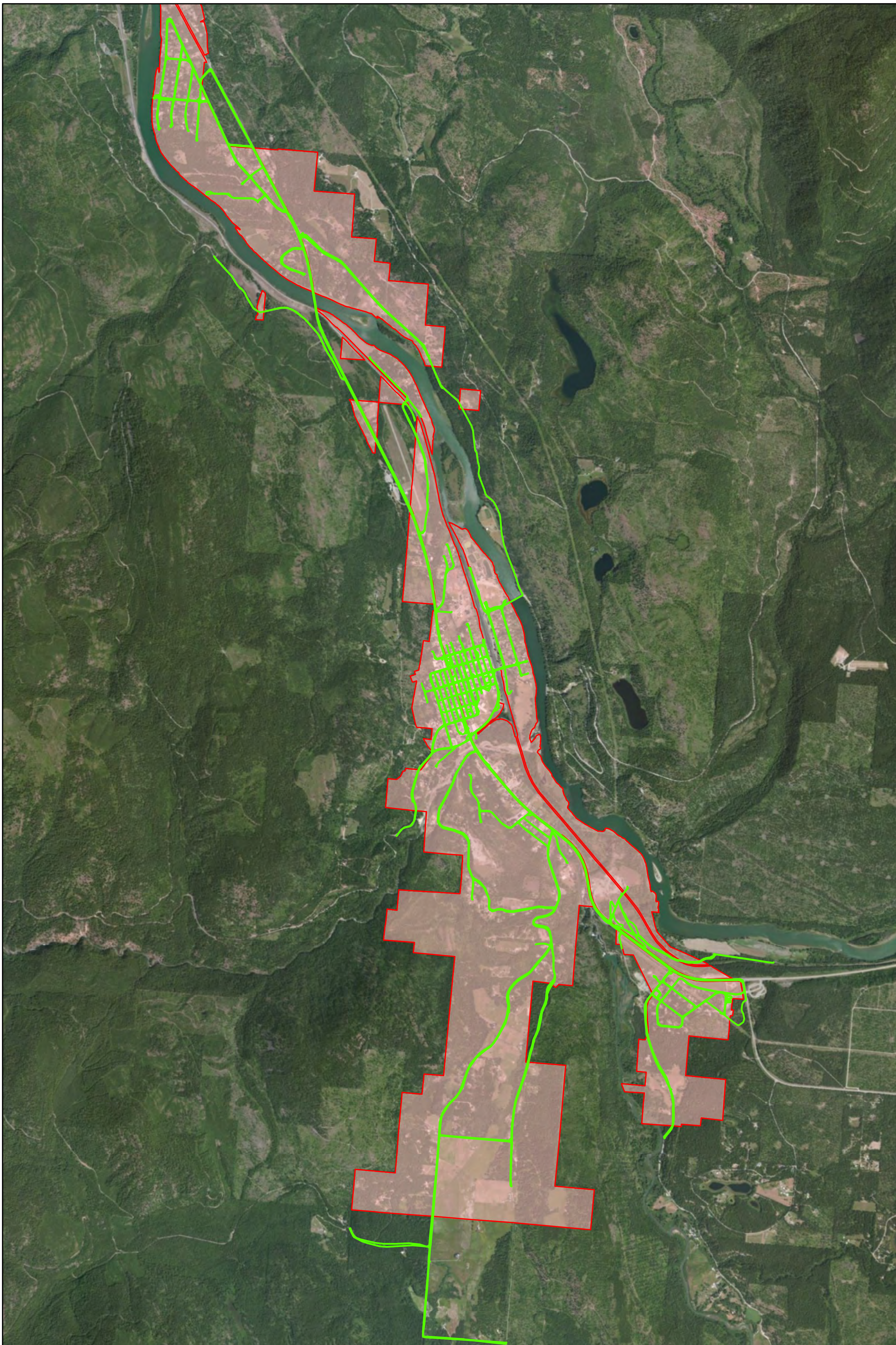
Project Number: 5539-140
Date: March 8, 2010
Drafted By: KLA
Reviewed By: SJC
Reference: 2006 Lincoln Aerial

EMR INCORPORATED
INFRASTRUCTURE AND ENVIRONMENT
11 E. Superior St. Suite #260
Duluth, MN 55802
Phone: 218.625.2332
Fax:218.625.2337



Libby
Driving Boundaries

FIGURE 6-13



Aerial Imagery Source: Esri, DigitalGlobe, i-cubed,USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

LEGEND

ABS DRIVING ROUTE - 2011

OPERABLE UNIT 7 AREA

N

0 1 Miles

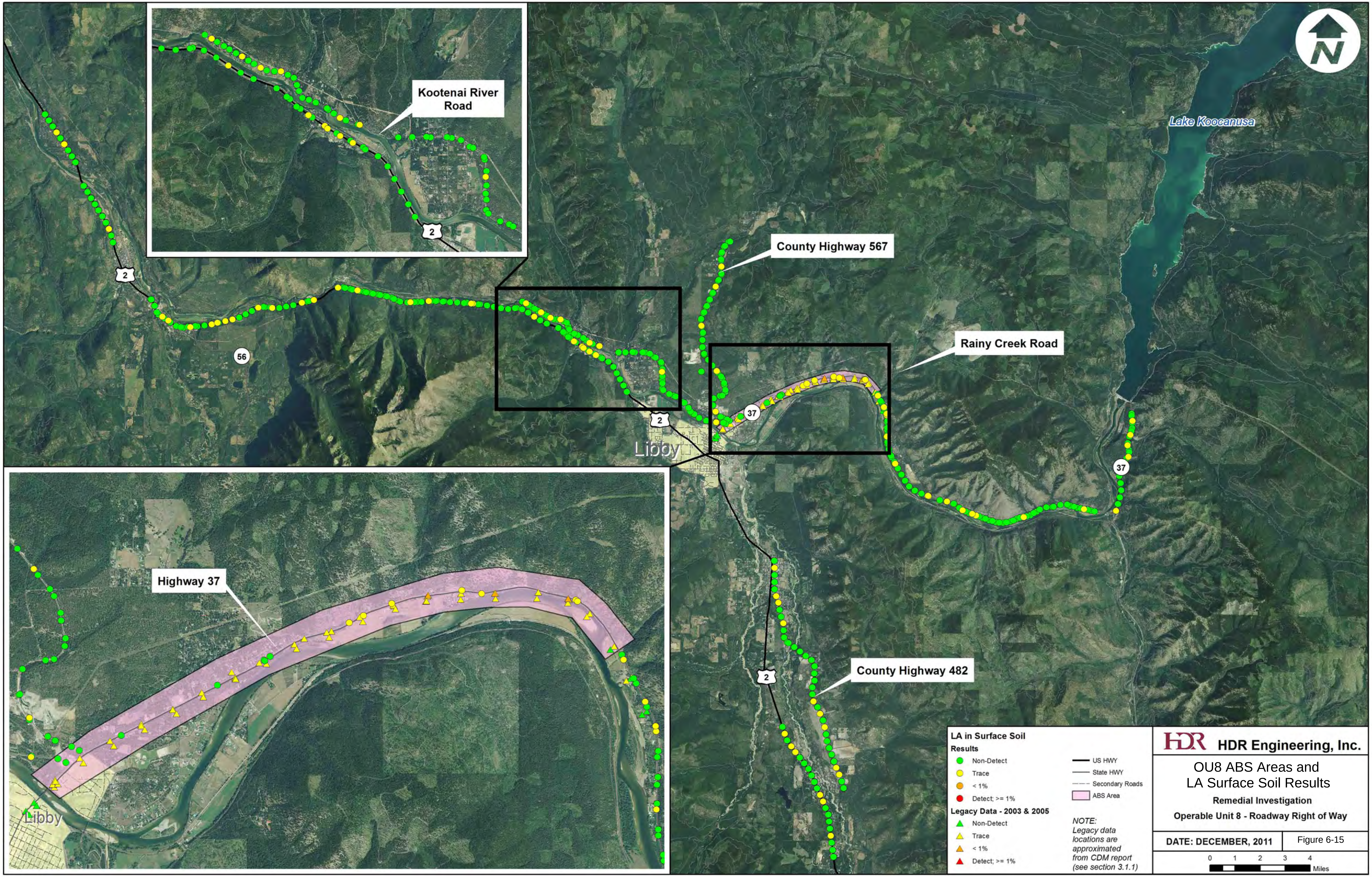
LIBBY ASBESTOS SUPERFUND SITE
LIBBY, MONTANA

FIGURE 6-14

TROY DRIVING BOUNDARIES

TETRA TECH EM INC.

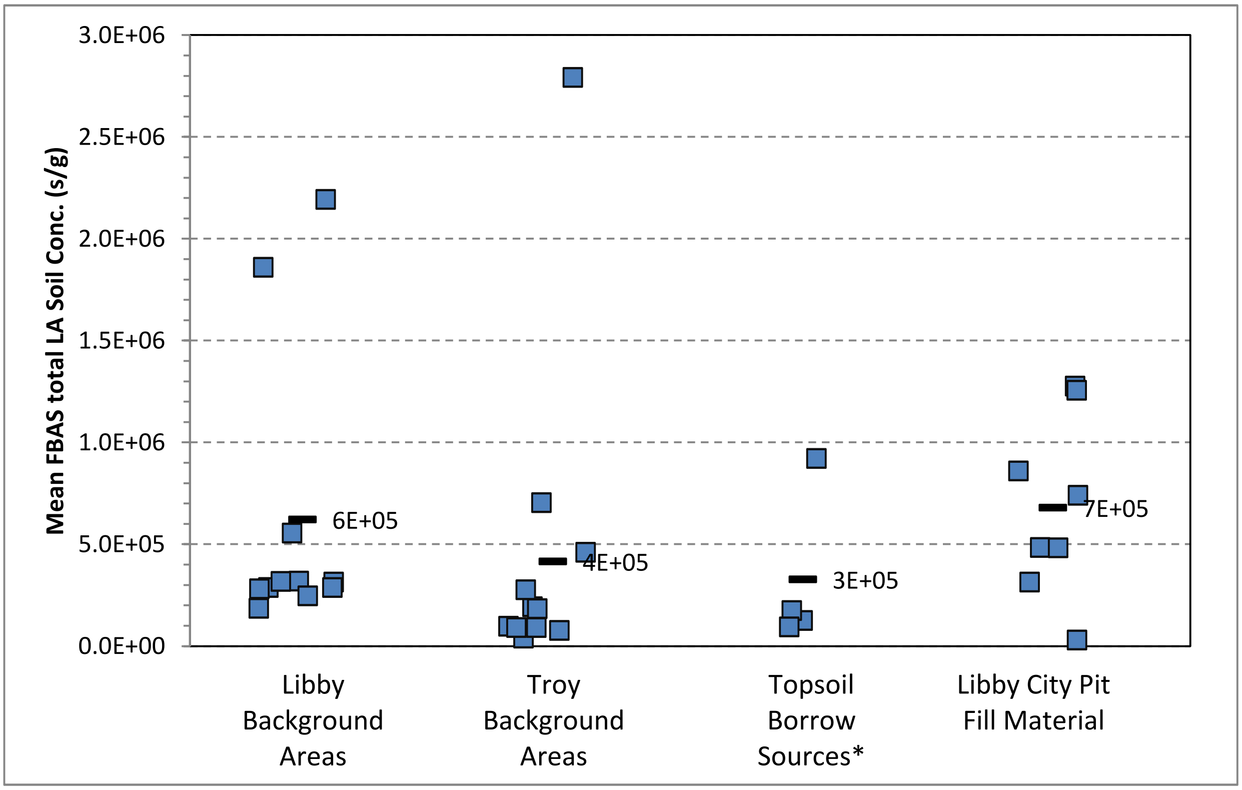
Driving_Track_Base_Map_021414.mxd - DWH - TTEMI HELENA



Kootenai River Road
County Highway 567
Rainy Creek Road
Lake Koocanusa
Libby
Highway 37
County Highway 482
2
56
37
LA in Surface Soil
Results
Non-Detect
Trace
< 1%
Detect; >= 1%
Legacy Data - 2003 & 2005
Non-Detect
Trace
< 1%
Detect; >= 1%
US HWY
State HWY
Secondary Roads
ABS Area
NOTE: Legacy data locations are approximated from CDM report (see section 3.1.1)
HDR Engineering, Inc.
OU8 ABS Areas and LA Surface Soil Results
Remedial Investigation
Operable Unit 8 - Roadway Right of Way
DATE: DECEMBER, 2011
Figure 6-15
0 1 2 3 4 Miles

FIGURE 6-16

Scatterplot of Total LA Soil Concentrations in Background Soils



*Only includes sources within the Kootenai Valley.

Each square represents the measured concentration for each location.

The mean concentration for each soil type is shown as a horizontal bar.

Notes:

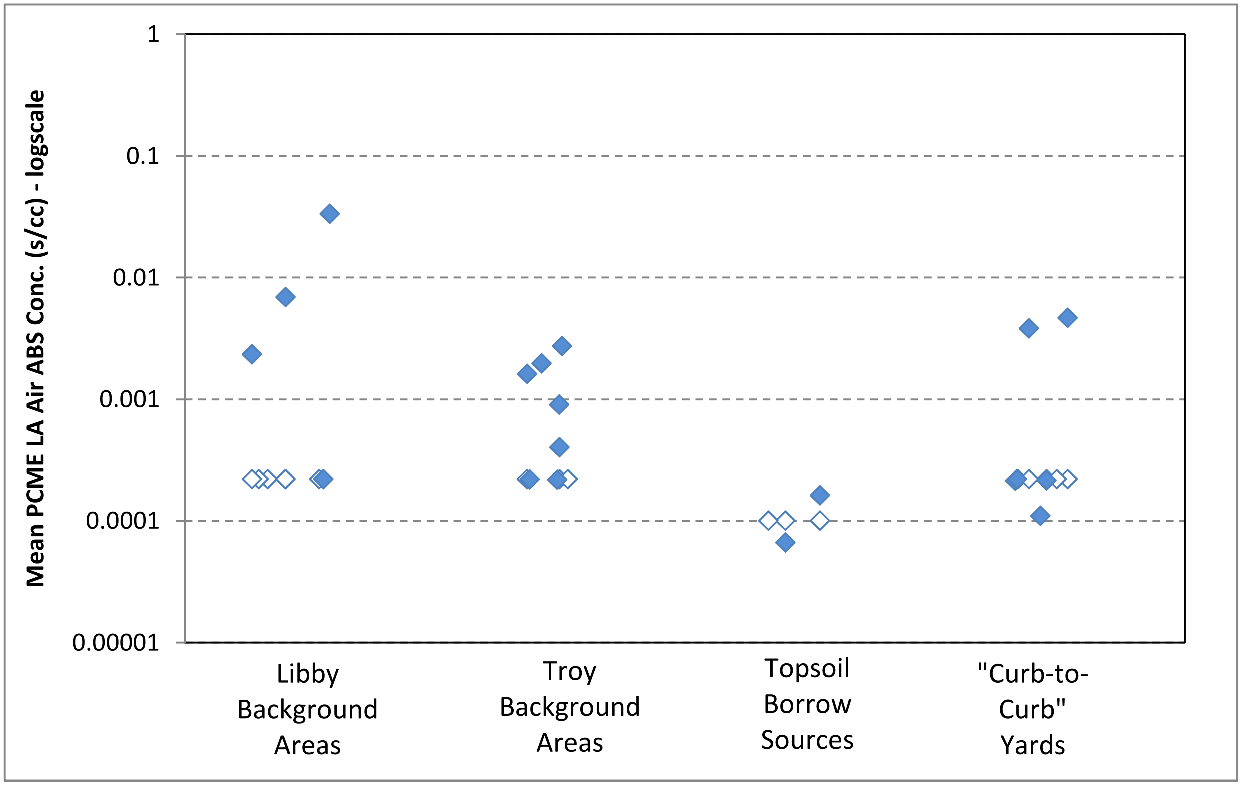
FBAS = fluidized bed asbestos segregator

LA = Libby amphibole

s/g = structures per gram

FIGURE 6-17. Example Photographs of the “Bucket of Dirt” ABS Activities

FIGURE 6-18. SCATTERPLOT OF PCME LA AIR CONCENTRATIONS IN BORROW SOURCES, BACKGROUND AREAS, AND CURB-TO-CURB PROPERTIES



Non-detects are shown as open symbols and plotted at the target sensitivity.

Notes:

ABS = activity-based sampling

LA = Libby amphibole

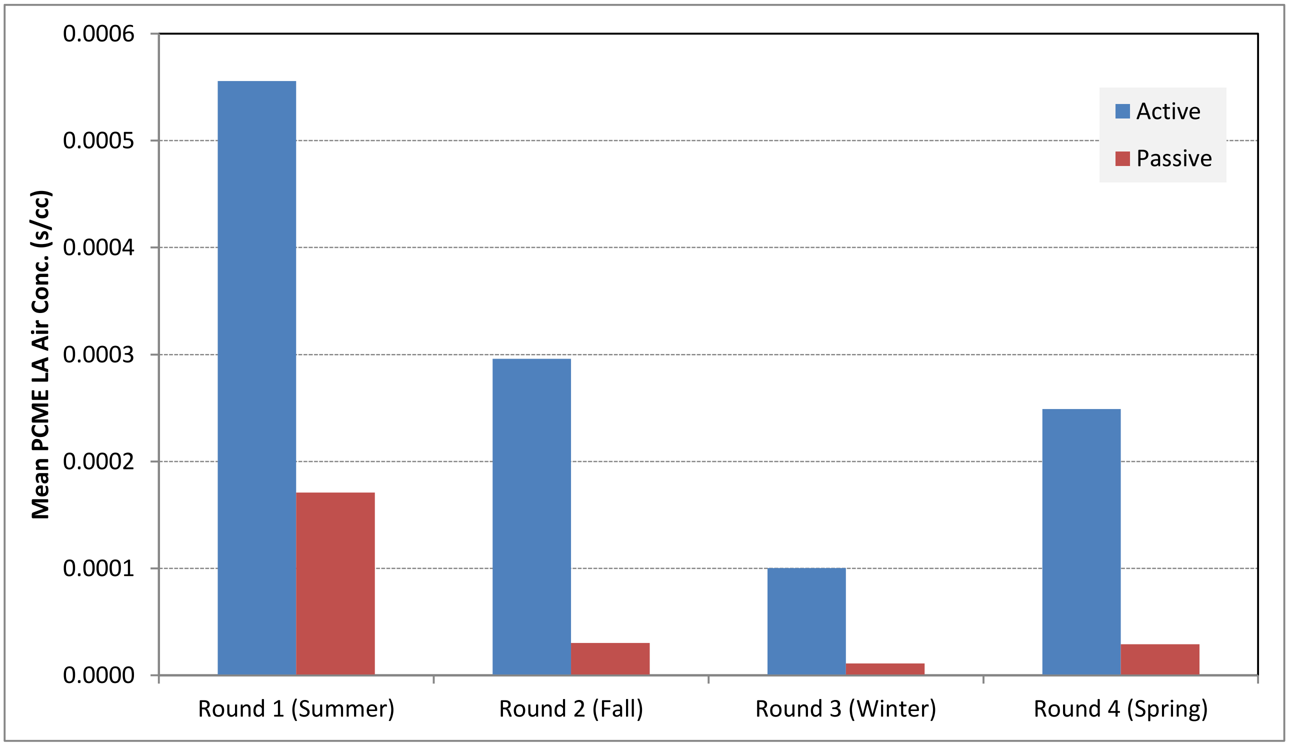
s/cc = structures per cubic centimeter

Conc. = concentration

FIGURE 7-1

ILLUSTRATION OF SEASONAL VARIABILITY IN INDOOR ABS AIR CONCENTRATIONS

Libby Asbestos Superfund Site

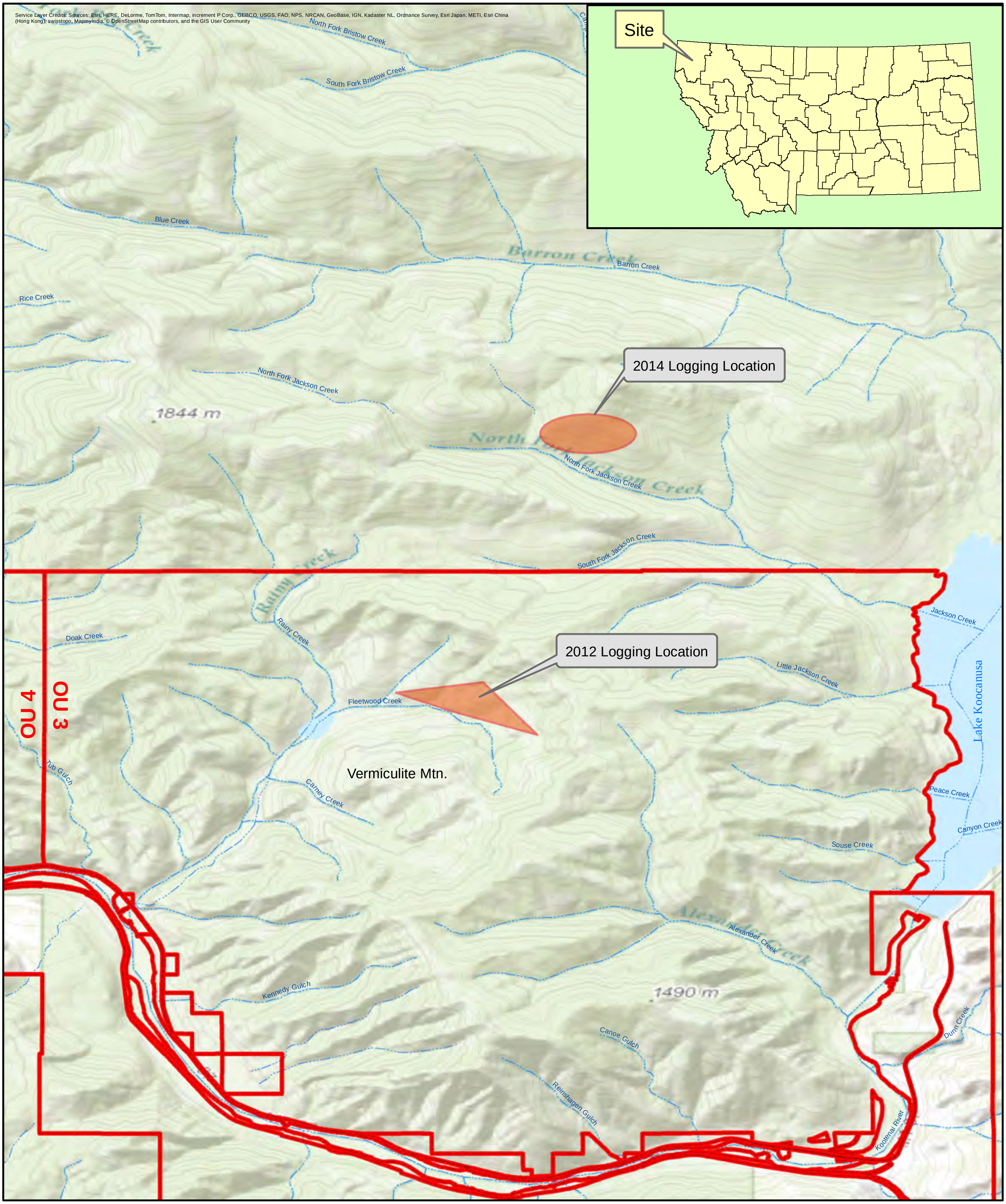


Conc. = concentration

LA = Libby amphibole asbestos

PCME = phase contrast microscopy-equivalent

s/cc = structures per cubic centimeter of air



Legend

Commercial Logging Study Area

Operable Unit 3

Streams

1.5 0.75 0 1.5 Miles

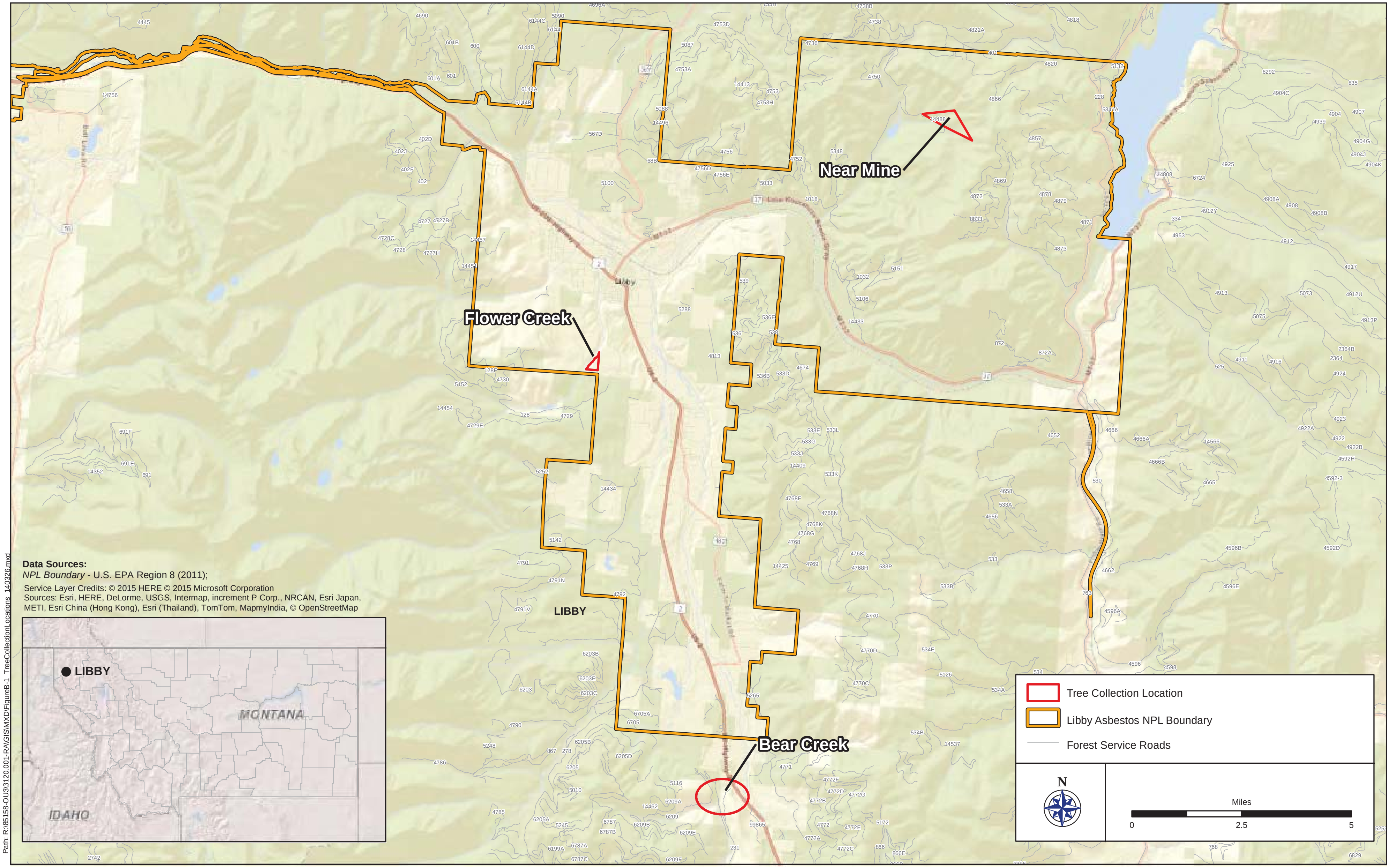
N

1:100,000

1 inch = 8,333 feet

Figure 8-1
Commercial Logging ABS Areas

CDM Smith



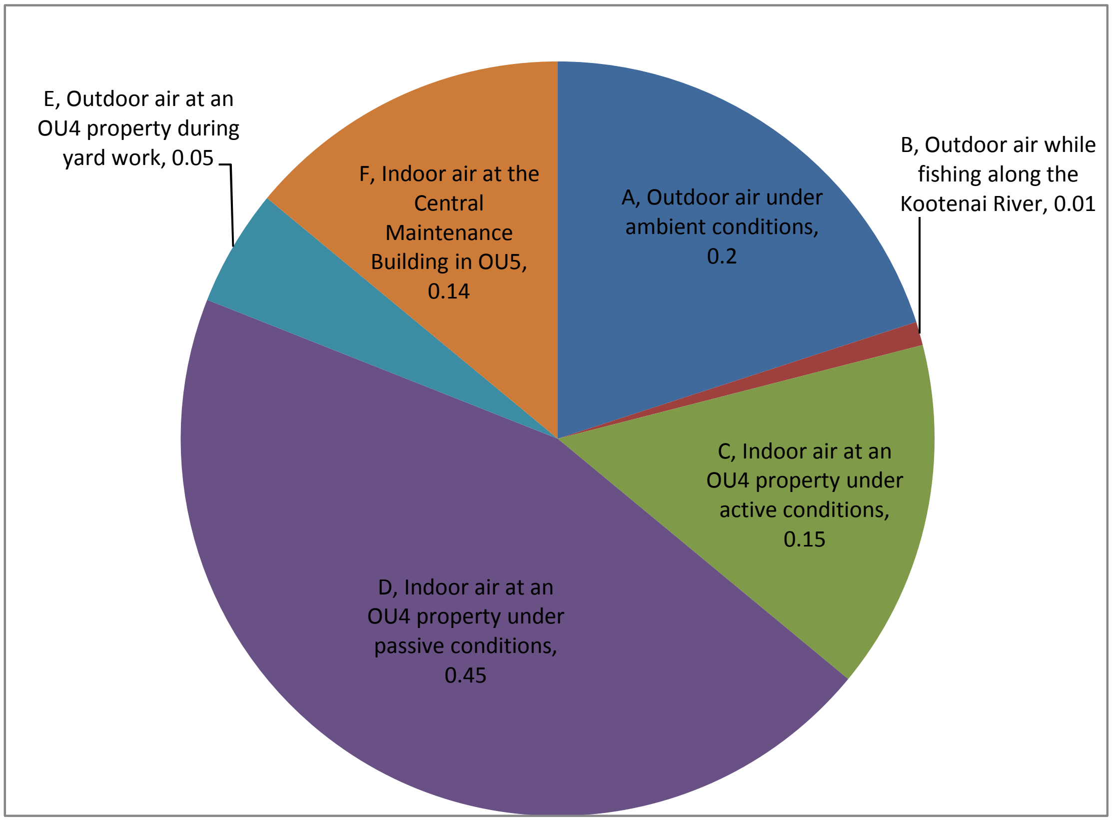
Path: R:\85158-OU3\3120.001-RA\GIS\MXD\FigureB-1_TreeCollectionLocations_140326.mxd

CDM Smith

Tree Collection Locations

FIGURE 8-2

FIGURE 9-1. ILLUSTRATION OF CUMULATIVE ASSESSMENT TWF APPROACH



Exposure Scenario		TWF	% of total
A	Outdoor air under ambient conditions	0.20	20%
B	Outdoor air while fishing along the Kootenai River	0.03	3%
C	Indoor air at an OU4 property under active conditions	0.15	15%
D	Indoor air at an OU4 property under passive conditions	0.48	48%
E	Outdoor air at an OU4 property during yard work	0.03	3%
F	Indoor air at the Central Maintenance Building in OU5	0.11	11%
	cumulative:	**1.00**	

Notes:

% - percent

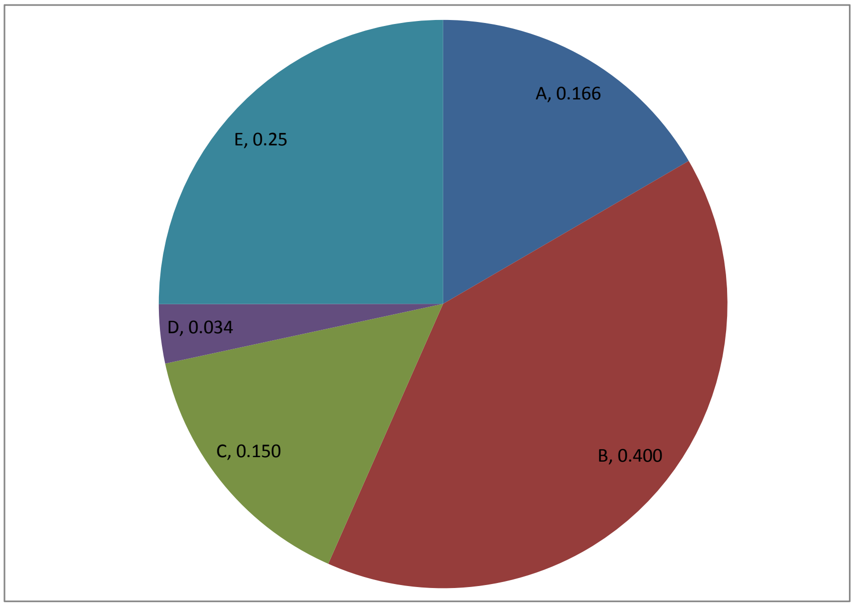
OU - Operable Unit

TWF - time-weighting factor

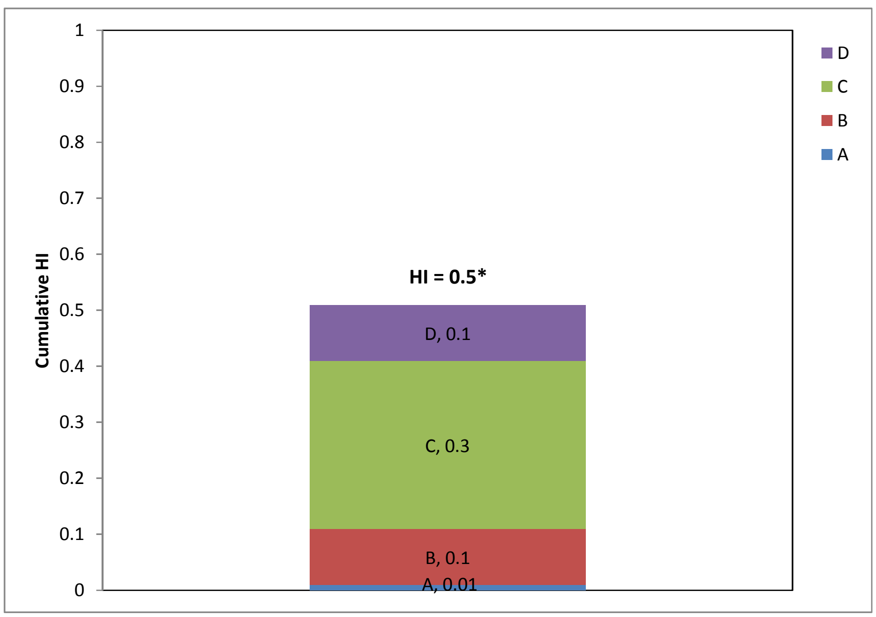
FIGURE 9-2a. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 1

["baseline" residential]

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI



	Exposure Scenario	TWF Value	TWF % of total	Risk Estimates Risk	Risk Estimates HQ	Risk Estimates % of total
A	Ambient air, OU4	0.17	17%	2E-07	0.01	2%
B	Indoor air, OU4, post-removal, resident, passive	0.40	40%	2E-06	0.1	20%
C	Indoor air, OU4, post-removal, resident,active	0.15	15%	5E-06	0.3	60%
D	Outdoor air, yard soil, curb-to-curb	0.034	3%	2E-06	0.1	20%
	cumulative*:	**1.000**		**9E-06**	**0.5**	

* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

Notes:

% - percent

HI - hazard index

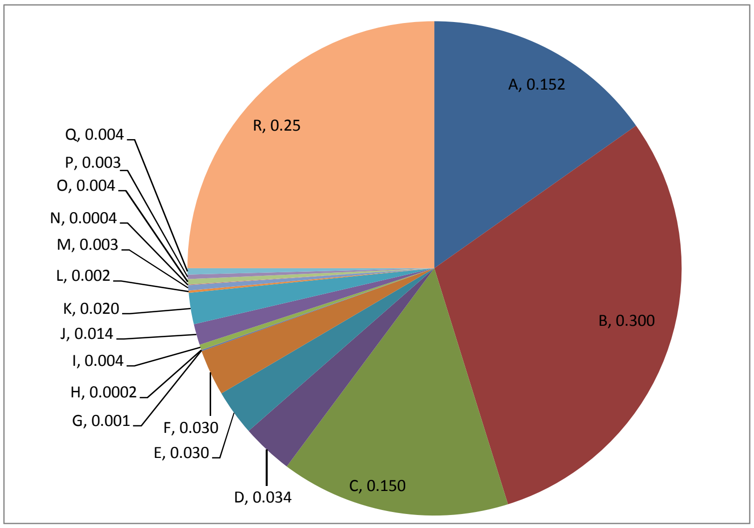
HQ - hazard quotient

OU - Operable Unit

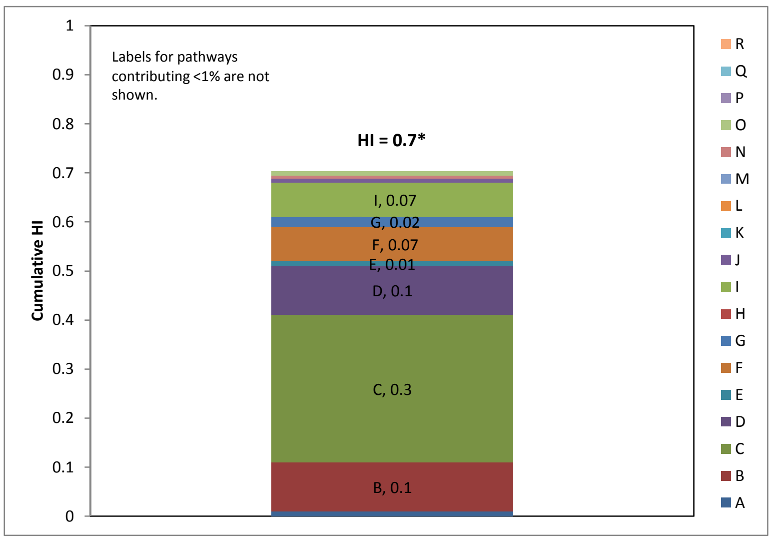
TWF - time-weighting factor

FIGURE 9-2b. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 1

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI



	Exposure Scenario	TWF		Risk Estimates		
		Value	% of total	Risk	HQ	% of total
A	Ambient air, OU4	0.15	15%	2E-07	0.01	1%
B	Indoor air, OU4, post-removal, resident, passive	0.30	30%	2E-06	0.1	14%
C	Indoor air, OU4, post-removal, resident,active	0.15	15%	5E-06	0.3	43%
D	Outdoor air, yard soil, curb-to-curb	0.034	3%	2E-06	0.1	14%
E	Indoor air, OU4, no removal, worker, passive	0.030	3%	2E-07	0.01	1%
F	Indoor air, OU4, no removal, worker, active	0.030	3%	1E-06	0.07	10%
G	Outdoor air, OU4, Libby Middle, student	0.00070	0.07%	2E-07	0.02	3%
H	Outdoor air, OU4, Koot. Valley HS, student	0.00021	0.02%	0E+00	0	0%
I	Outdoor air, OU4, Libby Elem., student	0.0035	0.4%	1E-06	0.07	10%
J	Indoor air, OU4, student, Elem. School	0.014	1%	1E-07	0.009	1%
K	Outdoor air, OU7, Golf course, adult	0.02	2%	0E+00	0	0%
L	Outdoor air, OU4, biking, adult	0.0016	0.2%	0E+00	0	0%
M	Outdoor air, OU5, MotoX, participant	0.0034	0.3%	0E+00	0	0%
N	Outdoor air, OU4, LUA soil, ATV, A	0.00036	0.04%	7E-08	0.005	0.7%
O	Outdoor air, OU3, forest, hiking, far	0.0036	0.4%	1E-07	0.009	1%
P	Outdoor air, OU3, Kootenai, fishing	0.0029	0.3%	0E+00	0	0%
Q	Outdoor air, OU8, Driving in Libby	0.0041	0.4%	0E+00	0	0%
R	Offsite	0.25	25%	0E+00	0	0%
	cumulative*:	**1.000**		**1E-05**	**0.7**	

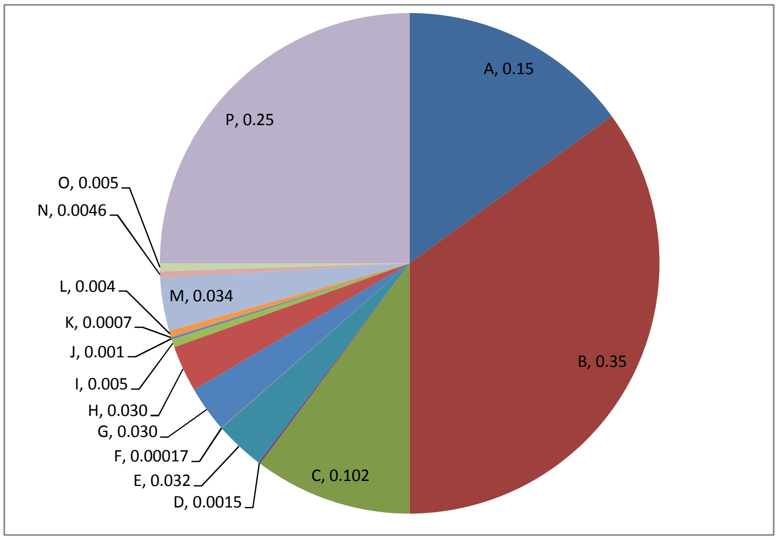
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

Notes:

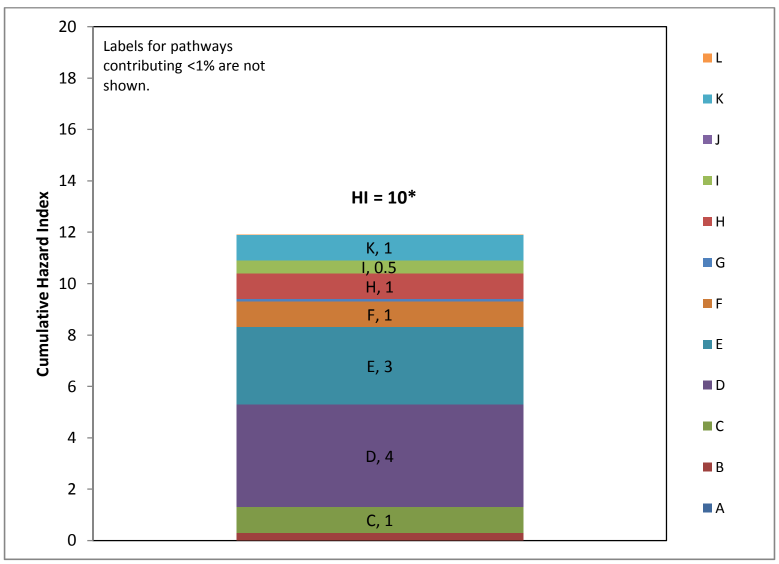
% - percent
< - less than
ATV - all-terrain vehicle
HI - hazard index
HQ - hazard quotient
LUA - limited use area
MotoX - motorcross
OU - Operable Unit
TWF - time-weighting factor

FIGURE 9-3. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 2

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI



	Exposure Scenario	TWF		Risk Estimates		
		Value	**% of total**	**Risk**	**HQ**	**% of total**
A	Ambient air, OU4	0.15	15%	2E-07	0.01	0.1%
B	Indoor air, OU4, pre-removal, resident, passive	0.35	35%	4E-06	0.3	3%
C	Indoor air, OU4, pre-removal, resident, active	0.10	10%	2E-05	1	10%
D	Outdoor air, OU4, yard soil, B2/C, high	0.0015	0.15%	5E-05	4	40%
E	Outdoor air, OU4, yard soil, B2/C, typical	0.032	3.2%	4E-05	3	30%
F	Outdoor air, OU4, subsurface soil, resident, B2/C	0.00017	0.017%	2E-05	1	10%
G	Indoor air, OU4, pre-removal, worker, passive	0.030	3%	1E-06	0.09	0.9%
H	Indoor air, OU4, pre-removal, worker, active	0.030	3%	2E-05	1	10%
I	Outdoor air, OU3, Rainy Creek, hiking	0.0050	0.5%	8E-06	0.5	5%
J	Outdoor air, OU3, forest, wood harvesting, intermed.	0.0010	0.10%	2E-07	0.01	0.1%
K	Indoor air, Woodstove ash, near	0.00070	0.07%	2E-05	1	10%
L	Outdoor air, OU8, ATV	0.0040	0.4%	1E-07	0.008	0.08%
M	Indoor, OU4, schools, student	0.0340	3.4%	3E-07	0.02	0.2%
N	Outdoor air, OU4, schools, student	0.0046	0.46%	2E-06	0.1	1.0%
O	Outdoor air, OU8, Driving in Libby	0.0050	0.50%	0E+00	0	0%
P	Offsite	0.2500	25%	0E+00	0	0%
	cumulative*:	**1.00**		**2E-04**	**10**	

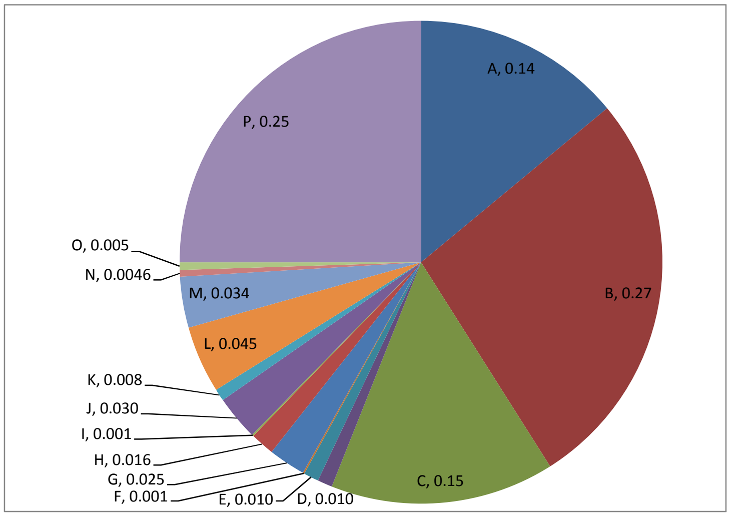
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

Notes:

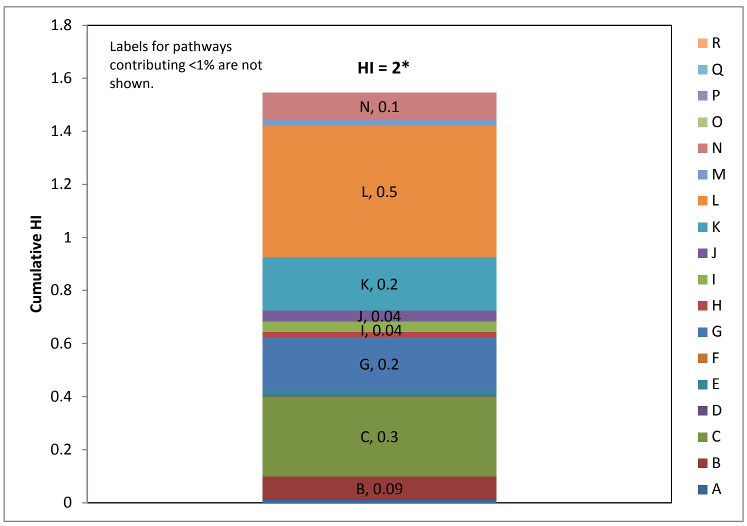
% - percent
< - less than
ATV - all-terrain vehicle
HI - hazard index
HQ - hazard quotient
OU - Operable Unit
TWF - time-weighting factor

FIGURE 9-4. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 3

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI



	Exposure Scenario	TWF		Risk Estimates		
		Value	% of total	Risk	HQ	% of total
A	Ambient air, OU4	0.14	14%	1E-07	0.01	0.5%
B	Indoor air, OU4, post-removal, resident, passive	0.27	27%	1E-06	0.09	5%
C	Indoor air, OU4, post-removal, resident,active	0.15	15%	5E-06	0.3	15%
D	Indoor air, OU4, no removal, worker, passive	0.010	1%	7E-08	0.004	0.2%
E	Indoor air, OU4, no removal, worker, active	0.010	1%	4E-07	0.02	1%
F	Outdoor air, OU5, biking, adult	0.0010	0.1%	6E-09	0.0004	0.02%
G	Outdoor air, OU3, forest, hiking, intermed.	0.025	2.5%	3E-06	0.2	10%
H	Outdoor air, OU7, Park, adult	0.016	1.6%	3E-07	0.02	1%
I	Outdoor air, OU4, yard soil, A, high	0.0010	0.1%	7E-07	0.04	2%
J	Outdoor air, OU4, yard soil, A, typical	0.030	3%	6E-07	0.04	2%
K	Outdoor air, OU3, forest, campfire, intermed.	0.0080	0.8%	3E-06	0.2	10%
L	Indoor air, OU5, Cent. Maint. Bldg, worker, active	0.045	4.5%	8E-06	0.5	25%
M	Indoor air, OU4, school, student	0.034	3.4%	3E-07	0.02	1%
N	Outdoor air, OU4, school, student	0.005	0.5%	2E-06	0.1	5%
O	Outdoor air, OU8, Driving in Libby	0.005	0.5%	0E+00	0	0%
P	Offsite	0.250	25%	0E+00	0	0%
	cumulative*:	**1.000**		**2E-05**	**2**	

* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

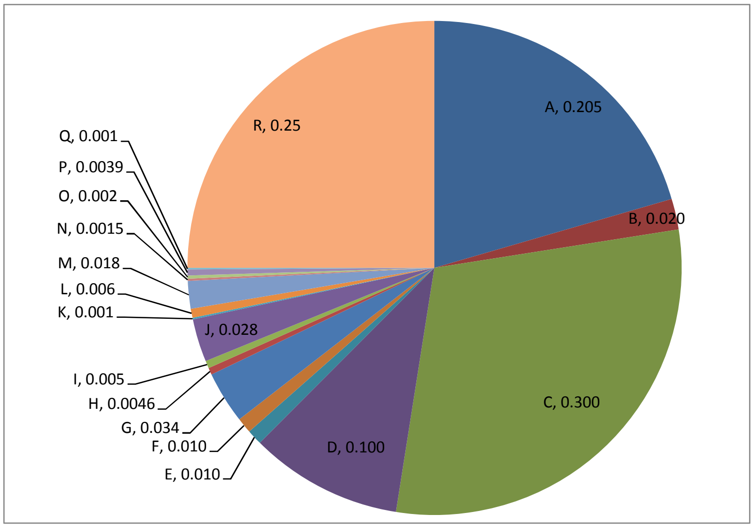
Notes:

% - percent | HI - hazard index | OU - Operable Unit

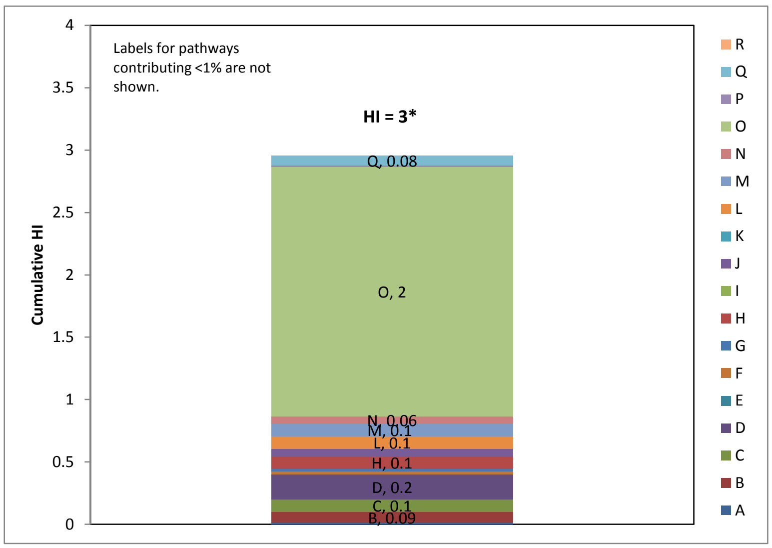
< - less than | HQ - hazard quotient | TWF - time-weighting factor

FIGURE 9-5. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 4

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI



	Exposure Scenario	TWF		Risk Estimates		
		Value	% of total	Risk	HQ	% of total
A	Ambient air, OU4	0.205	21%	2E-07	0.01	0.3%
B	Outdoor air, yard soil, curb-to-curb	0.020	2%	1E-06	0.09	3%
C	Indoor air, OU4, post-removal, resident, passive	0.3	30%	2E-06	0.1	3%
D	Indoor air, OU4, post-removal, resident,active	0.1	10%	3E-06	0.2	7%
E	Indoor air, OU4, no removal, worker, passive	0.01	1%	7E-08	0.004	0%
F	Indoor air, OU4, no removal, worker, active	0.01	1%	4E-07	0.02	1%
G	Indoor air, OU4, schools, student	0.034	3%	3E-07	0.02	1%
H	Outdoor air, OU4, schools, student	0.0046	0.5%	2E-06	0.1	3%
I	Outdoor air, OU8, Driving in Libby	0.005	1%	0E+00	0	0%
J	Ambient air, OU3	0.0280	2.8%	9E-07	0.06	2%
K	Outdoor air, OU3, driving, intermed.	0.0010	0.1%	2E-08	0.001	0%
L	Outdoor air, OU3, forest, campfire, intermed.	0.0060	0.6%	2E-06	0.1	3%
M	Outdoor air, OU3, forest, hiking, intermed.	0.0180	1.8%	2E-06	0.1	3%
N	Outdoor air, OU3, forest, logging near, felling	0.0015	0.2%	9E-07	0.06	2.0%
O	Outdoor air, OU3, forest, logging near, skidding	0.0020	0.2%	4E-05	2	67%
P	Outdoor air, OU3, forest, USFS worker, intermed.	0.0039	0.4%	2E-07	0.01	0.3%
Q	Outdoor air, OU3, forest, Pulaski, intermed.	0.0010	0.1%	1E-06	0.08	3%
R	Offsite	0.2500	25%	0E+00	0	0.0%
	cumulative*:	**1.000**		**5E-05**	**3**	

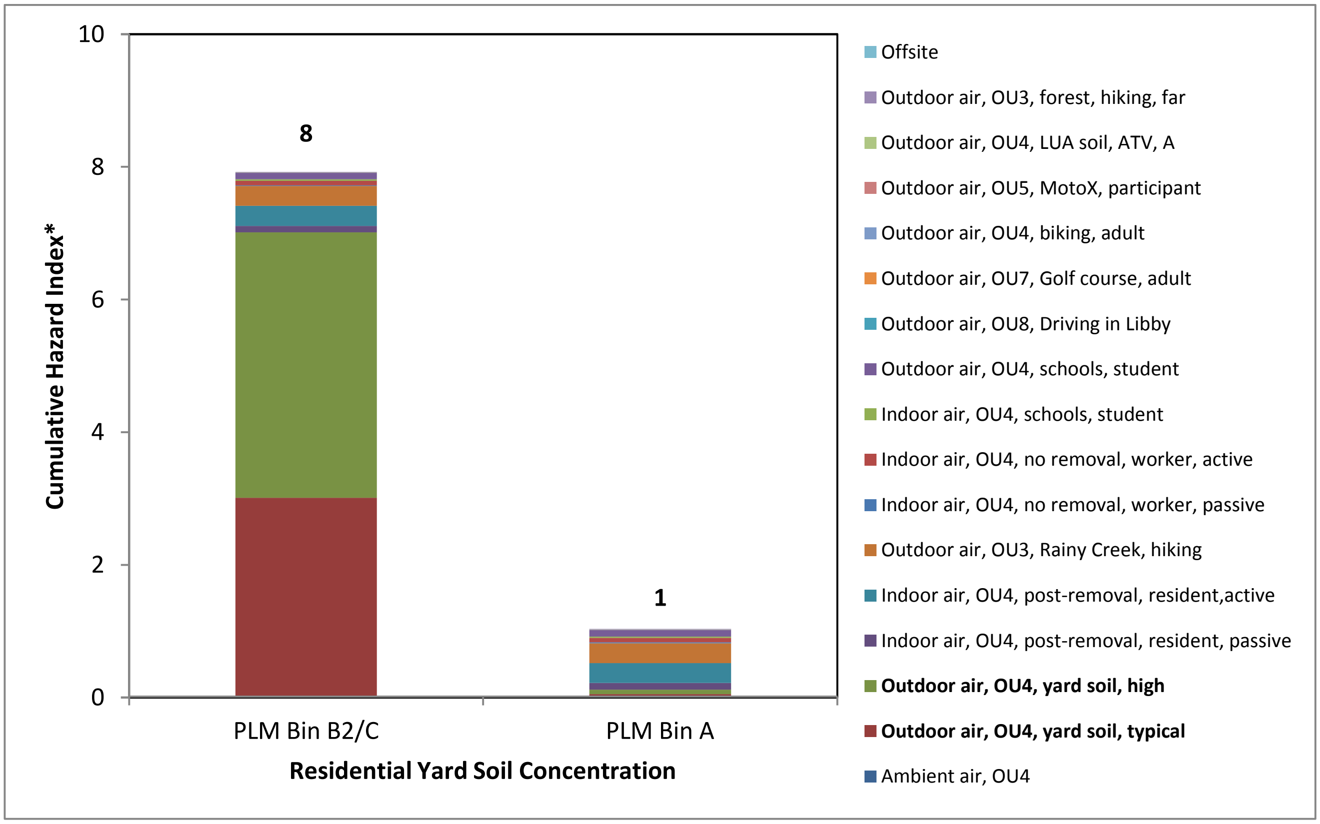
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

Notes:

% - percent HI - hazard index OU - Operable Unit USFS - U.S. Forest Service
< - less than HQ - hazard quotient TWF - time-weighting factor

FIGURE 9-6. ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT YARD SOIL CONCENTRATIONS

Libby Asbestos Superfund Site



* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

ATV - all-terrain vehicle

HI - hazard index

HQ - hazard quotient

LUA - limited use area

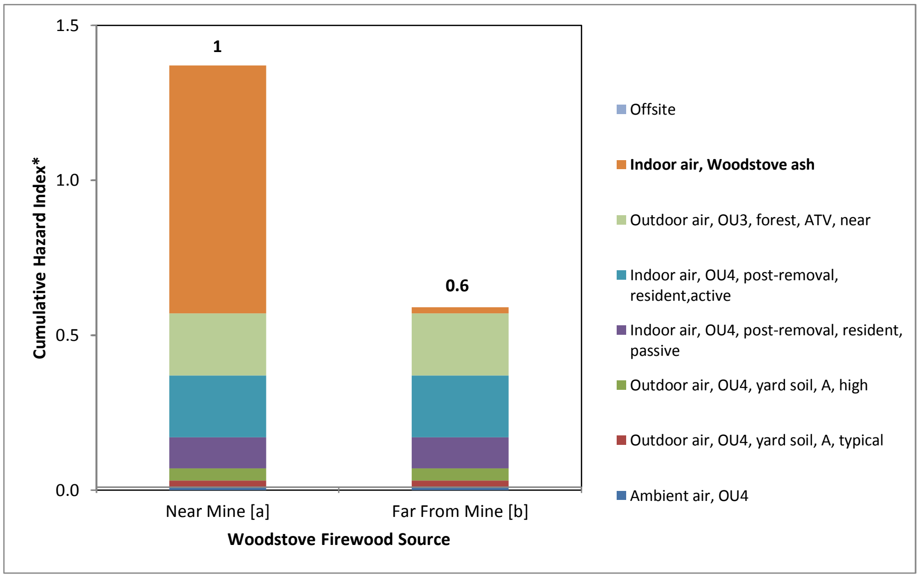
MotoX - motorcross

OU - Operable Unit

PLM - polarized light microscopy

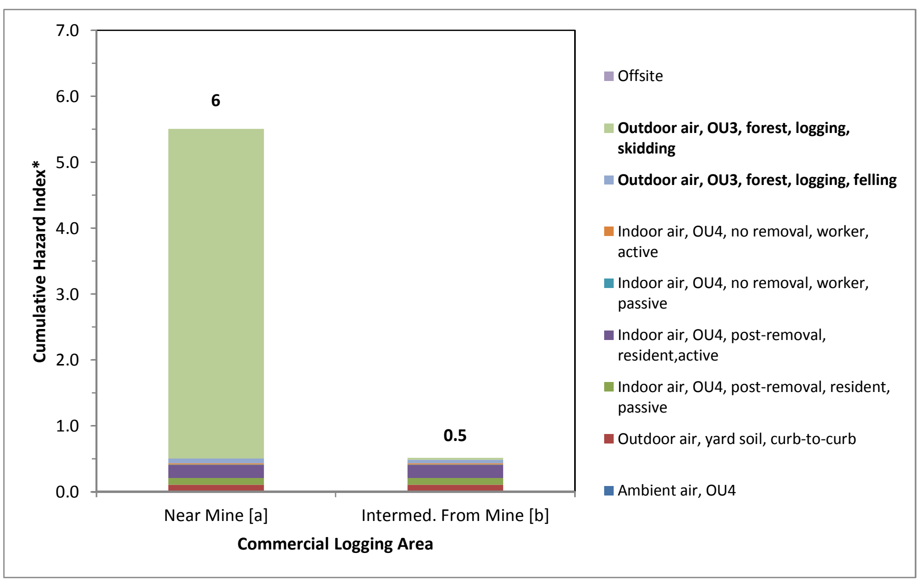
FIGURE 9-7. ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT ACTIVITY LOCATIONS
Libby Asbestos Superfund Site

Panel A: Woodstove Firewood Source



[a] Near mine: firewood collected approximately one mile downwind of the mine site
[b] Far from mine: firewood collected approximately 10 miles south of Libby and outside the current NPL boundary

Panel B: Commercial Logging Area



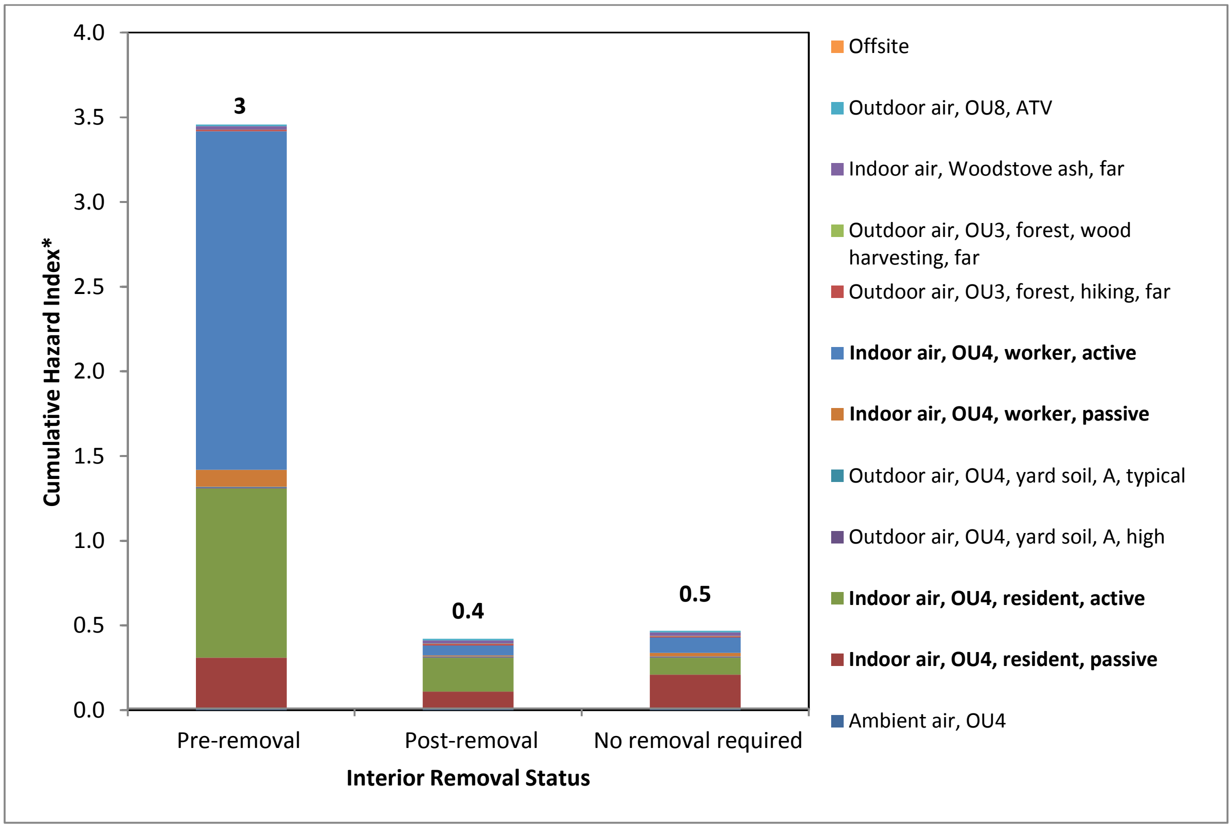
[a] Near mine: Logging activities performed within 1 mile of the mine
[b] Intermed. from mine: Logging activities performed about 4 miles from the mine

* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:
ATV - all-terrain vehicle
HI - hazard index
HQ - hazard quotient
NPL - National Priorities List
OU - Operable Unit

FIGURE 9-8. ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT INTERIOR REMOVAL STATUS CONDITIONS

Libby Asbestos Superfund Site



* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

ATV - all-terrain vehicle

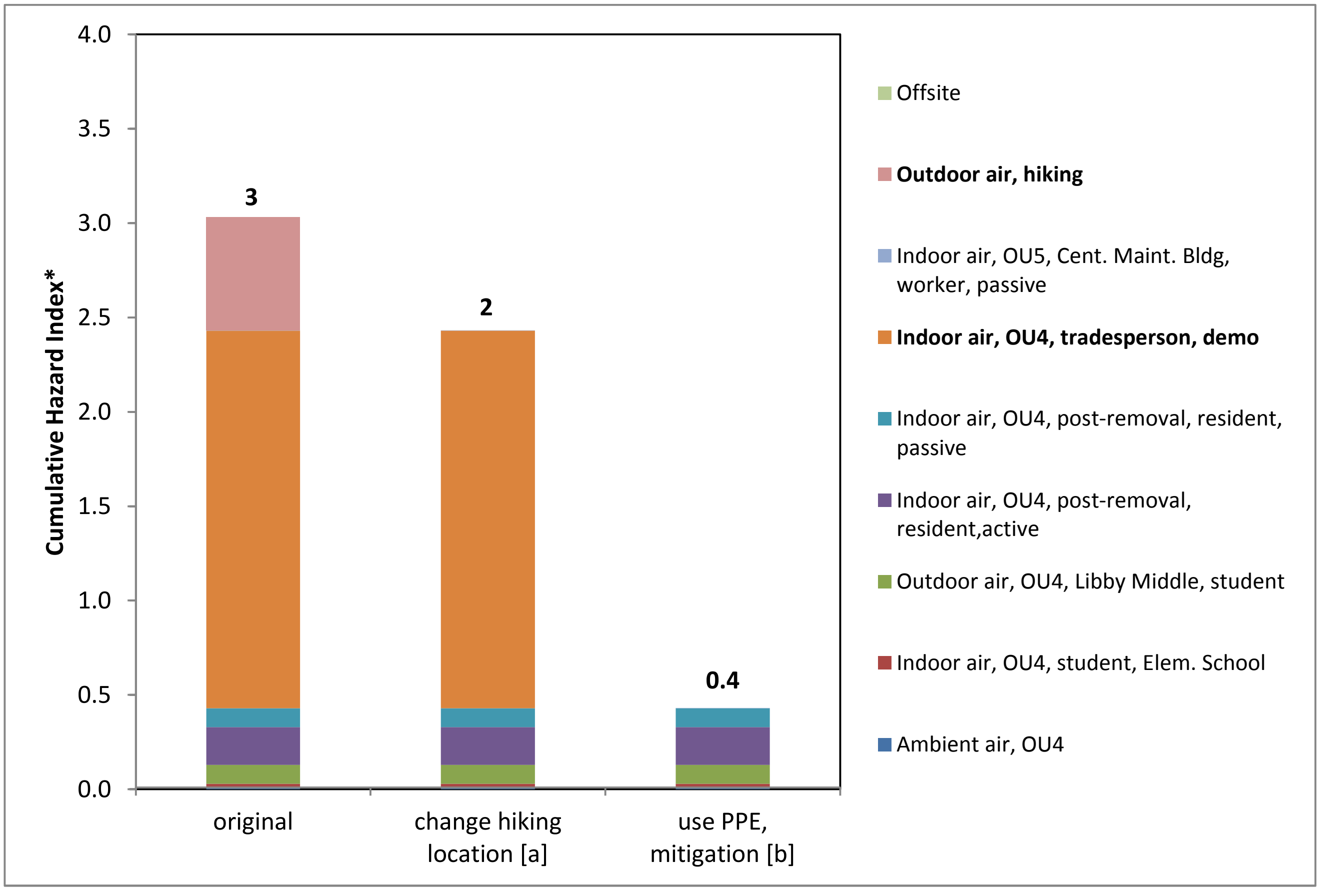
HI - hazard index

HQ - hazard quotient

OU - Operable Unit

FIGURE 9-9. ILLUSTRATION OF CUMULATIVE HI CHANGE WHEN ADDRESSING MAIN RISK DRIVERS

Libby Asbestos Superfund Site



[a] Change hiking location from along Rainy Creek to along the Kootenai River

[b] Use appropriate personal protective equipment and employ dust mitigation measures during tradesperson

* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

HI - hazard index

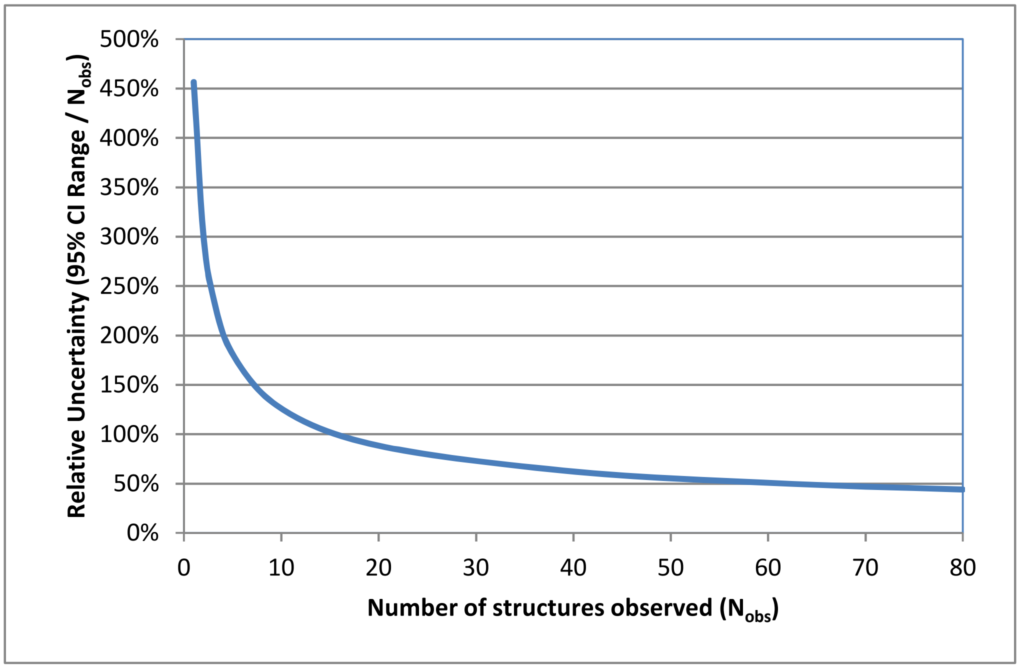
HQ - hazard quotient

OU - Operable Unit

PPE - personal protective equipment

FIGURE 10-1. Relationship Between Number of Structures Observed and Relative Uncertainty

Libby Asbestos Superfund Site

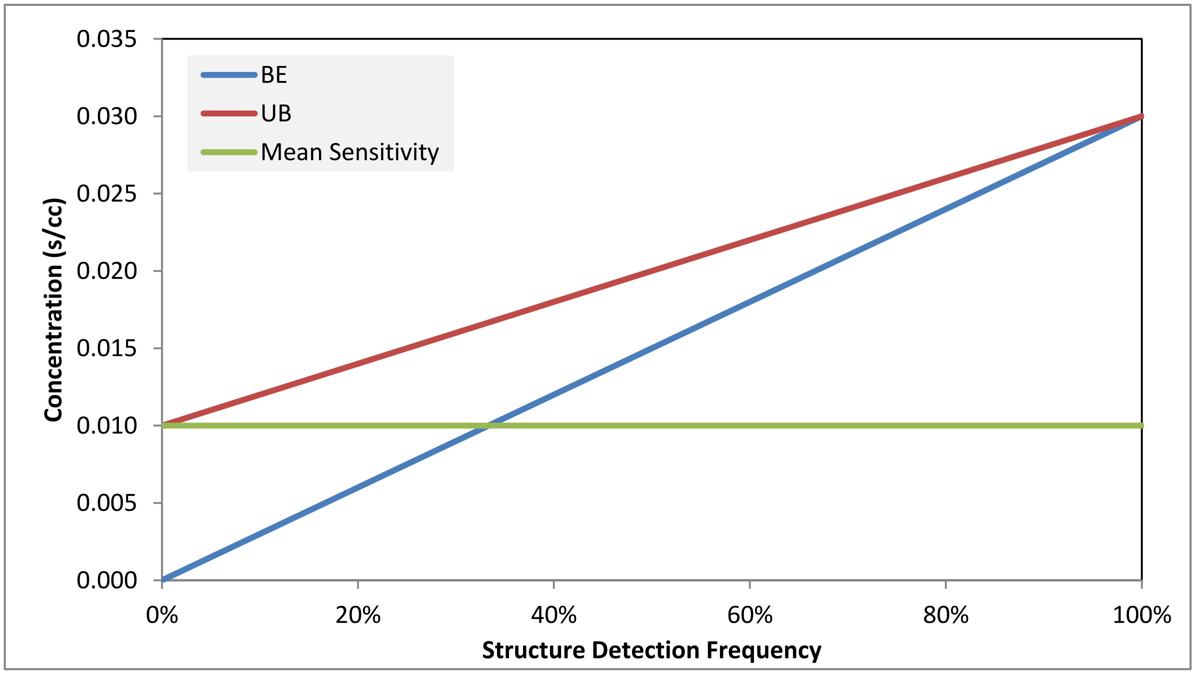


% = percent

CI = confidence interval

N_{obs} = number of observed structures

FIGURE 10-2
ILLUSTRATION OF BEST ESTIMATE AND UPPER-BOUND CONCENTRATIONS AS A FUNCTION OF STRUCTURE DETECTION FREQUENCY
Libby Asbestos Superfund Site



BE = Best estimate of the mean (calculated using zero for non-detects)

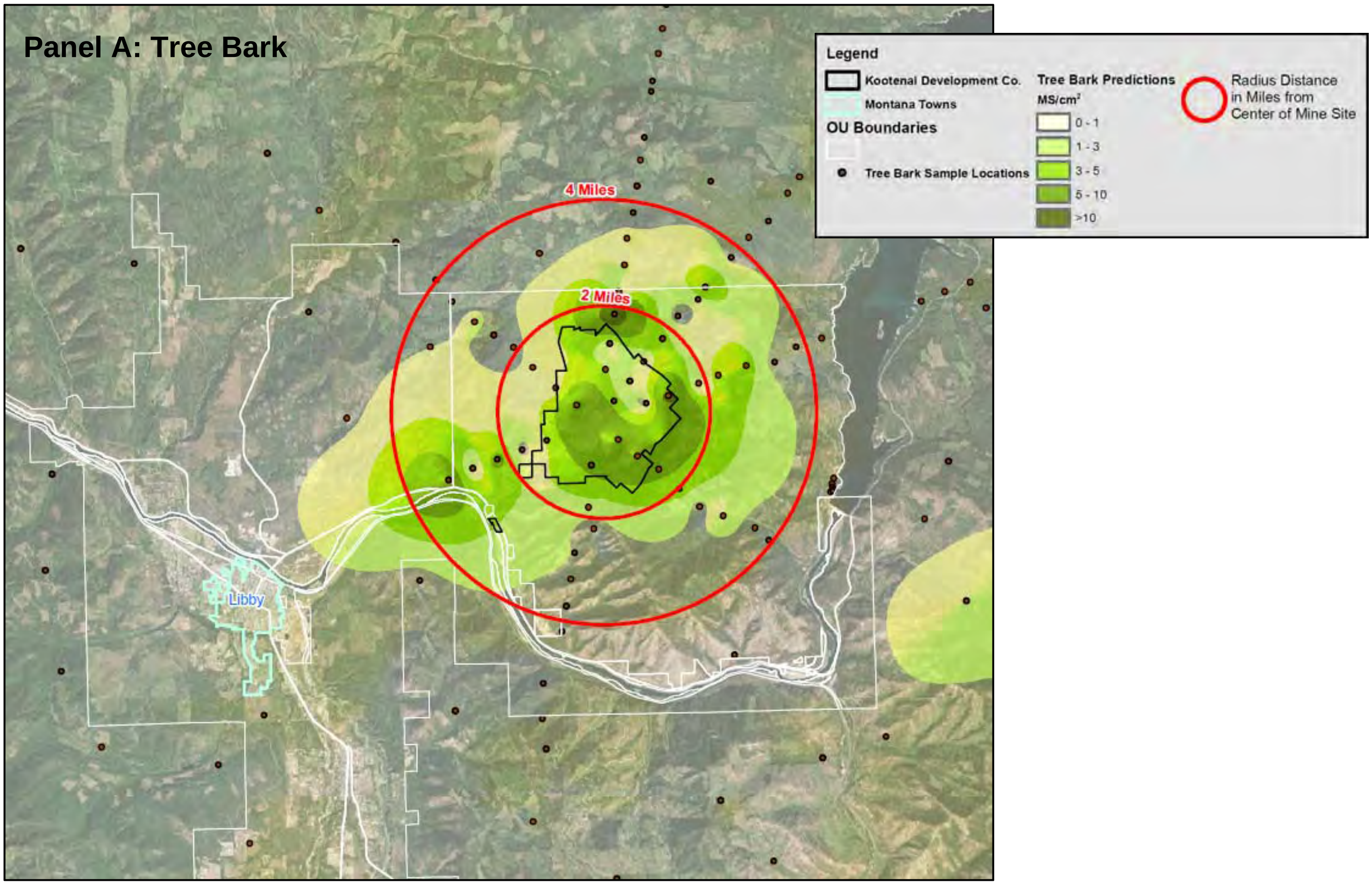
UB = Upper-bound estimate of the mean (calculated using the achieved sensitivity for non-detects)

% = percent

s/cc = structures per cubic centimeter

FIGURE 10-3. Spatial Pattern of LA Levels in Tree Bark and Duff

Libby Asbestos Superfund Site



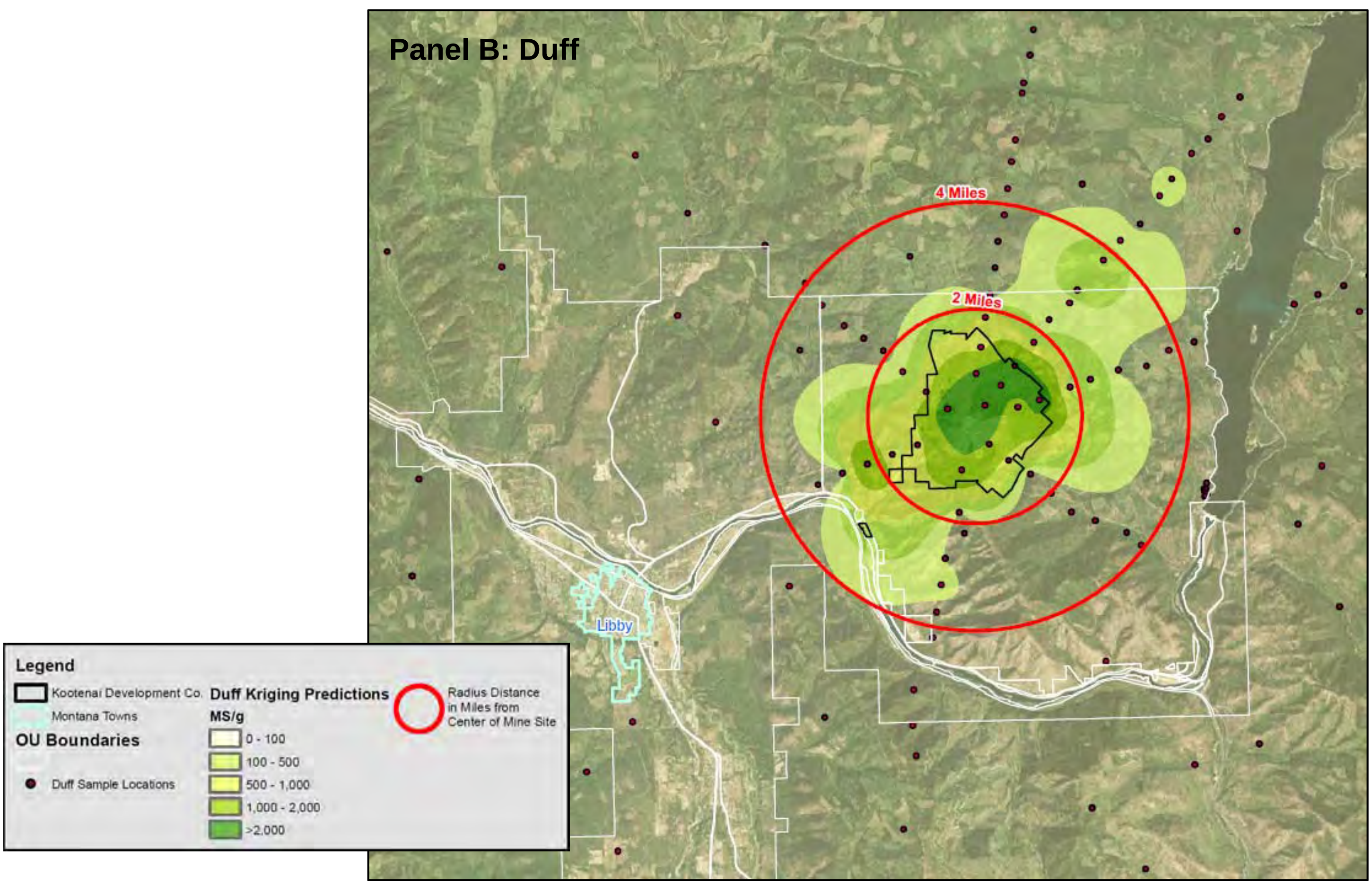


FIGURE 11-1. SUMMARY OF HQs FOR ALL AMBIENT AIR EXPOSURE SCENARIOS
Libby Asbestos Superfund Site

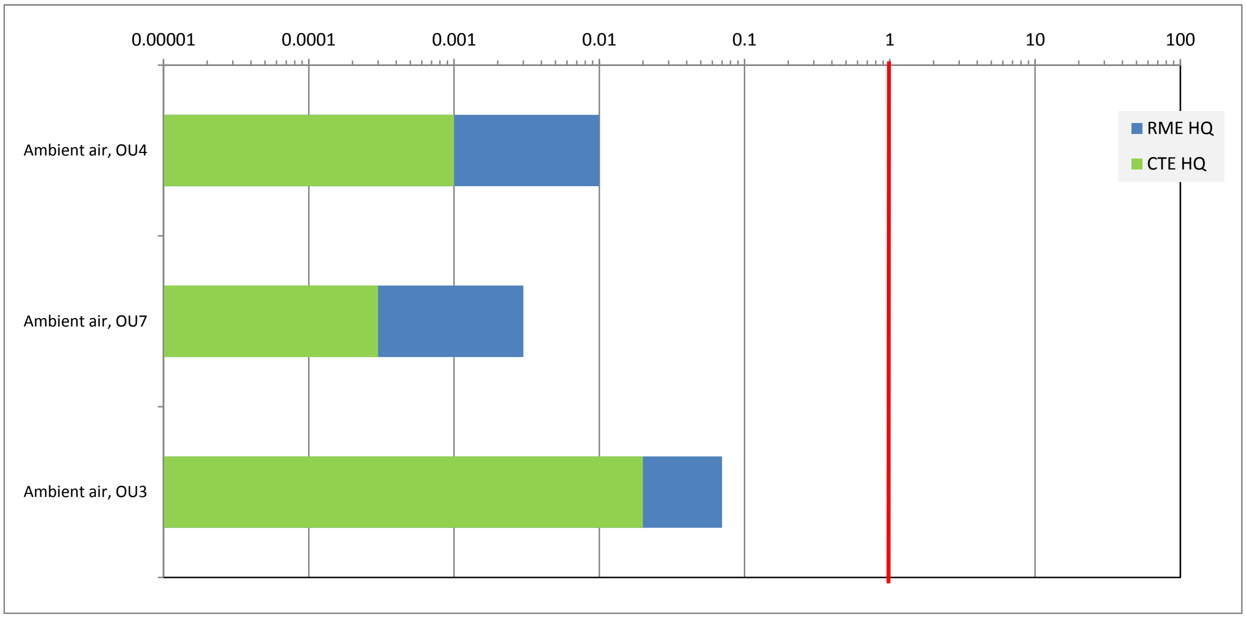
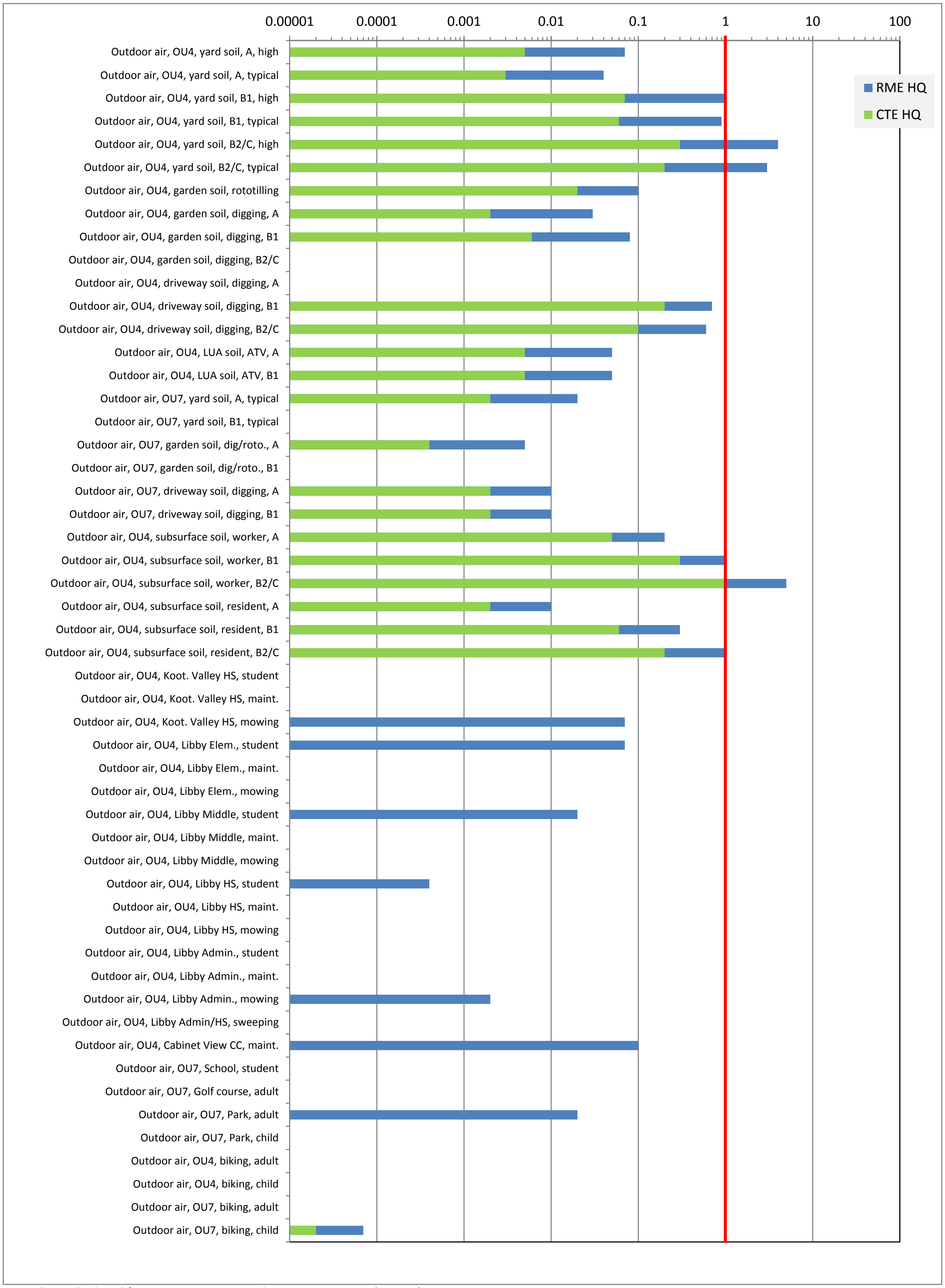


FIGURE 11-2. SUMMARY OF HQs FOR ALL SOIL DISTURBANCE EXPOSURE SCENARIOS (page 1 of 2)

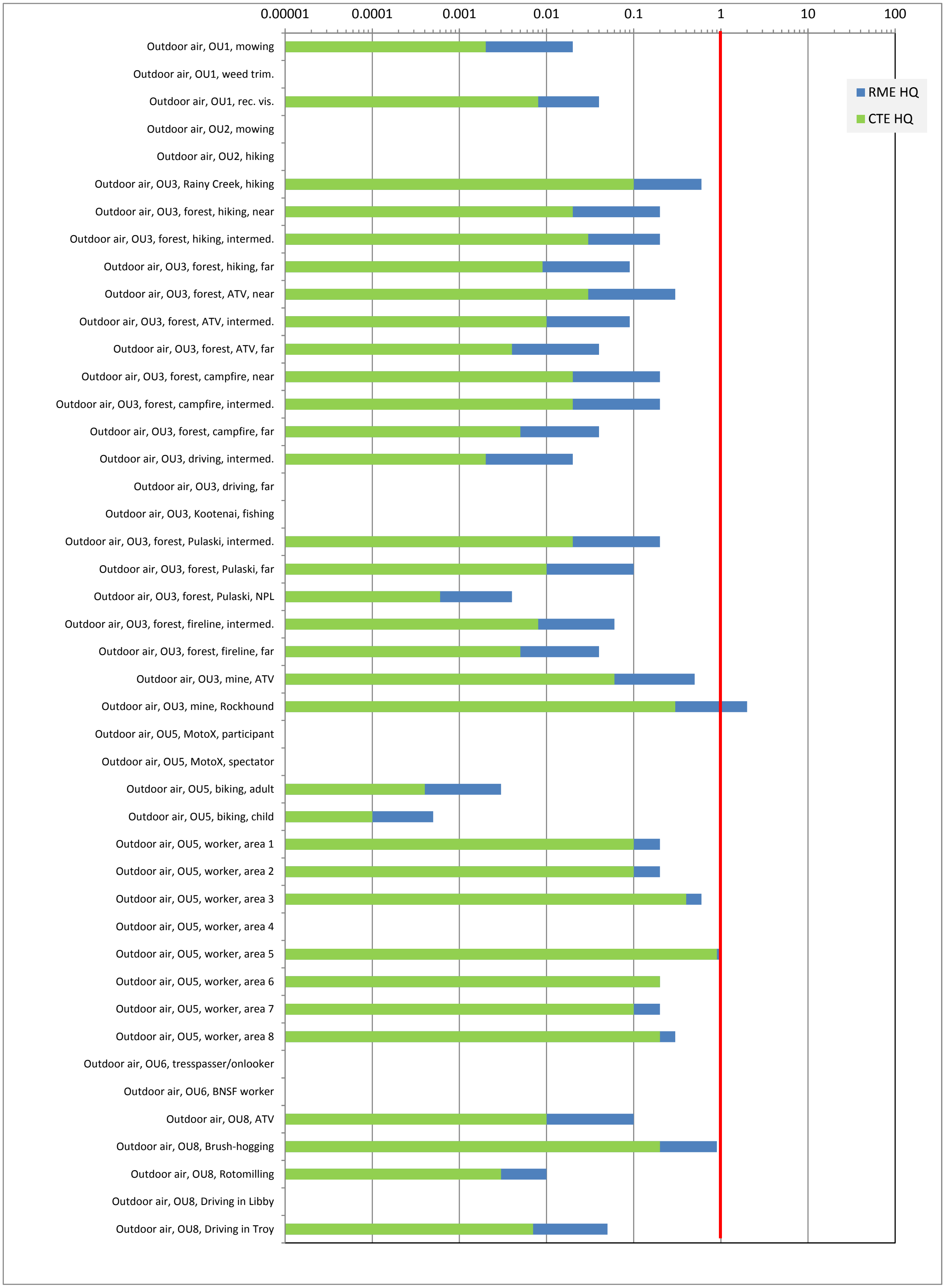
Libby Asbestos Superfund Site



No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

FIGURE 11-2. SUMMARY OF HQs FOR ALL SOIL DISTURBANCE EXPOSURE SCENARIOS (page 2 of 2)

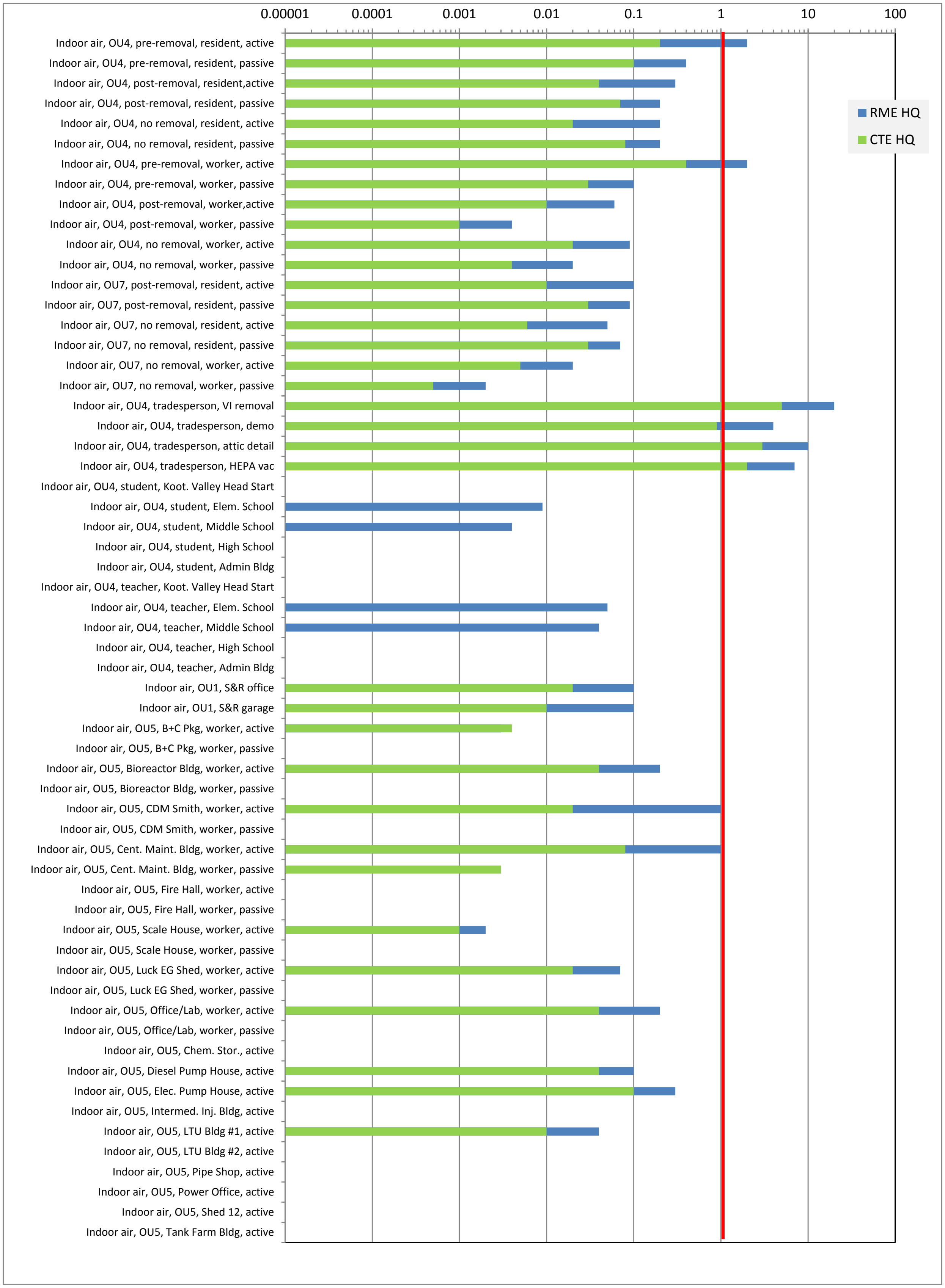
Libby Asbestos Superfund Site



No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

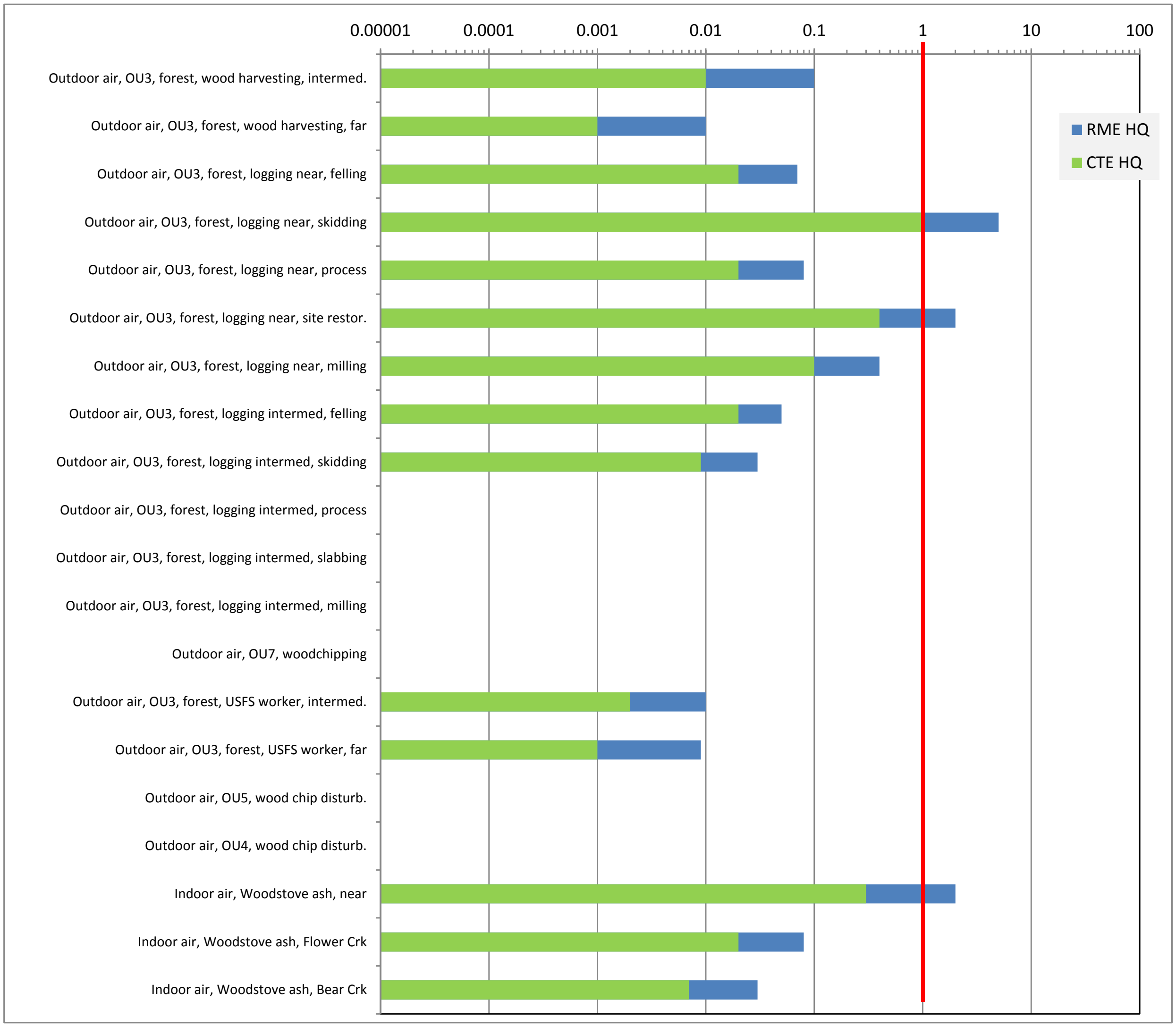
FIGURE 11-3. SUMMARY OF HQs FOR ALL INDOOR AIR EXPOSURE SCENARIOS

Libby Asbestos Superfund Site



No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

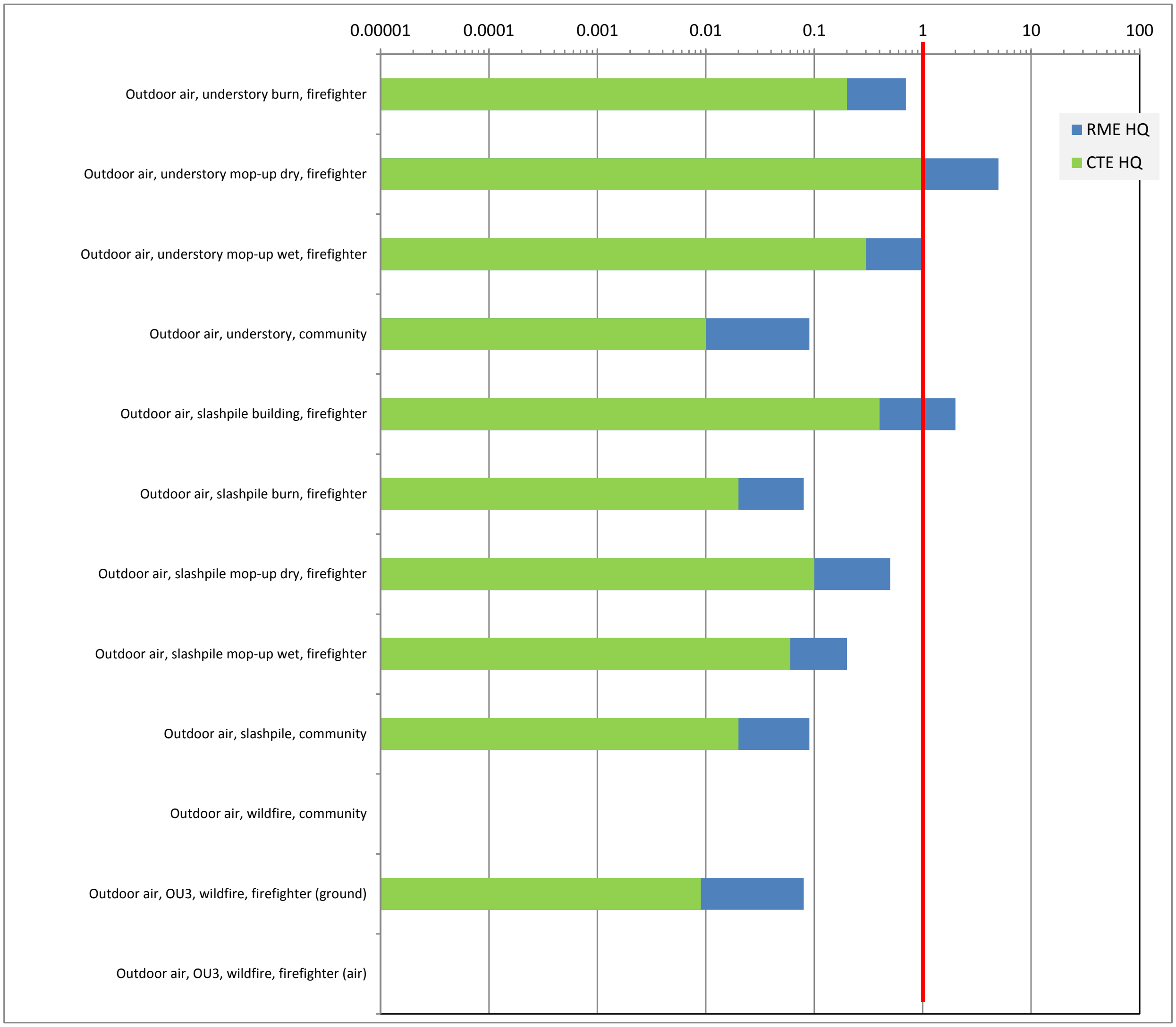
FIGURE 11-4. SUMMARY OF HQs FOR ALL WOOD-RELATED DISTURBANCE EXPOSURE SCENARIOS
Libby Asbestos Superfund Site



No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

FIGURE 11-5. SUMMARY OF HQs FOR ALL FIRE-RELATED EXPOSURE SCENARIOS

Libby Asbestos Superfund Site



No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

TABLES

TABLE 2-1
Conceptual Site Model, Exposure Scenarios and Populations
Libby Asbestos Superfund Site

Exposure Media	Exposure Locations	Operable Unit	Disturbance Description	Exposure Population[a]					
				Resident	Recreational Visitor	Teachers/ students	Worker: Indoor Worker	Worker: Tradesperson	Worker: Outdoor Worker
Outdoor air, ambient conditions	Outdoor	All	---	●	●	●	●	●	●
Outdoor air, during soil/duff disturbance activities	Parks	OU1, OU4, OU7	lawn/park maintenance						●
			park use		●				
	Road ROW	OU2, OU8	mowing/brush-hogging						●
	Kootenai River	OU2, OU3	hiking on trails/paths		●				
			fishing/boating		●				
	Mine Site, Rainy Creek	OU3	hiking, ATV riding, rockhound		●				
	Forested Areas	OU3, OU4	hiking		●				
			building campfires		●				
			ATV riding		●				
			USFS forest maintenance						●
			cutting firelines						●
	Residential/Commercial Properties	OU2, OU4, OU7	yard work	●					●
			gardening	●					●
			playing on driveways	●					
			ATV riding in LUAs	●					
	Schools	OU4, OU7	outdoor maintenance						●
			playing on playgrounds			●			
	Bike Trails/Paths	OU4, OU5, OU7	riding bicycles		●				
	Roads	OU3, OU8	driving cars	●	●	●	●	●	●
	Motocross Track	OU5	motocross participant/spectator		●				
	Industrial Properties	OU5	site maintenance						●
	Railyard/Railroad Corridors	OU6	RR maintenance						●
Outdoor air, during tree bark disturbance activities	Forested Areas	OU3, OU4	local wood harvesting	●					
			commercial logging						●
			campfire burning		●				
			wildfire, prescribed burns	●	●	●	●	●	●
	Landfills	OU4, OU7	woodchipping						●
Outdoor air, during woodchip/mulch disturbance activities	Residential/Commercial Properties	OU2, OU4, OU7	gardening/landscaping	●					●
	Woodchip Piles	OU5	pile maintenance						●
Outdoor air, during ash disturbance activities	Forested Areas	OU3, OU4	after wildfire, prescribed burns						●
			after campfires		●				
Indoor air, passive conditions	Residential/Commercial Properties	OU4, OU7	---	●			●		
	Industrial Properties	OU5	---				●		
	Schools	OU4, OU7	---			●			
Indoor air, during VI disturbance activities	Residential/Commercial Properties	OU4, OU7	attic use, routine property maintenance	●				●	
			construction/demolition	●				●	
Indoor air, during indoor dust disturbance activities	Residential/Commercial Properties	OU4, OU7	cleaning (sweeping, dusting, vacuuming)	●					
	Commercial/Industrial Buildings	OU1, OU5	general				●		
	Schools	OU4, OU7	general			●			
Indoor air, during woodstove ash disturbance activities	Residential/Commercial Properties	OU4, OU7	woodstove ash removal	●					

[a] Note that a given individual may be a member of several exposure populations. For example, an individual may live in OU7, work in OU4, and recreate in OU3. In this example, aspects of the exposure scenarios for a resident, indoor worker, and recreational visitor would apply to the individual. The cumulative assessment addresses cumulative exposures that span multiple exposure scenarios.

Notes:

ATV - all-terrain vehicle
LUAs - limited-use areas
OU - operable unit
ROW - right-of-way
USFS - United States Forest Service
VI - vermiculite insulation
RR - railroad

TABLE 2-2
Summary of ABS Investigations Performed at the Site
Libby Asbestos Superfund Site

Panel A: Outdoor ABS Studies During Soil/Duff Disturbances

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU1	Summer 2013	Post-Construction ABS	Collection of personal ABS air samples during mowing and weed-trimming activities at the park	9 ABS air (6 mowing, 3 weed-trimming)
OU2	Summer 2012	Post-Construction ABS	Collection of personal ABS air samples during mowing along the Flyway right-of-way and while hiking along the Kootenai River	9 ABS air (3 mowing, 6 hiking)
OU3	Summer 2009	Phase III	Collection of personal ABS air samples during recreational activities in the forest (ATV-riding, hiking, campfire building/burning)	227 ABS air (6-8 sampling events for each of 11 areas)
OU3	Summer 2010	Phase IV-A	Collection of personal ABS air samples while hiking along Rainy Creek	10 ABS air
OU3	Summer 2010	Phase IV-A	Collection of personal ABS air samples during USFS firefighter activities in the forest (cutting firelines manually and with heavy equipment)	60 ABS air (5 sampling events for each of 3 areas)
OU3	Summer 2012	Phase V-A	Collection of personal ABS air samples during recreational activities in the Kootenai River	2 ABS air 4 sediment
OU3	Summer 2014	Pulaski Nature & Extent	Collection of personal ABS air samples during USFS firefighter activities in the forest (cutting firelines manually)	60 ABS air (3 sampling events)
OU3	Summer 2015	Mine Trespasser	Collection of personal ABS air samples during ATV riding (on-road and off-road) and during rockhound activities at the mine	60 ABS air (3 sampling events) 40 roadway soil
OU4	Summer 2001	Phase 2, Scenario 4	Collection of personal ABS air samples during garden rototilling	2 ABS air
OU4	Summer 2005	SQAPP, Task 3	Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	169 ABS air 36 soil
OU4	Summer 2007, Spring 2008	2007-2008 OU4 Residential Outdoor ABS	Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	450 ABS air (1 sampling event in summer, 1 sampling event in spring) 225 soil
OU4	Summer 2009	Libby Schools Outdoor ABS	Collection of personal ABS air samples while playing outside at schools	30 ABS air
OU4	Summer 2009	Libby Schools Outdoor ABS	Collection of personal ABS air samples while mowing lawns at schools	15 ABS air
OU4	Summer 2009	Libby Schools Outdoor ABS	Collection of personal ABS air samples while performing maintenance activities at schools (power-sweeping, digging, raking, and sweeping)	18 ABS air
OU4	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	120 ABS air (3 sampling events) 120 soil
OU4	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 2: Collection of personal ABS air samples during digging activities in residential gardens	60 ABS air (3 sampling events) 60 soil
OU4	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 3: Collection of personal ABS air samples during playing, digging activities on residential driveways	62 ABS air (3 sampling events) 62 soil
OU4	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 5: Collection of personal ABS air samples while bicycling on paths/trails in Libby	90 ABS air (60 rider, 30 trailer)
OU4	Summer 2011	2011 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards (using 2 different ABS scripts)	80 ABS air (3 sampling events) 40 soil
OU4	Summer 2011	2011 Residential Outdoor ABS	Scenario 2: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards previously evaluated in 2010	31 ABS air (3 sampling events) 31 soil
OU4	Summer 2011	2011 Residential Outdoor ABS	Scenario 3: Collection of personal ABS air samples during mowing in residential yards pre- and post-irrigation	18 ABS air (3 sampling events) 18 soil
OU4	Summer 2011	2011 Residential Outdoor ABS	Scenario 4: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards where curb-to-curb removal has been completed	31 ABS air (3 sampling events) 31 soil
OU4	Summer 2011	2011 Residential Outdoor ABS	LUA: Collection of personal ABS air samples during ATV riding in limited-use areas at residential properties	60 ABS air (3 sampling events, two riders per event) 30 soil

TABLE 2-2
Summary of ABS Investigations Performed at the Site
Libby Asbestos Superfund Site

Panel A: Outdoor ABS Studies During Soil/Duff Disturbances (cont.)

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU5	Summer/Fall 2008	Worker ABS	Collection of personal ABS air samples during outdoor worker activities (bulldozer operator, raking)	48 ABS air 462 soil
		MotoX ABS	Collection of personal and stationary ABS air samples during activities at the MotoX track	34 ABS air (24 rider, 10 spectator) 21 soil
		Recreational ABS	Collection of personal ABS air samples while bicycling on bike path in OU5	46 ABS air (39 rider, 7 trailer)
OU6	Summer 2008	BNSF ABS	Collection of personal and stationary ABS air samples during rail maintenance activities	46 ABS air (35 personal, 11 stationary)
OU7	Spring/Summer 2011	OU7 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	41 ABS air (1 sampling event in spring 1 sampling event in summer) 41 soil
			Scenario 2: Collection of personal ABS air samples during digging activities in residential gardens	38 ABS air (1 sampling event in spring, 1 sampling event in summer) 38 soil
			Scenario 3: Collection of personal ABS air samples during playing, digging activities on residential driveways	40 ABS air (1 sampling event in spring, 1 sampling event in summer) 40 soil
			Scenario 4: Collection of personal ABS air samples while bicycling on paths/trails in Troy	40 ABS air (20 rider, 20 trailer)
OU8	Spring 2011, Summer 2010	OU8 Outdoor Worker ABS	Collection of equipment and stationary ABS air samples during road rotomilling activities	61 ABS air (10 equipment, 51 stationary)
			Collection of equipment ABS air samples during mowing and brush-hogging activities	14 ABS air
	Summer 2010	2010 OU4 Residential Outdoor ABS, Scenario 5	Collection of personal ABS air while driving on roads in Libby	20 ABS air (20 sampling events)
	Summer 2011	OU7 Residential Outdoor ABS	Collection of personal ABS air while driving on roads in Troy	20 ABS air (20 sampling events)

Panel B: ABS Studies During Disturbances of Wood-Related Materials and Fire-Related Activities

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU3	Summer 2010	2010 OU3 Phase IVA ABS	Collection of ABS air samples while performing activities as part of the USFS land management responsibilities, including maintenance of roads and trails, thinning of trees and vegetation, and surveying trees (i.e., stand examination).	90 ABS air (30 trail maintenance, 30 thinning trees, 30 stand exam)
	Summer 2010	2010 OU3 Phase IVA ABS	Collection of personal ABS air during wood harvesting at three locations in the forested area downwind (northeast) of the mine site (i.e., approximately 2 miles, 4 miles, and 8 miles from the mine site)	62 ABS air (30 driving, 6 cutting and hauling, 32 felling and limbing, 24 cutting and stacking)
	Summer 2012	2012 OU3 Commercial Logging ABS	Collection of personal ABS air during hand-felling of trees, "hooking and skidding" felled trees to a central landing area, mechanical processing, milling, and site restoration of the landing area using a bulldozer -ABS area within one mile of mine (high source concentrations)	13 ABS air (3 hand felling, 5 skidding/hooking of timber, 2 site restoration, 1 mechanical processing, and 2 milling) 5 tree bark 5 duff
	Summer 2013	2013 Souse Gulch Wildfire Contingency Monitoring Plan Air	Collection of air samples to provide measured data on LA exposures of responding firefighters (both to the ground crews and the aircraft support pilot) and downwind LA concentrations in air during the fire.	18 ABS air
	Summer 2014	2014 OU3 Commercial Logging ABS	Collection of personal ABS air during hand-felling of trees, "hooking and skidding" felled trees to a central landing area, mechanical processing, milling, cutting slabs pre-milling, and site restoration of the landing area using a bulldozer -ABS area about four miles from mine (lower source concentrations)	29 ABS air (3 hand felling, 4 skidding/hooking of timber, 2 site restoration, 4 mechanical processing, 8 milling and 8 cutting slabs pre-milling) 6 tree bark 6 duff
	Spring 2015	Understory Burn	Collection of personal and perimeter ABS air during a simulated 0.1-acre understory burn. Samples collected during burn and during mop-up activities in the burn area. Activities conducted in an area about one mile from the mine.	16 ABS air, personal 34 ABS air, perimeter 6 soil (pre/post-burn) 4 tree bark, 5 duff, 3 ash

TABLE 2-2
Summary of ABS Investigations Performed at the Site
Libby Asbestos Superfund Site

Panel B: ABS Studies During Disturbances of Wood-Related Materials and Fire-Related Activities (cont.)

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU3 (cont.)	Spring 2015	Slashpile Burn	Collection of personal and perimeter ABS air during a simulated slash pile burn. Samples collected during slashpile building, during burn, and during mop-up activities in the burn area. Activities conducted in an area about one mile from the mine.	18 ABS air, personal 44 ABS air, perimeter 6 soil (pre/post-burn) 3 tree bark, 5 duff, 3 ash
OU4	Summer 2011	2011 OU4 Miscellaneous ABS	Collection of ABS air samples from each of the two piles in OU5	15 ABS air (3 sampling events for each of the 5 woodchip material draws)
	Summer 2012	2012 OU4 ABS Woodstove Ash	Collection of air samples to measure LA concentrations in air during woodstove ash-removal activities	9 ABS air (3 events for each of 3 locations) 9 tree bark 9 ash
OU5	Fall 2007	Former Stimson Lumber Mill Site-Wood Chip Pilot Study	Collection of personal ABS air samples for the excavator operator and sampling personnel during the waste bark and wood chip pile test pit excavations	16 ABS air (12 woodchip piles, 4 waste bark piles)
OU7	Spring 2013	2013 Troy Landfill Activity-Based Sampling	Collection of ABS air samples during woodchipping of a woodwaste pile at the Lincoln County Landfill in Troy	6 ABS air

Panel C: Indoor ABS Studies

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU1	Winter 2012	Clearance Sampling	Search and Rescue Building clearance samples	5 air samples
OU4	Summer 2001	Phase 2	Scenario 1 & 2: Collection of personal ABS air during active and passive residential/commercial behaviors	59 ABS air (16 passive, 43 active) 47 dust
			Scenario 3: Collection of personal ABS air during simulated tradesperson activities	17 ABS air
	Summer 2005	SQAPP, Task 2	Collection of personal ABS air samples during passive (no active) residential behaviors	29 ABS air (11 personal, 18 stationary) 34 dust
	Summer 2007 - Spring 2008	2007-2008 OU4 Residential Indoor ABS	Collection of personal ABS air samples during active and passive residential behaviors	642 ABS air (4 sampling rounds - 1 per season) 334 dust 162 soil
	Summer 2009	Libby Schools Indoor ABS	Collection of stationary ABS air samples inside schools	50 stationary air
	Various	Tradesperson Re-Analysis	Re-analysis of collected personal H&S samples of workers during interior removal activities (bulk removal, demolition, detailing attic, and wet wipe/HEPA vacuum)	17 H&S personal air
	Winter 2013, Summer 2013	2013 OU4 Residential Indoor ABS	Scenario 1: Collection of personal ABS air samples during active and passive residential behaviors at properties where a curb-to-curb soil removal has been completed	40 ABS air (1 sampling event in winter, 1 sampling event in summer) (20 active, 20 passive)
	Summer 2013		Scenario 2: Collection of personal ABS air samples during active and passive residential behaviors at properties evaluated in 2007/08	20 ABS air (10 active, 10 passive)
OU5	Winter 2007	Indoor Worker ABS	Collection of personal ABS air samples during active and passive worker behaviors inside occupied OU5 buildings	37 ABS air (28 active, 9 passive) 24 dust
			Collection of stationary ABS air samples inside vacant OU5 buildings	50 ABS air 70 dustfall
OU7	Spring, Summer 2011	OU7 Residential/Commercial Indoor ABS	Collection of personal ABS air samples during active and passive residential and commercial behaviors	80 ABS air (72 residential, 8 commercial) (1 sampling event in spring 1 sampling event in summer)

Notes:
ABS - activity-based sampling
ATV - all-terrain vehicle
BNSF - Burlington Northern and Santa Fe
H&S - health and safety
HEPA - high efficiency particulate air
LA - Libby amphibole asbestos
OU - operable unit
SQAPP - Supplemental Remedial Investigative Quality Assessment and Project Plan
USFS - United States Forest Service

TABLE 5-1
Summary Statistics For Ambient Air Monitoring Locations
Libby Asbestos Superfund Site

Station ID	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Libby (within community)					
L1	37	4	0.0000052	0.000079	0.000038
L2	30	6	0.0000089	0.000080	0.000038
L3	32	0	0	All ND	0.000038
L4	38	7	0.000011	0.00011	0.000038
L5	38	8	0.0000096	0.000079	0.000038
L6	36	3	0.0000063	0.00015	0.000038
L7	36	3	0.0000032	0.000040	0.000038
L8	83	7	0.0000032	0.000040	0.000038
L9	38	4	0.0000040	0.000040	0.000038
L10	32	2	0.0000024	0.000039	0.000038
L11	30	1	0.0000028	0.000085	0.000038
L12	52	6	0.0000067	0.000080	0.000038
L13	31	2	0.0000024	0.000038	0.000038
L14	38	0	0	All ND	0.000038
L15	16	1	0.0000025	0.000040	0.000038
L16	18	1	0.0000021	0.000037	0.000038
L17	17	0	0	All ND	0.000038
L18	18	3	0.000017	0.00023	0.000038
Libby (along transportation corridors)					
L20	18	0	0	All ND	0.000039
L21	60	4	0.0000031	0.000078	0.000039
L22	49	6	0.0000070	0.00012	0.000039
L23	46	13	0.000028	0.00028	0.000039
L24	18	2	0.0000043	0.000039	0.000039
L25	33	5	0.000012	0.00014	0.000039
L26	14	4	0.000013	0.000064	0.000038
OU3 (at mine site)					
A-1	4	0	0	All ND	0.00053
A-2	4	0	0	All ND	0.00053
A-3	4	0	0	All ND	0.00053
A-4	12	0	0	All ND	0.00053
A-5	12	4	0.00040	0.0026	0.00053
A-6	12	1	0.000043	0.00051	0.00053
A-7	4	0	0	All ND	0.00053
A-8	12	0	0	All ND	0.00056
A-9	8	3	0.00096	0.0056	0.00057
A-10	8	0	0	All ND	0.00056
A-11	8	2	0.00045	0.0026	0.00052
A-12	8	0	0	All ND	0.00053

TABLE 5-1
Summary Statistics For Ambient Air Monitoring Locations
Libby Asbestos Superfund Site

Station ID	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Troy (Zone 1)					
T1	35	2	0.0000032	0.000074	0.000039
T2	35	2	0.0000022	0.000038	0.000039
T11	35	1	0.0000011	0.000039	0.000039
T12	33	1	0.0000012	0.000039	0.000039
T21	30	2	0.0000027	0.000040	0.000039
Troy (Zone 2)					
T3	36	0	0	All ND	0.000039
T4	36	1	0.0000010	0.000037	0.000039
T5	35	1	0.00000080	0.000028	0.000044
T13	36	0	0	All ND	0.000039
T14	36	1	0.00000044	0.000016	0.000046
T15	36	0	0	All ND	0.000039
T22	30	3	0.0000080	0.00016	0.000045
Troy (Zone 3)					
T6	36	1	0.0000010	0.000036	0.000039
T16	35	0	0	All ND	0.000039
T23	27	2	0.0000030	0.000040	0.000039
Troy (Zone 4)					
T7	35	1	0.0000010	0.000036	0.000039
T17	36	0	0	All ND	0.000039
T24	30	1	0.0000013	0.000040	0.000039
Eureka, MT					
R1	32	0	0	All ND	0.000037
Helena, MT					
R2	39	4	0.0000054	0.000076	0.000038

Notes:
cc^{-1} - per cubic centimeter
Conc. - concentration
ID - identification
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy-equivalent
s/cc - structures per cubic centimeter

TABLE 5-2
Exposure Point Concentrations for Ambient Air
Libby Asbestos Superfund Site

Exposure Area	Number of Samples	Mean PCME LA Air Concentration (s/cc) Across Stations by Month												EPC Mean Across Months
		January	February	March	April	May	June	July	August	September	October	November	December	
Libby	858	0	0.0000032	0.0000047	0.0000035	0.0000084	0.0000076	0.0000082	0.000017	0.000016	0.0000048	0.00000095	0.00000018	**0.0000062**
Within community	620	0	0.0000014	0.0000023	0.0000018	0.0000066	0.0000075	0.0000083	0.000012	0.000011	0.0000062	0.00000064	0.00000022	**0.0000048**
Along transportation corridors	238	0	0.000011	0.000014	0.000010	0.000013	0.0000079	0.0000081	0.000026	0.000024	0.0000014	0.0000018	0	**0.0000098**
Troy	612	0.00000095	0.0000040	0.0000026	0.00000086	0.00000070	0.0000014	0.0000014	0	0.0000054	0.00000047	0	0	**0.0000015**
OU3, near mine site	96	--	--	--	--	--	--	0.000065	0.00054	0.00018	0	--	--	**0.00020**

-- = no samples collected in this month.

Notes:
EPC - exposure point concentration
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
s/cc - structures per cubic centimeter

TABLE 5-3
Exposure Parameters For Ambient Air Exposure Scenarios
Libby Asbestos Superfund Site

Exposure Media	Exposure Location	Receptor Type	Parameter Type	Exposure Parameter/ Source						Time-weighting Factor [TWF]**
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Ambient Air	Libby/Troy	Resident	RME	6.9	[1] a.1	350	[2] b.1	52	[4] c.1	0.20
			CTE	1.6	[1] a.1	350	[2] b.1	22	[4] c.1	0.020
	OU3	Recreational Visitor	RME	8.0	[3] a.2	50	[3] b.2	52	[4] c.1	0.034
			CTE	8.0	[3] a.2	25	[3] b.3	22	[4] c.1	0.0072

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.

[2] EPA. 1991. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors".* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[3] Professional judgment using site-specific considerations.

[4] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[5] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day spent breathing ambient air are default values found in EPA (2011), Table 16-20. CTE is the 50th percentile and RME is the 95th percentile.

a.2 Assumes full-day excursion into forested areas surrounding OU3.

b) Exposure Frequency [EF]

b.1 Days/year at residence. Recommended default for residents in EPA (1991) (350 days/year is based on the assumption the resident spends a 2 week vacation each year away from residence).

b.2 Assumes recreational activities are performed every weekend (Saturday & Sunday) from April to September (25 weeks).

b.3 CTE is assumed to be 1/2 RME.

c) Exposure Duration [ED]

c.1 ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 5-4
Estimated Risks from Exposure to LA in Ambient Air
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Exposure Media	Receptor Population	Exposure Location	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, under ambient conditions	Resident	Libby	0.0000062	6.9	350	52	0.20	**2E-07**	**0.01**
		Within community	0.0000048	6.9	350	52	0.20	**2E-07**	**0.01**
		Along transportation corridors	0.0000098	6.9	350	52	0.20	**3E-07**	**0.02**
		Troy	0.0000015	6.9	350	52	0.20	**5E-08**	**0.003**
	Recreational visitor	OU3, mine site	0.00020	8	50	52	0.034	**1E-06**	**0.07**

Panel B: Risk Estimates Based on CTE Exposure Parameters

Exposure Media	Receptor Population	Exposure Location	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, under ambient conditions	Resident	Libby	0.0000062	1.6	350	22	0.020	**2E-08**	**0.001**
		Within community	0.0000048	1.6	350	22	0.020	**2E-08**	**0.001**
		Along transportation corridors	0.0000098	1.6	350	22	0.020	**3E-08**	**0.002**
		Troy	0.0000015	1.6	350	22	0.020	**5E-09**	**0.0003**
	Recreational visitor	OU3, mine site	0.00020	8	25	22	0.0072	**2E-07**	**0.02**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4

Notes:

CTE - central tendancy exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-1

Exposure Parameters During Residential/Commercial Soil Disturbance Activities in OU4 and OU7

Libby Asbestos Superfund Site

Panel A: Surface Soil Disturbances

Exposure Media	Receptor Type	Exposure Location	Parameter Type	Exposure Parameters: Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-weighting Factor [TWF]**
Outdoor Air During Surface Soil/Duff Disturbance Activities	Resident	Yard	RME	6.6	[3] a.1	60	[2] b.1	52	[4] c.1	0.034
			CTE	2.2	[3] a.1	30	[2] b.1	22	[4] c.1	0.0024
		Garden (digging)	RME	3.3	[2] a.2	40	[2] b.2	52	[4] c.1	0.011
			CTE	1.1	[2] a.2	20	[2] b.2	22	[4] c.1	0.00079
		Garden (rototilling)	RME	2.0	[2] a.5	2	[2] b.5	52	[4] c.1	0.00034
			CTE	1.0	[2] a.5	1	[2] b.5	22	[4] c.1	0.000036
		Driveway	RME	2.0	[2] a.3	225	[2] b.3	15	[1] c.2	0.011
			CTE	0.9	[2] a.3	113	[2] b.3	15	[1] c.2	0.0025
		Limited-use Areas (LUAs)	RME	2.0	[2] a.4	20	[2] b.4	52	[4] c.1	0.0034
			CTE	1.0	[2] a.4	10	[2] b.4	22	[4] c.1	0.00036
	Outdoor Worker	Yard	RME	8.0	[2] a.6	100	[2] b.6	25	[5]	0.033
			CTE	8.0	[2] a.6	50	[2] b.6	15	[2]	0.010
		Garden (digging)	RME	2.0	[2] a.2	100	[2] b.6	25	[5]	0.008
			CTE	1.0	[2] a.2	50	[2] b.6	15	[2]	0.0012
		Garden (rototilling)	RME	2.0	[2] a.7	100	[2] b.6	25	[5]	0.0082
			CTE	1.0	[2] a.7	50	[2] b.6	15	[2]	0.0012

** TWF calculated as ET/24 · EF/365 · ED/70

Panel B: Subsurface Soil Disturbances

Exposure Media	Exposure Location	Recepltor Type	Parameter Type	Exposure Parameters: Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-weighting Factor [TWF]**
Outdoor Air During Subsurface Soil Disturbance Activities	Yard	Resident	RME	2.0	[2]	1	[2] b.7	52	[4] c.1	0.00017
			CTE	2.0	[2]	0.5	[2] b.7	22	[4] c.1	0.000036
		Outdoor Worker	RME	2.0	[2]	50	[2] b.8	25	[5]	0.0041
			CTE	2.0	[2]	25	[2] b.8	15	[2]	0.0012

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.

[2] Professional judgment using site specific considerations.

[3] U.S. Bureau of Labor Statistics, American Time Use Survey (http://www.bls.gov/tus/).

[4] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[5] EPA. 1991. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors".* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[6] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day based on mean and 95th percentile for activity category 020501 (lawn, garden, and houseplant care), as derived from the raw data for years 2009-2013. [mean = 2.12, rounded to 2.2; 95th percentile = 6.56, rounded to 6.6]

a.2 Hours/day doing intensive gardening (digging) are based on professional judgment assuming 1/2 of total yard work time is spent gardening.

a.3 Hours/day spent playing on dirt (driveways) are EPA default values in EPA (2011), Tables 16-1, 16-38. Values are rounded for children < 21 years.

a.4 Hours/day riding ATV in LUAs are based on professional judgment. CTE assumes 1/2 RME value.

a.5 Assumed that 2 hours/day spent rototilling gardens. CTE assumes 1/2 RME value.

a.6 Assumed 8-hour workday; entire day is spent engaged in soil disturbance activities with half of the time in the yard and the other half in the garden.

a.7 Hours/day doing intensive gardening (digging and rototilling) are based on professional judgment assuming 1/2 of the work day is spent gardening. Half of the gardening time is assumed to be rototilling.

b) Exposure Frequency [EF]

b.1 Days/year performing yard work is based on professional judgment considering site specific conditions - assumes yard work will take place during warmer months (mainly between May and September; 20 weeks) for 3 days/week for RME for a total of 60 days/year; CTE was assumed to be 1/2 RME value.

b.2 Days/year gardening is based on professional judgment considering site-specific conditions - assumes garden work will take place during warmer months mainly between May and September for 1 to 2 days/week (total 20 to 40 days/year).

b.3 Days/year are site-specific. Default residential exposure frequency estimate of 350 days/year was adjusted to account for days when releases due to soil disturbance activities were unlikely, either due to snow cover or high soil moisture content (i.e., November to March) (350 days - 126 days (18 weeks for 7 days/week) = 224 days, rounded to 225).

b.4 Days/year riding ATV in LUAs are based on professional judgment. CTE assumes 1/2 RME value.

b.5 RME assumes rototilling is performed twice per year (at the beginning and end of the growing season). CTE assumes one rototilling is performed each year.

b.6 Days/year performing yard work is based on professional judgment considering site specific conditions - assumes yard work will take place during warmer months mainly between May and September for 5 days/week for RME for a total of 100 days/year; CTE was assumed to be 1/2 RME value.

b.7 Assumes that deeper digging (>1 to 3+ feet), such as digging a hole for a tree, occurs once per year for RME; CTE was assumed to be 1/2 RME value.

b.8 Assumes that deeper digging (>1 to 3+ feet), such as digging a hole for a sewer line or septic tank, during warmer months (mainly between May and September) for approximately 2-3 days/week for RME for a total of 50 days/year; CTE was assumed to be 1/2 RME value.

c) Exposure Duration [ED]

c.1 ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

c.2 Years spent playing on dirt driveways are based on EPA default values in EPA (2011), Tables 16-1, 16-38. Values are rounded for children < 21 years. This scenario assumes that toddlers through teenagers play on driveways. Activities vary according to age group from playing in the dirt, to riding big wheels or playing games like basketball.

<u>Notes:</u>

ATSDR - Agency for Toxic Substances and Disease Registry
ATV - all-terrain vehicle
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
LUA - limited use area
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 6-2

Summary Statistics for Outdoor ABS Studies During Disturbances of Residential/Commercial Soils

Libby Asbestos Superfund Site

Panel A: Yard Soil Disturbances

LA Soil Concentration+	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)++		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
OU4					
High intensity ABS script					
Bin A	251	115	0.0040	0.20	0.0050
Bin B1	221	155	0.061	8.3	0.015
Bin B2	31	27	0.25	5.8	0.032
Bin C	7	5	0.039	0.19	0.0061
Bin B2/C	38	32	0.21	5.8	0.028
Typical intensity ABS script					
Bin A	110	15	0.00011	0.0029	0.0014
Bin B1	72	21	0.0024	0.077	0.0014
Bin B2	7	4	0.0080	0.044	0.00061
Bin C	--	--	--	--	--
Bin B2/C	7	4	0.0080	0.044	0.00061
OU7					
Typical intensity ABS script*					
Bin A	40	5	0.000062	0.0014	0.00022
Bin B1	1	0	0	All ND	0.00022

Panel B: Garden Soil Disturbances

LA Soil Concentration+	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)++		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
OU4: Digging					
Bin A	36	5	0.00020	0.0029	0.0016
Bin B1	21	5	0.00066	0.0039	0.0056
Bin B2	2	0	0	All ND	0.0030
Bin C	1	0	0	All ND	0.0029
Bin B2/C	3	0	0	All ND	0.0030
OU4: Rototilling					
Bin B1	2	2	0.039	0.057	0.0036
OU7: Digging & Rototilling					
Bin A	37	3	0.000023	0.00040	0.00023
Bin B1	1	0	0	All ND	0.00022

TABLE 6-2

Summary Statistics for Outdoor ABS Studies During Disturbances of Residential/Commercial Soils

Libby Asbestos Superfund Site

Panel C: Driveway Soil Disturbances

LA Soil Concentration+	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)++		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
OU4					
Bin A	44	0	0	All ND	0.0039
Bin B1	15	2	0.0057	0.076	0.0043
Bin B2	2	1	0.0075	0.015	0.0034
Bin C	1	0	0	All ND	0.0039
Bin B2/C	3	1	0.0050	0.015	0.0036
OU7					
Bin A	35	5	0.000079	0.0015	0.00023
Bin B1	5	2	0.000085	0.00021	0.00021

Panel D: OU4 Limited Use Area Soil Disturbances

LA Soil Concentration+	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)++		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Bin A	40	14	0.0012	0.0069	0.0022
Bin B1	20	8	0.0014	0.0062	0.0017

+PLM-VE LA Result:

Bin A = ND (non-detect)

Bin B1 = Tr (trace; <0.2%)

Bin B2 = <1%

Bin C = ≥1%

++ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

*No high intensity ABS script samples were collected.

Notes:

ABS - activity-based sampling

cc^{-1} - per cubic centimeter

Conc. - concentration

LA - Libby amphibole asbestos

N - number

OU - operable unit

PCME - phase contrast microscopy-equivalent

PLM-VE - polarized light microscopy - visual area estimation

s/cc - structures per cubic centimeter

TABLE 6-3a
Estimated Residential Risks from Exposure to LA During Disturbances of Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Exposure Scenario & Soil Concentration[1]	Yard ABS Script Intensity	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	**Yards (Mowing, Raking, Digging)**								
	Bin A	**high intensity**	0.0040	0.3	60	52	0.0015	**1E-06**	**0.07**
		typical intensity	0.00011	6.3	60	52	0.032	**6E-07**	**0.04**
							TOTAL	**2E-06**	**0.1**
	Bin B1	**high intensity**	0.061	0.3	60	52	0.0015	**2E-05**	**1**
		typical intensity	0.0024	6.3	60	52	0.032	**1E-05**	**0.9**
							TOTAL	**3E-05**	**2**
	Bin B2/C	**high intensity**	0.21	0.3	60	52	0.0015	**5E-05**	**4**
		typical intensity	0.0080	6.3	60	52	0.032	**4E-05**	**3**
							TOTAL	**1E-04**	**7**
	Gardens (Rototilling)								
	Bin B1	---	0.039	2	2	52	0.00034	**2E-06**	**0.1**
	Gardens (Digging)								
	Bin A	---	0.00020	3.3	40	52	0.011	**4E-07**	**0.03**
	Bin B1	---	0.00066	3.3	40	52	0.011	**1E-06**	**0.08**
	Bin B2/C	---	0	3.3	40	52	0.011	**0E+00**	**0**
	Driveway (Playing & Digging)								
	Bin A	---	0	2	225	15	0.011	**0E+00**	**0**
	Bin B1	---	0.0057	2	225	15	0.011	**1E-05**	**0.7**
	Bin B2/C	---	0.0050	2	225	15	0.011	**9E-06**	**0.6**
	LUAs (ATV-riding)								
	Bin A	---	0.0012	2	20	52	0.0034	**7E-07**	**0.05**
	Bin B1	---	0.0014	2	20	52	0.0034	**8E-07**	**0.05**
OU7	**Yards (Mowing, Raking, Digging)**								
	Bin A	**typical intensity**	0.000062	6.6	60	52	0.034	**4E-07**	**0.02**
	Bin B1	**typical intensity**	0	6.6	60	52	0.034	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Bin A	---	0.000023	5.3	42	52	0.019	**7E-08**	**0.005**
	Bin B1	---	0	5.3	42	52	0.019	**0E+00**	**0**
	Residential, Outdoor Driveway (Playing & Digging)								
	Bin A	---	0.000079	2	225	15	0.011	**1E-07**	**0.01**
	Bin B1	---	0.000085	2	225	15	0.011	**2E-07**	**0.01**

TABLE 6-3a
Estimated Residential Risks from Exposure to LA During Disturbances of Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Exposure Scenario & Soil Concentration[1]	Yard ABS Script Intensity	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	**Yards (Mowing, Raking, Digging)**								
	Bin A	**high intensity**	0.0040	0.1	30	22	0.00011	**7E-08**	**0.005**
		typical intensity	0.00011	2.1	30	22	0.0023	**4E-08**	**0.003**
							TOTAL	**1E-07**	**0.008**
	Bin B1	**high intensity**	0.061	0.1	30	22	0.00011	**1E-06**	**0.07**
		typical intensity	0.0024	2.1	30	22	0.0023	**9E-07**	**0.06**
							TOTAL	**2E-06**	**0.1**
	Bin B2/C	**high intensity**	0.21	0.1	30	22	0.00011	**4E-06**	**0.3**
		typical intensity	0.0080	2.1	30	22	0.0023	**3E-06**	**0.2**
							TOTAL	**7E-06**	**0.5**
	Gardens (Rototilling)								
	Bin B1	---	0.039	1	1	22	0.000036	**2E-07**	**0.02**
	Gardens (Digging)								
	Bin A	---	0.00020	1.1	20	22	0.00079	**3E-08**	**0.002**
	Bin B1	---	0.00066	1.1	20	22	0.00079	**9E-08**	**0.006**
	Bin B2/C	---	0	1.1	20	22	0.00079	**0E+00**	**0**
	Driveway (Playing & Digging)								
	Bin A	---	0	0.9	113	15	0.0025	**0E+00**	**0**
	Bin B1	---	0.0057	0.9	113	15	0.0025	**2E-06**	**0.2**
	Bin B2/C	---	0.0050	0.9	113	15	0.0025	**2E-06**	**0.1**
	LUAs (ATV-riding)								
	Bin A	---	0.0012	1	10	22	0.00036	**7E-08**	**0.005**
	Bin B1	---	0.0014	1	10	22	0.00036	**8E-08**	**0.005**
OU7	**Yards (Mowing, Raking, Digging)**								
	Bin A	**typical intensity**	0.000062	2.2	30	22	0.0024	**2E-08**	**0.002**
	Bin B1	**typical intensity**	0	2.2	30	22	0.0024	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)++								
	Bin A	---	0.000023	2.1	21	22	0.0016	**6E-09**	**0.0004**
	Bin B1	---	0	2.1	21	22	0.0016	**0E+00**	**0**
	Residential, Outdoor Driveway (Playing & Digging)								
	Bin A	---	0.000079	0.9	113	15	0.0025	**3E-08**	**0.002**
	Bin B1	---	0.000085	0.9	113	15	0.0025	**4E-08**	**0.002**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4).
++ Exposure time and frequency have been summed because the EPC is based on a combination of the activities.

[1] PLM-VE Bin:
A - ND (non-detect)
B1 - Tr (trace; <0.2%)
B2 - <1%
C - ≥1%

Notes:
ABS - activity-based sampling
ATV - all- terrain vehicle
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
LUA - limited use areas
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-3b
Estimated Outdoor Worker Risks from Exposure to LA During Disturbances of Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Expsosure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	**Yards (Mowing, Raking, Digging)**								
	Bin A	**high intensity**	0.0040	0.4	100	25	0.0016	**1E-06**	**0.07**
		typical intensity	0.00011	7.6	100	25	0.031	**6E-07**	**0.04**
							TOTAL	**2E-06**	**0.1**
	Bin B1	**high intensity**	0.061	0.4	100	25	0.0016	**2E-05**	**1**
		typical intensity	0.0024	7.6	100	25	0.031	**1E-05**	**0.8**
							TOTAL	**3E-05**	**2**
	Bin B2/C	**high intensity**	0.21	0.4	100	25	0.0016	**6E-05**	**4**
		typical intensity	0.0080	7.6	100	25	0.031	**4E-05**	**3**
							TOTAL	**1E-04**	**7**
	Gardens (Rototilling)								
	Bin B1	---	0.039	2	100	25	0.008	**5E-05**	**4**
	Gardens (Digging)								
	Bin A	---	0.00020	2	100	25	0.008	**3E-07**	**0.02**
	Bin B1	---	0.00066	2	100	25	0.008	**9E-07**	**0.06**
	Bin B2/C	---	0	2	100	25	0.008	**0E+00**	**0**
OU7	**Yards (Mowing, Raking, Digging)**								
	Bin A	**typical intensity**	0.000062	8	100	25	0.033	**3E-07**	**0.02**
	Bin B1	**typical intensity**	0	8	100	25	0.033	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Bin A		0.000023	4	100	25	0.016	**6E-08**	**0.004**
	Bin B1	---	0	4	100	25	0.016	**0E+00**	**0**

TABLE 6-3b
Estimated Outdoor Worker Risks from Exposure to LA During Disturbances of Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Expsoure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	**Yards (Mowing, Raking, Digging)**								
	Bin A	**high intensity**	0.0040	0.4	50	15	0.00049	**3E-07**	**0.02**
		typical intensity	0.00011	7.6	50	15	0.0093	**2E-07**	**0.01**
							TOTAL	**5E-07**	**0.03**
	Bin B1	**high intensity**	0.061	0.4	50	15	0.00049	**5E-06**	**0.3**
		typical intensity	0.0024	7.6	50	15	0.0093	**4E-06**	**0.2**
							TOTAL	**9E-06**	**0.5**
	Bin B2/C	**high intensity**	0.21	0.4	50	15	0.00049	**2E-05**	**1**
		typical intensity	0.0080	7.6	50	15	0.0093	**1E-05**	**0.8**
							TOTAL	**3E-05**	**2**
	Gardens (Rototilling)								
	Bin B1	---	0.039	1	50	15	0.0012	**8E-06**	**0.5**
	Gardens (Digging)								
	Bin A	---	0.00020	1	50	15	0.0012	**4E-08**	**0.003**
	Bin B1	---	0.00066	1	50	15	0.0012	**1E-07**	**0.009**
	Bin B2/C	---	0	1	50	15	0.0012	**0E+00**	**0**
OU7	**Yards (Mowing, Raking, Digging)**								
	Bin A	**typical intensity**	0.000062	4	50	15	0.0049	**5E-08**	**0.003**
	Bin B1	**typical intensity**	0	4	50	15	0.0049	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Bin A		0.000023	2	50	15	0.0024	**9E-09**	**0.0006**
	Bin B1	---	0	2	50	15	0.0024	**0E+00**	**0**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[++] Exposure time has been summed because the EPC is based on a combination of the activities.

[1] PLM-VE Bin:
A - ND
B1 - Tr
B2 - <1
C - ≥ 1

Notes:
ABS - activity-based sampling
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
PLM-VE - polarized light microscopy - visual area estimation
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-4

Nature of Surface Soil Materials Left in Place

Libby Asbestos Superfund Site

LA Soil Concentration	Properties with a Soil Removal									Properties without a Soil Removal					
	SUA		CUA			LUA				SUA		CUA		LUA	
	2003-2013	2014 - present	2003-2006	2007-2013	2014 - present	2003-2006	2006-2010	2011-2013	2014 - present	2003-2013	2014 - present	2003-2013	2014 - present	2003-2013	2014 - present
Topsoil Fill Material Bin A (ND)															
Bin A (ND)	Vis -		Vis - or Vis +	Vis -		Vis - or Vis +	Vis -	Vis - or low Vis +		Vis -		Vis - or Vis +		Vis - or Vis +	
Bin B1 (Trace)		**			**			Vis - or low Vis +		Vis -	**	Vis - or Vis +	**	Vis - or Vis +	
Bin B2 (<1%)								Vis - or low Vis +		Vis -		Vis - or Vis +		Vis - or Vis +	
Bin C (≥1%)															

condition is not expected to be present

condition may be present

**Trace levels may be present in less than 25% of the total area;
where: total area = SUA + CUA + SS + SB

<u>Notes:</u>

CUA - common-use area (e.g., yard)

LUA - limited-use area (e.g., pasture, maintained/mowed fields)

ND - non-detect

PLM-VE - polarized light microscopy - equivalent

SB - secondary building (e.g., soil floor of a garage or shed)

SS - secondary structure (e.g., unpaved carport or lean-to)

SUA - specific-use area (e.g., garden, flowerbed, unpaved driveway, play area)

Vis - - no visible vermiculite present

Vis + - visible vermiculite present

% - percent

< - less than

≥ - greater than or equal

<u>PLM-VE Bin:</u>

A - ND (non-detect)

B1 - Tr (trace; <0.2%)

B2 - <1%

C - ≥1%

TABLE 6-5
Screening Level Risk Estimates from Exposure to LA During Disturbances of Subsurface Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Receptor Type	Soil Concentration[1]	Yard ABS Script	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)[++]	ED (years)	TWF		
OU4/OU7	Outdoor Worker	Bin A	digging, high intensity	0.0053	2	32.5	25	0.0027	**2E-06**	**0.2**
		Bin B1	digging, high intensity	0.16	2	7.5	25	0.00061	**2E-05**	**1**
		Bin B2/C	digging, high intensity	0.52	2	10	25	0.00082	**7E-05**	**5**
								TOTAL	**9E-05**	**6**
	Resident	Bin A	digging, high intensity	0.0053	2	1	52	0.00017	**2E-07**	**0.01**
		Bin B1	digging, high intensity	0.16	2	1	52	0.00017	**4E-06**	**0.3**
		Bin B2/C	digging, high intensity	0.52	2	1	52	0.00017	**2E-05**	**1**

Panel B: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Receptor Type	Soil Concentration[1]	Yard ABS Script	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)[++]	ED (years)	TWF		
OU4/OU7	Outdoor Worker	Bin A	digging, high intensity	0.0053	2	16.25	15	0.00080	**7E-07**	**0.05**
		Bin B1	digging, high intensity	0.16	2	3.75	15	0.00018	**5E-06**	**0.3**
		Bin B2/C	digging, high intensity	0.52	2	5	15	0.00024	**2E-05**	**1**
								TOTAL	**3E-05**	**1**
	Resident	Bin A	digging, high intensity	0.0053	2	0.5	22	0.000036	**3E-08**	**0.002**
		Bin B1	digging, high intensity	0.16	2	0.5	22	0.000036	**9E-07**	**0.06**
		Bin B2/C	digging, high intensity	0.52	2	0.5	22	0.000036	**3E-06**	**0.2**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[++] The total exposure frequency for the worker has been allocated to the various soil conditions according to the assumed frequency each condition is expected to be encountered.

[1] PLM-VE Bin:
A - ND
B1 - Tr
B2 - <1
C - ≥ 1

Notes:
ABS - activity-based sampling
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
PLM-VE - polarized light microscopy - visual area estimation
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-6
Exposure Parameters During Soil Disturbances at Schools and Parks in OU4 and OU7
Libby Asbestos Superfund Site

Exposure Media	Operable Unit	Exposure Location	Receptor Type	Parameter Type	Exposure Parameter [1]						
					Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
					Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	OU4	Kootenai Valley Head Start	Student	--- [b]	0.5	[1]	128	[1]	2	[1]	0.00021
			Maintenance Worker	--- [b]	1.0	[1]	128	[1]	25	[1]	0.0052
		Libby Elementary School	Student	--- [b]	2.0	[1]	180	[1]	6	[1]	0.0035
			Maintenance Worker	--- [b]	1.5	[1]	260	[1]	25	[1]	0.016
		Libby Middle School	Student	--- [b]	1.6	[1]	90	[1]	3	[1]	0.00070
			Maintenance Worker	--- [b]	0.5	[1]	260	[1]	25	[1]	0.0053
		Libby High School	Student	--- [b]	0.67	[1]	45	[1]	4	[1]	0.00020
			Maintenance Worker	--- [b]	1.0	[1]	260	[1]	25	[1]	0.011
		Libby Admin. Building	Student [a]	--- [b]	0.75	[1]	180	[1]	6	[1]	0.0013
			Maintenance Worker	--- [b]	1.5	[1]	260	[1]	25	[1]	0.016
		All Schools	Lawn Mower	--- [b]	10.0	[1]	22	[1]	25	[1]	0.0090
		Libby High School, Libby Admin. Bldg.	Power Sweeper	RME	2.0	[1]	22	[1]	25	[1]	0.0018
		Cabinet View Country Club	Maintenance Worker	RME	8.0	[2]	100	[2]	15	[2]	0.020
	OU7	Morrison Elementary School	Student	RME	2.0	[3]	180	[3]	6	[3]	0.0035
		Timberbeast Disc Golf Course	Recreational Visitor (adult)	RME	5.0	[4]	48	[5]	52	[6]	0.020
		Roosevelt Park, Ball Fields	Recreational Visitor (adult)	RME	5.0	[4]	48	[5]	52	[6]	0.020
		Roosevelt Park, Playground	Recreational Visitor (child)	RME	10.7	[4]	48	[5]	10	[4]	0.0084

** TWF calculated as ET/24 · EF/365 · ED/70

[a] Classes are held in the Libby Administration Building

[b] The basis (RME/CTE) of the exposure parameters provided by school administrators was not specified.

Source Citations:

[1] All OU4 exposure parameters are based on interviews with school administrators at each school. Outdoor exposure assumptions were developed to be representative of the entire year, which includes extreme variations in weather.

[2] Based on professional judgment; CTE exposure frequency is assumed to be 1/2 RME.

[3] Assumed to be equal to Libby Elementary School.

[4] Hours/day spent at parks or golf courses for based on in EPA (2011), Table 16-20. Hours/day spent at parks for children <11 years in age in EPA (2011), Table 16-19. RME is 95th percentile (rounded), CTE is 50th percentile (rounded).

[5] Assumes recreational activities occur twice per week for RME from late spring to late fall (late April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (24 weeks for 2 days per week (48 days) for RME and 1 day/week for CTE (24 days).

[6] Assumed to be a local resident. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the 95th percentile. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

[7] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[8] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Notes:

CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 6-7
Summary Statistics for Outdoor ABS Air Samples at Schools and Parks in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: OU4 Schools

School Building	ABS Description	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
Kootenai Valley Head Start	Student	6	0	0	All ND	0.0066
	Maintenance Worker	3	0	0	All ND	0.0018
	Lawn Mower	3	1	0.00074	0.0022	0.0025
Libby Elementary School	Student	9	2	0.0019	0.016	0.0067
	Maintenance Worker	3	0	0	All ND	0.0029
	Lawn Mower	3	0	0	All ND	0.0031
Libby Middle School	Student	6	2	0.0020	0.0080	0.0054
	Maintenance Worker	3	0	0	All ND	0.0026
	Lawn Mower	3	0	0	All ND	0.0023
Libby High School	Student	6	1	0.00017	0.0010	0.0022
	Maintenance Worker	3	0	0	All ND	0.0028
	Lawn Mower	3	0	0	All ND	0.0017
Libby Public Schools, Admin Building	Student	3	0	0	All ND	0.0028
	Maintenance Worker	3	0	0	All ND	0.0027
	Lawn Mower	3	1	0.000019	0.000056	0.0019
Libby High School & Admin Building	Power Sweeper	3	0	0	All ND	0.0061

Panel B: OU7 Schools and Parks

Location	ABS Description	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
Morrison Elementary School	Student	13	0	0	All ND	0.00022
Timber Beast Disk Golf Course	Recreational, adult	12	0	0	All ND	0.00022
Roosevelt Park, ball fields	Recreational, adult	8	2	0.00011	0.00064	0.00022
Roosevelt Park, playground	Recreational, child	7	0	0	All ND	0.00022

Panel C: OU4 Golf Course

Location	ABS Description	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
Cabinet View Country Club	Course maintenance worker	7	3	0.00056	0.0020	0.00096

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy-equivalent
s/cc - structures per cubic centimeter

TABLE 6-8
Estimated Risks from Exposure to LA During Disturbances of Soils at Schools and Parks
Libby Asbestos Superfund Site

Operable Unit	Exposure Location	Receptor Type	EPC Mean Air Conc. (PCME LA s/cc)+	Exposure Parameters ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Cancer Risk	Non-cancer HQ
OU4	Kootenai Valley Head Start	Student	0	0.5	128	2	0.00021	**0E+00**	**0**
		Maintenance Worker	0	1.0	128	25	0.0052	**0E+00**	**0**
		Lawn Mower	0.00074	10	22	25	0.0090	**1E-06**	**0.07**
	Libby Elementary School	Student	0.0019	2.0	180	6	0.0035	**1E-06**	**0.07**
		Maintenance Worker	0	1.5	260	25	0.016	**0E+00**	**0**
		Lawn Mower	0	10	22	25	0.0090	**0E+00**	**0**
	Libby Middle School	Student	0.0020	1.6	90	3	0.00070	**2E-07**	**0.02**
		Maintenance Worker	0	0.5	260	25	0.0053	**0E+00**	**0**
		Lawn Mower	0	10	22	25	0.0090	**0E+00**	**0**
	Libby High School	Student	0.00017	0.67	45	4	0.00020	**6E-09**	**0.0004**
		Maintenance Worker	0	1.0	260	25	0.011	**0E+00**	**0**
		Lawn Mower	0	10	22	25	0.0090	**0E+00**	**0**
	Libby Admin. Building	Student	0	0.75	180	6	0.0013	**0E+00**	**0**
		Maintenance Worker	0	1.5	260	25	0.016	**0E+00**	**0**
		Lawn Mower	0.000019	10	22	25	0.0090	**3E-08**	**0.002**
	Libby High School and Libby Admin Building	Power Sweeper	0	2.0	22	25	0.0018	**0E+00**	**0**
	Cabinet View Country Club	Maintenance Worker	0.00056	8.0	100	15	0.020	**2E-06**	**0.1**
OU7	Morrison Elementary School	Student	0	2.0	180	6	0.0035	**0E+00**	**0**
	Timber Beast Disk Golf Course	Recreational Visitor, adult	0	5.0	48	52	0.020	**0E+00**	**0**
	Roosevelt Park, ball fields	Recreational Visitor, adult	0.00011	5.0	48	52	0.020	**4E-07**	**0.02**
	Roosevelt Park, playground	Recreational Visitor, child	0	10.7	48	10	0.0084	**0E+00**	**0**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-9
Exposure Parameters for Outdoor Air During Recreational Activities in OU4 and OU7
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Exposure Location	Exposure Scenario	Parameter Type	Exposure Parameter / Source						Time-Weighting Factor [TWF]**
					Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		
					Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	Recreational Visitor	OU4	Biking on Trails (as adult rider)	RME	2	[2] a.1	90	[2] b.1	52	[2,5] c.1	0.015
				CTE	1	[2] a.2	45	[2] b.2	22	[2,5] c.1	0.0016
			Biking on Trails (as child in trailer)	RME	2	[2] a.1	90	[2] b.1	5	[1] c.2	0.0015
				CTE	1	[2] a.2	45	[2] b.2	5	[1] c.2	0.00037
		OU7	Biking on Trails (as adult rider)	RME	0.75	[3] a.1	90	[2] b.1	52	[2,5] c.1	0.0057
				CTE	0.38	[3] a.2	45	[2] b.2	22	[2,5] c.1	0.00061
			Biking on Trails (as child in trailer)	RME	0.75	[3] a.1	90	[2] b.1	5	[1] c.2	0.00055
				CTE	0.38	[3] a.2	45	[2] b.2	5	[1] c.2	0.00014

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.
[2] Professional judgment using site specific considerations. Recreational scenarios assume that residents are most likely participants and assumptions reflect this.
[3] Professional judgment using site specific considerations; adjusted based on Troy versus Libby city size.
[4] EPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.
[5] ATSDR 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana* A Report to the Community. August 23, 2001.
[6] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day biking are based on professional judgment. Because Troy city extent is smaller than Libby, time spent biking in Troy is assumed to be less than time spent biking in Libby.
a.2 Hours/day for CTE assumed to be 1/2 RME value.

b) Exposure Frequency [EF]

b.1 Assumes biking on trails occurs in the area from late spring to late fall (late April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (90 days/year) for RME and 1/2 the RME value for CTE (45 days). SAP/QAPP 2010.
b.2 Days/year for CTE assumed to be 1/2 RME value.

c) Exposure Duration [ED]

c.1 Assumes residents are the most likely exposed receptors. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".
c.2 Default age group (1 to 6 years) for evaluation of exposure to young children.

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF -exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
SAP/QAPP - sampling and analysis plan/quality assurance project plan
TWF - time-weighting factor

TABLE 6-10
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils on Bike Paths and Trails
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Sector	ABS Sample Type	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
					Mean	Maximum Detect	
OU4	Sector A	Adult Rider	20	0	0	All ND	0.0033
		Inside Trailer	10	0	0	All ND	0.0082
	Sector B	Adult Rider	20	0	0	All ND	0.0035
		Inside Trailer	10	0	0	All ND	0.0085
	Sector C	Adult Rider	20	0	0	All ND	0.0035
		Inside Trailer	10	0	0	All ND	0.0091
OU7	---	Adult Rider	20	0	0	All ND	0.00022
		Inside Trailer	20	1	0.000011	0.00022	0.00022

Panel B: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Sector	Receptor Type	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	Sector A-C	Adult Rider	0	2	90	52	0.015	**0E+00**	**0**
		Inside Trailer	0	2	90	5	0.0015	**0E+00**	**0**
OU7	---	Adult Rider	0	0.75	90	52	0.0057	**0E+00**	**0**
		Inside Trailer	0.000011	0.75	90	5	0.00055	**1E-09**	**0.00007**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Sector	Receptor Type	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	Sector A-C	Adult Rider	0	1	45	22	0.0016	**0E+00**	**0**
		Inside Trailer	0	1	45	5	0.00037	**0E+00**	**0**
OU7	---	Adult Rider	0	0.38	45	22	0.00061	**0E+00**	**0**
		Inside Trailer	0.000011	0.38	45	5	0.00014	**3E-10**	**0.00002**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-11
Exposure Parameters for Outdoor Air During Soil/Duff Disturbance Activities in OU1
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						Time-weighting Factor [TWF]**
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	Outdoor Worker (Park Maintenance Worker)	Mowing	RME	6	[1] a.1	13	[1] b.1	25	[1] c.1	0.0032
			CTE	6	[1] a.1	6	[1] b.2	7	[2] c.2	0.00041
		Weed-trimming	RME	1	[1] a.2	13	[1] b.1	25	[1] c.1	0.00053
			CTE	1	[1] a.2	6	[1] b.2	7	[2] c.2	0.000068
	Recreational Visitor	Recreating at park	RME	2	[1] a.3	48	[1] b.3	52	[3] c.3	0.0081
			CTE	2	[1] a.3	24	[1] b.2	22	[3] c.3	0.0017

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] Professional judgment using site specific considerations.

[2] EPA. 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.

[3] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[4] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 The time required to mow the park is based on the area of the park (≈12 acres) assuming that 2 acres per hour are mowed.

a.2 The time spent weed trimming is based on the area of the park that cannot be accessed by mowers which is a fraction of the total area.

a.3 Based on professional judgment using site specific considerations such as the size and location of the of area.

b) Exposure Frequency [EF]

b.1 Assumes that workers mow the park every other week during spring and summer (13 days/year).

b.2 Days/year for CTE assumed to be 1/2 RME value.

b.3 Assumes recreational activities occur twice per week from late spring to late fall (late April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (24 weeks for 2 days /week, or 48 days).

c) Exposure Duration [ED]

c.1 ED for RME is based on professional judgment.

c.2 ED is recommended mean value for workers in EPA (2011).

c.3 Assumes that residents are the most likely recreational visitors. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

Notes:

CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 6-12
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU1
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Exposure Scenario	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU1	Mowing	6	1	0.00044	0.0026	0.0028
	Weed-trimming	3	0	0	All ND	0.011

Panel B: Risk Estimates Based on RME Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker	Mowing	0.00044	6	13	25	0.0032	**2E-07**	**0.02**
	Weed-trimming	0	1	13	25	0.00053	**0E+00**	**0**
Recreational Visitor	Recreating at park [a]	0.00044	2	48	52	0.0081	**6E-07**	**0.04**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker	Mowing	0.00044	6	6	7	0.00041	**3E-08**	**0.002**
	Weed-trimming	0	1	6	7	0.000068	**0E+00**	**0**
Recreational Visitor	Recreating at park [a]	0.00044	2	24	22	0.0017	**1E-07**	**0.008**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] ABS was not performed for recreational activities; results from the mowing scenario are used to evaluate recreational exposures.

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-13

Exposure Parameters for Outdoor Air During Soil/Duff Disturbance Activities in OU2

Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Exposure Scenario	Parameter Type	Exposure Parameters						Time-weighting Factor [TWF]**
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	Outdoor Worker (MDT Maintenance Worker)	ROW Maintenance (Mowing)	RME	1	[1] a.1	5	[1 b.1	15	[1] c.1	0.00012
			CTE	1	[1] a.1	5	[1] b.1	7	[2] c.2	0.000057
	Recreational Visitor (Hiking)	Hiking along Kootenai River	RME	2	[1] a.2	10	[1] b.2	52	[3] c.3	0.0017
			CTE	1	[1] a.3	5	[1] b.3	22	[3] c.3	0.00018

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] Professional judgment using site specific considerations. Recreational scenarios assume that residents are most likely the participants and assumptions reflect this.

[2] EPA. 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.

[3] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[4] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 Due to the limited extent of the ROW (≈1,500 feet in length) the time required to mow the ROW is only a fraction of the worker's day.

a.2 Hours/day for RME is based on professional judgment using site specific considerations such as the size and location of the of area.

a.3 Hours/day for CTE is assumed to be 1/2 RME value.

b) Exposure Frequency [EF]

b.1 Assumes MDT workers mow the right-of-way once a month during the summer from May through September.

b.2 Assumes hiking occurs in the area 10 days/year for RME during late spring to early fall (May through September) based on the limited spatial extent of the frontage area along the Kootenai River. Exposure frequency also considers days when releases due to soil disturbance activities are unlikely either due to snow cover or high soil moisture content.

b.3 CTE is assumed to be 1/2 RME value.

c) Exposure Duration [ED]

c.1 RME ED is based on professional judgment using site specific considerations.

c.2 Years is recommended mean value for workers in EPA (2011).

c.3 Assumes that residents are the most likely recreational users of this area. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry

CTE - central tendency exposure

ED - exposure duration

EF - exposure frequency

EPA - environmental protection agency

ET - exposure time

MDT - Montana Department of Transportation

OU - operable unit

RME - reasonable maximum exposure

ROW - right-of-way

TWF - Time Weighted Factor

TABLE 6-14
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU2
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Exposure Scenario	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU2	Mowing Hwy 37 ROW	3	0	0	All ND	0.018
	Hiking along Kootenai River	6	0	0	All ND	0.0048

Panel B: Risk Estimates Based on RME Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker	Mowing Hwy 37 ROW	0	1	5	15	0.00012	**0E+00**	**0**
Recreational Visitor	Hiking along Kootenai River	0	2	10	52	0.0017	**0E+00**	**0**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker	Mowing Hwy 37 ROW	0	1	5	7	0.000057	**0E+00**	**0**
Recreational Visitor	Hiking along Kootenai River	0	1	5	22	0.00018	**0E+00**	**0**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:

ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
ROW - right-of-way
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-15

Exposure Parameters for Outdoor Air During Soil/Duff Disturbance Activities in OU3

Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Exposure Location	Exposure Scenario	Parameter Type	Exposure Parameters: Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-weighting Factor [TWF]**
Outdoor Air During Soil/Duff Disturbance Activities	Recreational Visitor	Forested Area	Hiking	RME	8	[1]	50	[1] b.1	52	[3] c.1	0.034
				CTE	4	a.1	25	b.2	22	[3] c.1	0.0036
			ATV Riding	RME	4	[2]	50	[1] b.1	52	[3] c.1	0.017
				CTE	2	a.1	25	b.2	22	[3] c.1	0.0018
			Camping (campfire building/burning)	RME	2	[2]	50	[1] b.1	52	[3] c.1	0.0085
				CTE	1	a.1	25	b.2	22	[3] c.1	0.00090
		Along Rainy Creek	Hiking	RME	3.6	a.2	20	[1] b.3	52	[3] c.1	0.0061
				CTE	3.6	a.2	10	b.2	22	[3] c.1	0.0013
		OU3 Roads	Driving	RME	3	[2]	50	[1] b.1	52	[3] c.1	0.013
				CTE	1.5	a.1	25	b.2	22	[3] c.1	0.0013
		Along Kootenai River	Fishing/boating	RME	8	[2]	60	[2]	52	[3] c.1	0.041
				CTE	4	a.1	20	[2]	22	[3] c.1	0.0029
	USFS Firefighter	Forested Area	Cutting firelines	RME	10	[2]	14	[2]	10	[2]	0.0023
				CTE	5	a.1	7	b.2	5	[2]	0.00029
	Trespasser	Mined Area	ATV Riding	RME	4	[1]	10	[1]	52	[3] c.1	0.0034
				CTE	2	a.1	5	b.2	22	[3] c.1	0.00036
			Rockhound	RME	6	[1]	3	[1]	52	[3] c.1	0.0015
				CTE	3	a.1	1.5	b.2	22	[3] c.1	0.00016

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] Professional judgment using site-specific considerations. Recreational scenarios assume that residents are most likely participants and assumptions reflect this.

[2] Personal communication with United States Forest Service (USFS); email dated 6/24/14.

[3] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[4] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day for CTE is assumed to be 1/2 RME value.

a.2 The OU3 Phase IV, Part A Rainy Creek hiking ABS was conducted for 1 hour and encompassed about 1 mile (round trip) of Rainy Creek. The full length of the creek to the mine is approximately 1.8 miles one way (3.6 round trip). Thus, it is assumed that it would take approximately 3.6 hours to travel the full distance round trip.

b) Exposure Frequency [EF]

b.1 Assumes hiking occurs in the forest every weekend for RME from spring to late fall (April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (25 weeks for 2 days/week for RME).

b.2 Days/year for CTE assumed to be 1/2 RME value.

b.3 Assumes hiking occurs along Rainy Creek about once per week for RME from late spring to fall (May through September) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (20 weeks for 1 day/week for RME).

c) Exposure Duration [ED]

c.1 Assumes that residents are the most likely recreational users of this area. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
ATV - all-terrain vehicle
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
RME - reasonable maximum exposure
SAP/QAPP - sampling and analysis plan/quality assurance project plan
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 6-16
ABS Air Summary Statistics For Disturbances of Soils in OU3
Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Exposure Area*	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
					Mean	Maximum	
Recreational Visitor	Hiking	Rainy Creek	10	7	0.0093	0.046	0.0039
		Forest, near	12	1	0.00050	0.0060	0.0042
		Forest, intermed.	37	3	0.00065	0.012	0.0054
		Forest, far	26	1	0.00023	0.0060	0.0052
	ATV Riding	Forest, near	13	2	0.0014	0.012	0.0060
		Forest, intermed.	36	2	0.00050	0.012	0.0060
		Forest, far	27	1	0.00022	0.0060	0.0060
	Campfire building/burning	Forest, near	10	2	0.0024	0.012	0.0060
		Forest, intermed.	40	12	0.0022	0.012	0.0060
		Forest, far	26	2	0.00046	0.0060	0.0060
	Driving	Forest, near	---	---	---	---	---
		Forest, intermed.	20	1	0.00013	0.0027	0.025
		Forest, far	10	0	0	All ND	0.024
	Fishing/boating	Kootenai River	2	0	0	All ND	0.00031
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	---	---	---	---	---
		Forest, intermed.	20	8	0.007	0.038	0.0088
		Forest, far	10	6	0.0045	0.013	0.0084
		Forest, NPL boundary	60	7	0.00017	0.0023	0.0010
	Cutting firelines with heavy machinery	Forest, near	---	---	---	---	---
		Forest, intermed.	20	10	0.0025	0.012	0.0080
		Forest, far	10	2	0.0016	0.014	0.011
Mine Trespasser	ATV Riding	Mine	42	27	0.014	0.066	0.0060
	Rockhound	Mine	18	18	0.14	0.32	0.0063

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
--- = No ABS air samples have been collected within two miles from the mine for this scenario

*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine.
Forest, far: greater than or equal to six miles from the mine
Forest, NPL boundary: locations along the NPL boundary evaluated in the nature & extent forest study (see Section 6.6.2.4)

Notes:
ABS - activity-based sampling
ATV - all-terrain vehicle
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
NPL - National Priority List
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 6-17
Estimated Risks from Exposures to LA During Disturbances of Soils in OU3
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Receptor Type	Exposure Scenario	Exposure Area*	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	Hiking	Rainy Creek	0.0093	3.6	20	52	0.006	1E-05	0.6
		Forest, near	0.00050	8	50	52	0.034	3E-06	0.2
		Forest, intermed.	0.00065	8	50	52	0.034	4E-06	0.2
		Forest, far	0.00023	8	50	52	0.034	1E-06	0.09
	ATV-riding	Forest, near	0.0014	4	50	52	0.017	4E-06	0.3
		Forest, intermed.	0.00050	4	50	52	0.017	1E-06	0.09
		Forest, far	0.00022	4	50	52	0.017	6E-07	0.04
	Campfire building/burning	Forest, near	0.0024	2	50	52	0.0085	3E-06	0.2
		Forest, intermed.	0.0022	2	50	52	0.0085	3E-06	0.2
		Forest, far	0.00046	2	50	52	0.0085	7E-07	0.04
	Driving	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.00013	3	50	52	0.013	3E-07	0.02
		Forest, far	0	3	50	52	0.013	0E+00	0
	Fishing/boating	Kootenai River	0	8	60	52	0.041	0E+00	0
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.0069	10	14	10	0.0023	3E-06	0.2
		Forest, far	0.0045	10	14	10	0.0023	2E-06	0.1
		Forest, NPL boundary	0.00017	10	14	10	0.0023	7E-08	0.004
	Cutting firelines with heavy machinery	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.0025	10	14	10	0.0023	1E-06	0.06
		Forest, far	0.0016	10	14	10	0.0023	6E-07	0.04
Mine Trespasser	ATV-riding	Mine (on/off-road)	0.014	4	10	52	0.0034	8E-06	0.5
	Rockhound	Disturbed area	0.14	6	3	52	0.0015	4E-05	2

Panel B: Risk Estimates Based on CTE Exposure Parameters

Receptor Type	Exposure Scenario	Exposure Area*	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	Hiking	Rainy Creek	0.0093	3	10	22	0.0011	2E-06	0.1
		Forest, near	0.00050	4	25	22	0.0036	3E-07	0.02
		Forest, intermed.	0.00065	4	25	22	0.0036	4E-07	0.03
		Forest, far	0.00023	4	25	22	0.0036	1E-07	0.009
	ATV-riding	Forest, near	0.0014	2	25	22	0.0018	4E-07	0.03
		Forest, intermed.	0.00050	2	25	22	0.0018	2E-07	0.01
		Forest, far	0.00022	2	25	22	0.0018	7E-08	0.004
	Campfire building/burning	Forest, near	0.0024	1	25	22	0.0009	4E-07	0.02
		Forest, intermed.	0.0022	1	25	22	0.0009	3E-07	0.02
		Forest, far	0.00046	1	25	22	0.0009	7E-08	0.005
	Driving	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.00013	1.5	25	22	0.0013	3E-08	0.002
		Forest, far	0	1.5	25	22	0.0013	0E+00	0
	Fishing/boating	Kootenai River	0	4	20	22	0.0029	0E+00	0
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.007	5	7	5	0.00029	3E-07	0.02
		Forest, far	0.0045	5	7	5	0.00029	2E-07	0.01
		Forest, NPL boundary	0.00017	5	7	5	0.00029	8E-09	0.0006
	Cutting firelines with heavy machinery	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.0025	5	7	5	0.00029	1E-07	0.008
		Forest, far	0.0016	5	7	5	0.00029	8E-08	0.005
Mine Trespasser	ATV-riding	Mine (on/off-road)	0.014	2	5	22	0.0004	9E-07	0.06
	Rockhound	Disturbed area	0.14	3	1.5	22	0.0002	4E-06	0.3

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
--- = No ABS air samples have been collected within two miles from the mine for this scenario

*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine
Forest, far: greater than or equal to six miles from the mine
Forest, NPL boundary: locations along the NPL boundary evaluated in the nature & extent forest study (see Section 6.6.2.4)

Notes:
ATV - all terrain vehicle
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
NPL - National Priorities List
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-18
Exposure Parameters for Outdoor Air during Soil/Duff Disturbance Activities in OU5
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	General Outdoor Worker	Industrial properties (outdoor maintenance)	RME	4	[1] a.1	135	[1] b.1	25	[1] c.1	0.022
			CTE	4	[1] a.1	90	[2] b.1	25	[1] c.1	0.015
	Recreational Visitor	Biking on Trails (as adult rider)	RME	2	[3] a.2	48	[3] b.2	52	[3,5] c.2	0.0081
			CTE	1	[3] a.3	24	[3] b.2	22	[3,5] c.2	0.00086
		Biking on Trails (as child in trailer)	RME	2	[3] a.2	48	[3] b.2	5	[3] c.3	0.00078
			CTE	1	[3] a.3	24	[3] b.2	5	[3] c.3	0.00020
		Motocross Participant	RME	4	[4]	40	[4]	55	[4]	0.014
			CTE	2	[4]	30	[4]	35	[4]	0.0034
		Motocross Spectator	RME	4	[4]	60	[4]	45	[4]	0.018
			CTE	4	[4]	30	[4]	45	[4]	0.0088

** TWF calculated as ET/24 · EF/365 · ED/70

<u>**Source Citations:**</u>

[1] EPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December.

[2] EPA. 1991. *Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors".* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[3] Professional judgment using site specific considerations. Recreational scenarios assume that residents are most likely participants and assumptions reflect this.

[4] Interviews with MotoX Park participants. EPA 2008. *Informed Consent for Personal Air Monitoring at the MotoX Track in Libby, Montana.*
Information on exposure parameters for riders at the MotoX Park was obtained from six volunteers who participated in the MotoX Park ABS investigation (Interviewed on September 10, 2008). See **Appendix H.2**.

[5] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[6] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

<u>**Source Notes:**</u>

a) Exposure Time [ET]

a.1 The default of 8 hours/day was adjusted by a factor of 0.5 to account for time spent disturbing soil or dust.
a.2 Hours/day biking on trails based on professional judgment.
a.3 Hours/day for CTE is assumed to be 1/2 RME value.

b) Exposure Frequency [EF]

b.1 Default exposure frequency estimates of 219 days/year (CTE) or 225 days/year (RME) for outdoor workers were adjusted to account for days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (i.e., November to March) (225 days - 90 days (18 weeks for 5 days/week)=135 days).
b.2 Assumes biking on trails occurs in the area twice per week for RME from late spring to late fall (late April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (24 weeks for 2 days/week (48 days) for RME and 1 day/week for CTE (24 days).

c) Exposure Duration [ED]

c.1 Years is recommended default for workers in EPA (2002).
c.2 Assumes that residents are the most likely recreational users of this area. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".
c.3 Default age group (1 to 6 years) for evaluation of exposure to young children.

<u>**Notes:**</u>

ABS - activity-based sampling
ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 6-19
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU5
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Receptor Type	Exposure Location	Exposure Type	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
					Mean	Maximum	
Recreational Visitor	MotoX Track	Participant	24	0	0	All ND	0.0098
		Spectator	10	0	0	All ND	0.0011
	Bike Path	Rider	39	3	0.000038	0.00071	0.0010
		Inside Trailer	7	1	0.000053	0.00037	0.0011
Outdoor Worker	Area 1	Worker	6	1	0.00080	0.0048	0.013
	Area 2	Worker	6	2	0.00091	0.0046	0.0040
	Area 3	Worker	6	4	0.0025	0.0091	0.0055
	Area 4	Worker	6	0	0	All ND	0.0043
	Area 5	Worker	6	3	0.0057	0.024	0.024
	Area 6	Worker	6	3	0.0010	0.0029	0.0034
	Area 7	Worker	6	2	0.00071	0.0023	0.0031
	Area 8	Worker	6	4	0.0013	0.0045	0.0028

Panel B: Risk Estimates Based on RME Exposure Parameters

Receptor Type	Exposure Location	Exposure Type	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	MotoX Track	Participant	0	4	40	55	0.014	**0E+00**	**0**
		Spectator	0	4	60	45	0.018	**0E+00**	**0**
	Bike Path	Rider, adult	0.000038	2	48	52	0.0081	**5E-08**	**0.003**
		Trailer, child	0.000053	2	48	5	0.00078	**7E-09**	**0.0005**
Outdoor Worker	Area 1	Worker	0.00080	4	135	25	0.022	**3E-06**	**0.2**
	Area 2	Worker	0.00091	4	135	25	0.022	**3E-06**	**0.2**
	Area 3	Worker	0.0025	4	135	25	0.022	**9E-06**	**0.6**
	Area 4	Worker	0	4	135	25	0.022	**0E+00**	**0**
	Area 5	Worker	0.0057	4	135	25	0.022	**2E-05**	**1**
	Area 6	Worker	0.0010	4	135	25	0.022	**4E-06**	**0.2**
	Area 7	Worker	0.00071	4	135	25	0.022	**3E-06**	**0.2**
	Area 8	Worker	0.0013	4	135	25	0.022	**5E-06**	**0.3**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Receptor Type	Exposure Location	Exposure Type	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	MotoX Track	Participant	0	2	30	35	0.0034	**0E+00**	**0**
		Spectator	0	4	30	45	0.0088	**0E+00**	**0**
	Bike Path	Rider, adult	0.000038	1	24	22	0.00086	**6E-09**	**0.0004**
		Trailer, child	0.000053	1	24	5	0.00020	**2E-09**	**0.0001**
Outdoor Worker	Area 1	Worker	0.00080	4	90	25	0.015	**2E-06**	**0.1**
	Area 2	Worker	0.00091	4	90	25	0.015	**2E-06**	**0.1**
	Area 3	Worker	0.0025	4	90	25	0.015	**6E-06**	**0.4**
	Area 4	Worker	0	4	90	25	0.015	**0E+00**	**0**
	Area 5	Worker	0.0057	4	90	25	0.015	**1E-05**	**0.9**
	Area 6	Worker	0.0010	4	90	25	0.015	**3E-06**	**0.2**
	Area 7	Worker	0.00071	4	90	25	0.015	**2E-06**	**0.1**
	Area 8	Worker	0.0013	4	90	25	0.015	**3E-06**	**0.2**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
OU - operable unit
PCME - phase contrast microscopy - equivalent
LA - Libby amphibole asbestos
ND - non-detect
N - number
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-20
Exposure Parameters During Soil/Duff Disturbance Activities in OU6
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance	BNSF Workers	Railroad Maintenance	RME	8	[1] a.1	60	[3]	50	[3]	0.039
			CTE	8	[1] a.1	10	[2,3]	25	[3] b.1	0.0033
	Trespasser	On-looker	RME	2	[3]	60	[3]	15	[2,3]	0.0029
			CTE	2	[3]	10	[3]	9	[2,3]	0.00029
		Pedestrian trespasser	RME	4	[3]	60	[3]	52	[4] b.2	0.020
			CTE	4	[3]	10	[3]	22	[4] b.2	0.0014

** TWF calculated as ET/24 · EF/365 · ED/70

<u>**Source Citations:**</u>

[1] EPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.

[2] Professional judgment using site specific considerations.

[3] Information provided by Burlington Northern (BN). BN. 2013. *Memorandum: Risk Calculations for Human Health Risk Assessment.* Prepared by TRC. January 2014.

[4] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[5] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

<u>**Source Notes:**</u>

a) Exposure Time [ET]

a.1 Hours/day is the recommended default for workers in EPA (2002); the default for outdoor workers is 8 hours/day.

b) Exposure Duration [ED]

b.1 Assumed based on USEPA standard default exposure factors (EPA 1991).

b.2 Assumes that residents are the most likely exposed receptors in this area. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

<u>**Notes:**</u>

ABS - activity-based sampling
ATSDR - Agency for Toxic Substances and Disease Registry
BN - Burlington Northern
BNSF - Burlington Northern Santa Fe
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
SAP - sampling and analysis plan
TWF - time-weighting factor

TABLE 6-21

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU6

Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Exposure Scenario	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU6	Pedestrian tresspasser	14	0	0	All ND	0.00065
	On-looker	7	0	0	All ND	0.0010
	BNSF worker	14	0	0	All ND	0.00034

Panel B: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU6	Pedestrian tresspasser	0	4	60	52	0.020	**0E+00**	**0**
	On-looker	0	2	60	15	0.0029	**0E+00**	**0**
	BNSF worker	0	8	60	50	0.039	**0E+00**	**0**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU6	Pedestrian tresspasser	0	4	10	22	0.0014	**0E+00**	**0**
	On-looker	0	2	10	9	0.00029	**0E+00**	**0**
	BNSF worker	0	8	10	25	0.0033	**0E+00**	**0**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:

ABS - activity-based sampling
BNSF - Burlington Northern Santa Fe
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-22
Exposure Parameters for Outdoor Air During Soil/Duff Disturbance Activities in OU8
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	Residents	Driving on Libby roads	RME	2	[4] a.2	225	[4] b.1	52	[1] c.1	0.038
			CTE	1	[4] a.2	113	[4] b.1	25	[1] c.1	0.0046
		Driving on Troy roads	RME	0.75	[5]	225	[4] b.1	52	[1] c.1	0.014
			CTE	0.5	[5]	113	[4] b.1	22	[1] c.1	0.0020
	Recreational Visitors	Hiking, biking, ATV riding along ROW	RME	4	[4] a.3	184	[4] b.2	52	[1] c.1	0.062
			CTE	2	[4] a.3	90	[4] b.2	22	[1] c.1	0.0065
	Outdoor Worker (MDT Maintenance Worker)	Rotomilling, mowing, brush-clearing along ROW	RME	8	[2] a.1	60	[2] b.3	30	[7] c.2	0.023
			CTE	8	[2] a.1	12	[3] b.4	30	[7] c.2	0.0047

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[2] EPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.

[3] EPA. 1991. *Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors"* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[4] Professional judgment using site specific considerations.

[5] Adjusted based on Troy vs Libby city size.

[6] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

[7] EPA. 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day is the recommended default for workers in EPA (2002); the default for outdoor workers is 8 hours/day.

a.2 Hours/day spent driving on Troy roads are based on professional judgment using site specific considerations.

a.3 Hours/day spent hiking, biking, or ATV riding driving on roads in OU8 are based on professional judgment using site specific considerations.

b) Exposure Frequency [EF]

b.1 Days/year are site specific. Default exposure frequency estimate of 350 days/year was adjusted to account for days when releases due to soil were unlikely either due to snow cover or high soil moisture content (i.e., November to March) (350 days - 126 days (18 weeks for 7 days/week)=224 days, rounded to 225) disturbance activities. CTE is 1/2 the RME value or 113 days.

b.2 184 days/year assumes daily exposure from April through September, during the warmer months of the year. 90 days/year assumes daily exposure for three summer months.

b.3 60 days/year assumes three months of exposure working 5-day work weeks, 4 weeks per month, with weekends off.

b.4 An EF of 12 days per year considers approximately 240 miles of roadway spanning both sides of all OU8 state highways (~120 miles for one side of the highway) and assumes three days of brush hogging or rotomilling, to occur twice a year, and accounts for variability in brush hogging or rotomilling efficiency. Example (240 miles @ average mowing speed of 10 mph): 3 days mowing @ 8 hours/day x 2 mowing operations/year = 6 mowing days/year. This estimate is doubled to account for 50% efficiency in operator differences, resulting in an effective exposure frequency of 12 days/year.

c) Exposure Duration [ED]

c.1 Assumes residents are the most likely exposed receptors. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

c.2 Years is recommended mean value for workers in EPA (2011).

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
ATV - all-terrain vehicle
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
MDT - Montana Department of Transportation
OU - operable unit
RME - reasonable maximum exposure
ROW - right-of-way
TWF - time-weighting factor

TABLE 6-23
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU8
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Exposure Scenario	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU8	ATV riding ROW	16	1	0.00018	0.0028	0.0029
	Brush-clearing ROW	14	6	0.0036	0.018	0.0036
	Mowing	4	0	0.0000	All ND	0.0041
	Rotomilling	61	1	0.000049	0.0030	0.0036
	Driving on Libby roads	20	0	0	All ND	0.00065
	Driving on Troy roads	20	7	0.00033	0.0028	0.00022

Panel B: Risk Estimates Based on RME Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-Cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	ATV riding ROW	0.00018	4	184	52	0.062	**2E-06**	**0.1**
Outdoor Worker	Brush-clearing ROW	0.0036	8	60	30	0.023	**1E-05**	**0.9**
	Mowing ROW	0	8	60	30	0.023	**0E+00**	**0**
	Rotomilling	0.000049	8	60	30	0.023	**2E-07**	**0.01**
Various	Driving on Libby roads	0	2	225	52	0.038	**0E+00**	**0**
	Driving on Troy roads	0.00033	0.75	225	52	0.014	**8E-07**	**0.05**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-Cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	ATV riding ROW	0.00018	2	90	22	0.0065	**2E-07**	**0.01**
Outdoor Worker	Brush-clearing ROW	0.0036	8	12	30	0.0047	**3E-06**	**0.2**
	Mowing ROW	0	8	12	30	0.0047	**0E+00**	**0**
	Rotomilling	0.000049	8	12	30	0.0047	**4E-08**	**0.003**
Various	Driving on Libby roads	0	1	113	22	0.0041	**0E+00**	**0**
	Driving on Troy roads	0.00033	0.5	113	22	0.0020	**1E-07**	**0.007**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:

ABS - activity-based sampling
ATV - all-terrain vehicle
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
ROW - right-of-way
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-24
Estimated Risks from Exposure to LA During Background Soil Disturbances
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

ABS Script	ABS Dataset*	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
"Bucket of dirt" digging	OU4 Background Areas	33	7	0.0016	0.019	0.00072
	OU7 Background Areas	11	7	0.00032	0.0011	0.00048
	OU4 Topsoil Borrow Sources	15	4	0.000046	0.00020	0.00011
Raking, mowing, digging	OU4 "Curb-to-Curb" Yards	31	8	0.00039	0.0049	0.00025

Panel B: Risk Estimates Based on RME Exposure Parameters

ABS Script	ABS Dataset*	EPC	RME Exposure Parameters++				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
"Bucket of dirt" digging	OU4 Background Areas	0.0016	6.6	60	52	0.034	**9E-06**	**0.6**
	OU7 Background Areas	0.00032	6.6	60	52	0.034	**2E-06**	**0.1**
	OU4 Topsoil Borrow Sources	0.000046	6.6	60	52	0.034	**3E-07**	**0.02**
Raking, mowing, digging	OU4 "Curb-to-Curb" Yards	0.00039	6.6	60	52	0.034	**2E-06**	**0.1**

*See the *Background Soil Summary Report* (CDM Smith 2014h) for a detailed discussion of each type of ABS dataset.
+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4).
++ Exposure parameters for the RME residential yard soil disturbance scenario are used in the risk estimates.

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-1
Exposure Parameters for Indoor Air Inside Residential/Commercial Properties in OU4 and OU7
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Ambient Conditions During Indoor Dust Disturbance	Resident	Passive Behaviors (e.g., sleeping, watching TV)	RME	16.9	[1] a.1	350	[3] b.1	52	[5] c.1	0.50
			CTE	14.9	[1] a.1	350	[3] b.1	22	[5] c.1	0.19
		Active Behaviors (e.g., house cleaning)	RME	5.8	[1] a.2	350	[3] b.1	52	[5] c.1	0.17
			CTE	1.5	[1] a.2	350	[3] b.1	22	[5] c.1	0.019
	Indoor Workers	Passive Behaviors (e.g., sitting at a desk)	RME	4	[2] a.3	250	[2] b.2	25	[2] c.2	0.041
			CTE	4	[2] a.3	219	[3] b.2	7	[1] c.3	0.010
		Active Behaviors (e.g., cleaning, walking)	RME	4	[2] a.3	250	[2] b.2	25	[2] c.2	0.041
			CTE	4	[2] a.3	219	[3] b.2	7	[1] c.3	0.010
Indoor Air During VI Disturbance Activities	Tradesperson	Worker	RME	4	[4] a.4	250	[2] b.2	25	[2] c.2	0.041
			CTE	4	[4] a.4	219	[3] b.2	7	[1] c.3	0.010

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.

[2] EPA 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December.

[3] EPA 1991. *Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors".* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[4] Professional judgment using site specific considerations.

[5] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[6] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day spent passively are calculated based on recommended default assumptions in EPA (2011); ET is assumed to be equal to the total indoor ET minus the active ET. Hours/day at residence (total) = 16.4 (CTE) to 22.7 (RME) (EPA (2011),Table 16-1).

a.2 Hours/day spent house cleaning (active) are EPA recommended default values in EPA (2011), Table 16-26. RME is 95th percentile, CTE is mean value.

a.3 Hours/day is the recommended default for workers in EPA (2002); the default for indoor workers and outdoor workers is 8 hours/day. This was assumed to be spent on active and passive behaviors equally (4 hours each).

a.4 The default of 8 hours/day was adjusted by a factor of 0.5 to account for time spent disturbing soil or dust.

b) Exposure Frequency [EF]

b.1 Days/year at residence. Recommended default for residents in EPA (1991) (350 days/year is based on the assumption the resident spends a 2 week vacation each year away from residence).

b.2 Days/year is recommended default for workers in EPA (2002); RME default for indoor workers is 250 days/year, CTE is 219 days/year.

c) Exposure Duration [ED]

c.1 ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

c.2 Years is recommended default for workers in EPA (2002).

c.3 Years is recommended mean value for workers in EPA (2011).

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor
VI - vermiculite insulation

TABLE 7-2
Exposure Point Concentrations For Indoor ABS Air During Residential/Commercial Disturbances
Libby Asbestos Superfund Site

Interior Removal Classification	Behavior Type	N Samples	Mean Seasonal PCME LA Air Conc. (s/cc)[a]				
			Spring	Summer	Fall	Winter	EPC (Average Mean Across Seasons)
OU4: Residential Properties in Libby							
Pre-removal	Active	42	0.0035	0.000016	0.00036	0.00011	0.00099
	Passive	29	0.00011	0.000099	--	0	0.000068
Post-removal	Active	131	0.00010	0.00022	0.00032	0.000093	0.00018
	Passive	132	0.000032	0.000041	0.000045	0.0000081	0.000032
No removal	Active	202	0.000071	0.00016	0.000064	0.000084	0.000095
	Passive	217	0.000025	0.000077	0.000027	0.000025	0.000038
OU4: Commercial Properties in Libby							
Pre-removal	Active	6	0.0092	0.00073	--	0	0.0033
	Passive	5	0.000021	0.00080	--	0	0.00027
Post-removal	Active	6	0.00027	0.00012	--	0	0.00013
	Passive	6	0.000029	0	--	0	0.0000096
No removal	Active	6	0	0.00062	--	0	0.00021
	Passive	7	0	0.000077	--	0.000039	0.000039
OU7: Residential Properties in Troy[b]							
Post-removal	Active	14	0.000012	--	0.00010	--	0.000056
	Passive	14	0.0000055	--	0.000026	--	0.000016
No removal	Active	22	0.000029	--	0.000024	--	0.000027
	Passive	22	0.000014	--	0.000012	--	0.000013
OU7: Commercial Properties in Troy[b]							
No removal	Active	4	0.000069	--	0.000023	--	0.000046
	Passive	4	0.0000096	--	0	--	0.0000048

-- = no samples collected in this season.
[a] Seasons are defined as follows: Spring (March, April, May), Summer (June, July, August), Fall (September, October, November), and Winter (December, January, February).
[b] No pre-removal data is available for Troy. Samples collected in late February have been grouped into "spring".

Notes:
ABS - activity-based sampling
Conc. - concentration
EPC - exposure point concentration
LA - Libby amphibole asbestos
N - number
OU - operable unit
PCME - phase-contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 7-3
Estimated Residential and Indoor Worker Risks from Exposure to LA from Indoor Air in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Receptor Type	Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	Resident	Residential Properties - "Pre-Removal"	Active Behaviors	0.00099	5.8	350	52	0.17	**3E-05**	**2**
			Passive Behaviors	0.000068	16.9	350	52	0.50	**6E-06**	**0.4**
								Total:	**3E-05**	**2**
		Residential Properties - "Post-Removal"	Active Behaviors	0.00018	5.8	350	52	0.17	**5E-06**	**0.3**
			Passive Behaviors	0.000032	16.9	350	52	0.50	**3E-06**	**0.2**
								Total:	**8E-06**	**0.5**
		Residential Properties - "No Removal"	Active Behaviors	0.000095	5.8	350	52	0.17	**3E-06**	**0.2**
			Passive Behaviors	0.000038	16.9	350	52	0.50	**3E-06**	**0.2**
								Total:	**6E-06**	**0.4**
	Indoor Worker	Commercial Properties - "Pre-Removal"	Active Behaviors	0.0033	4	250	25	0.041	**2E-05**	**2**
			Passive Behaviors	0.00027	4	250	25	0.041	**2E-06**	**0.1**
								Total:	**2E-05**	**2**
		Commercial Properties - "Post-Removal"	Active Behaviors	0.00013	4	250	25	0.041	**9E-07**	**0.06**
			Passive Behaviors	0.0000096	4	250	25	0.041	**7E-08**	**0.004**
								Total:	**1E-06**	**0.06**
		Commercial Properties - "No Removal"	Active Behaviors	0.00021	4	250	25	0.041	**1E-06**	**0.09**
			Passive Behaviors	0.000039	4	250	25	0.041	**3E-07**	**0.02**
								Total:	**2E-06**	**0.1**
OU7	Resident	Residential Properties - "Post-Removal"	Active Behaviors	0.000056	5.8	350	52	0.17	**2E-06**	**0.1**
			Passive Behaviors	0.000016	16.9	350	52	0.50	**1E-06**	**0.09**
								Total:	**3E-06**	**0.2**
		Residential Properties - "No Removal"	Active Behaviors	0.000027	5.8	350	52	0.17	**8E-07**	**0.05**
			Passive Behaviors	0.000013	16.9	350	52	0.50	**1E-06**	**0.07**
								Total:	**2E-06**	**0.1**
	Indoor Worker	Commercial Properties - "No Removal"	Active Behaviors	0.000046	4	250	25	0.041	**3E-07**	**0.02**
			Passive Behaviors	0.0000048	4	250	25	0.041	**3E-08**	**0.002**
									4E-07	**0.02**

TABLE 7-3
Estimated Residential and Indoor Worker Risks from Exposure to LA from Indoor Air in OU4 and OU7
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Receptor Type	Receptor Type	Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	Resident	Residential Properties - "Pre-Removal"	Active Behaviors	0.00099	1.5	350	22	0.019	**3E-06**	**0.2**
			Passive Behaviors	0.000068	14.9	350	22	0.19	**2E-06**	**0.1**
								Total:	**5E-06**	**0.3**
		Residential Properties - "Post-Removal"	Active Behaviors	0.00018	1.5	350	22	0.019	**6E-07**	**0.04**
			Passive Behaviors	0.000032	14.9	350	22	0.19	**1E-06**	**0.07**
								Total:	**2E-06**	**0.1**
		Residential Properties - "No Removal"	Active Behaviors	0.000095	1.5	350	22	0.019	**3E-07**	**0.02**
			Passive Behaviors	0.000038	14.9	350	22	0.19	**1E-06**	**0.08**
								Total:	**2E-06**	**0.1**
	Indoor Worker	Commercial Properties - "Pre-Removal"	Active Behaviors	0.0033	4	219	7	0.010	**6E-06**	**0.4**
			Passive Behaviors	0.00027	4	219	7	0.010	**5E-07**	**0.03**
								Total:	**6E-06**	**0.4**
		Commercial Properties - "Post-Removal"	Active Behaviors	0.00013	4	219	7	0.010	**2E-07**	**0.01**
			Passive Behaviors	0.0000096	4	219	7	0.010	**2E-08**	**0.001**
								Total:	**2E-07**	**0.01**
		Commercial Properties - "No Removal"	Active Behaviors	0.00021	4	219	7	0.010	**4E-07**	**0.02**
			Passive Behaviors	0.000039	4	219	7	0.010	**7E-08**	**0.004**
								Total:	**4E-07**	**0.02**
OU7	Resident	Residential Properties - "Post-Removal"	Active Behaviors	0.000056	1.5	350	22	0.019	**2E-07**	**0.01**
			Passive Behaviors	0.000016	14.9	350	22	0.19	**5E-07**	**0.03**
								Total:	**7E-07**	**0.04**
		Residential Properties - "No Removal"	Active Behaviors	0.000027	1.5	350	22	0.019	**9E-08**	**0.006**
			Passive Behaviors	0.000013	14.9	350	22	0.19	**4E-07**	**0.03**
								Total:	**5E-07**	**0.04**
	Indoor Worker	Commercial Properties - "No Removal"	Active Behaviors	0.000046	4	219	7	0.010	**8E-08**	**0.005**
			Passive Behaviors	0.0000048	4	219	7	0.010	**8E-09**	**0.0005**
									9E-08	**0.006**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:

Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-4
Summary Statistics During Indoor Tradesperson Activities
Libby Asbestos Superfund Site

Activity Description	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Achieved Sensitivity (cc^{-1})
			Mean[a]	Maximum	
Bulk VI removal	4	4 [b]	0.044	0.12	0.0017
Demolition	4	4	0.0078	0.028	0.0012
Detailing attic	5	5	0.025	0.12	0.0010
Wet wipe/HEPA vacuum in living space	4	4 [c]	0.015	0.030	0.0027

[a] The mean PCME concentration was selected as the EPC.
[b] One sample also reported detected structures of chrysotile and amosite.
[c] All samples also reported detected structures of chrysotile and/or amosite, crocidolite, and anthophyllite.

Notes:
cc^{-1} - per cubic centimeter
Conc. - concentration
EPC - exposure point concentraion
HEPA - high-efficiency particulate air
LA - Libby amphibole asbestos
N - number
PCME - phase-contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 7-5
Estimated Tradesperson Risks from Exposure to LA from Indoor Air in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Receptor Type	Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Tradesperson, worker	OU4/OU7, Residential/ Commerical Properties	Bulk VI Removal	0.044	4	250	25	0.041	**3E-04**	**20**
		Demolition	0.0078	4	250	25	0.041	**5E-05**	**4**
		Detailing attic	0.025	4	250	25	0.041	**2E-04**	**10**
		Wet wipe/HEPA vac	0.015	4	250	25	0.041	**1E-04**	**7**

Panel B: Risk Estimates Based on CTE Exposure Parameters

Receptor Type	Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Tradesperson, worker	OU4/OU7, Residential/ Commerical Properties	Bulk VI Removal	0.044	4	219	7	0.010	**7E-05**	**5**
		Demolition	0.0078	4	219	7	0.010	**1E-05**	**0.9**
		Detailing attic	0.025	4	219	7	0.010	**4E-05**	**3**
		Wet wipe/HEPA vac	0.015	4	219	7	0.010	**3E-05**	**2**

Panel C: Risk Estimates Based on "Weekend Warrior" Exposure Parameters

Receptor Type	Building Description	Exposure Scenario	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Resident	OU4/OU7, Residential/ Commerical Properties	Bulk VI Removal	0.044	4	24	10	0.0016	**1E-05**	**0.8**
		Demolition	0.0078	4	24	10	0.0016	**2E-06**	**0.1**
		Detailing attic	0.025	4	24	10	0.0016	**7E-06**	**0.4**
		Wet wipe/HEPA vac	0.015	4	24	10	0.0016	**4E-06**	**0.3**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4).

<u>Notes:</u>

Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HEPA - high-efficiency particulate air
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-6
Exposure Parameters for Indoor Air During Typical School Activities in OU4
Libby Asbestos Superfund Site

Exposure Media & Disturbance Description	Receptor Group	Building Description	Exposure Parameters [1]			
			Exposure Time [ET] (hours/day)	Exposure Frequency [EF] (days/year)	Exposure Duration [ED] (years)	Time-weighting Factor [TWF]**
Indoor Air During Typical School Activities	Student	Kootenai Valley Head Start	7	200	2	0.0046
		Libby Elementary School	7	200	6	0.014
		Libby High School	7	200	4	0.0091
		Libby Middle School	7	200	3	0.0068
		Libby Admin. Building[a]	7	200	6	0.014
	Teacher	All Schools	8	210	25	0.068

** TWF calculated as ET/24 · EF/365 · ED/70

[a] Classes are held in the Libby Administration Building

Source Citations:

[1] All OU4 exposure parameters are based on interviews with school administrators at each school (EPA 2010). Both the indoor and outdoor exposure assumptions were developed to be representative of the entire year, which includes extreme variations in weather. There is no separation of active and passive indoor activities.
[2]EPA. 2010. *Public Schools Asbestos Sampling Summary Report.* Libby, Montana, Superfund Site. July 2010.

Notes:
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
TWF - time-weighting factor

TABLE 7-7
Summary Statistics During Indoor Activities at Schools in OU4
Libby Asbestos Superfund Site

School Building	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Kootenai Valley Head Start	10	0	0	All ND	0.00057
Libby Elementary School	10	1	0.000059	0.00059	0.00056
Libby Middle School	10	1	0.000051	0.00051	0.00056
Libby High School	10	0	0	All ND	0.00054
Libby Public Schools Admin. Building	10	0	0	All ND	0.00058

+Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 7-8
Estimated Risks from Exposure to LA from Indoor Air in OU4 Schools
Libby Asbestos Superfund Site

Receptor Type	Building Description	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Student	Kootenai Valley Head Start	0	7	200	2	0.0046	**0E+00**	**0**
	Libby Elementary School	0.000059	7	200	6	0.014	**1E-07**	**0.009**
	Libby Middle School	0.000051	7	200	3	0.0068	**6E-08**	**0.004**
	Libby High School	0	7	200	4	0.0091	**0E+00**	**0**
	Libby Admin. Building	0	7	200	6	0.014	**0E+00**	**0**
Teacher	Kootenai Valley Head Start	0	8	210	25	0.068	**0E+00**	**0**
	Libby Elementary School	0.000059	8	210	25	0.068	**7E-07**	**0.05**
	Libby Middle School	0.000051	8	210	25	0.068	**6E-07**	**0.04**
	Libby High School	0	8	210	25	0.068	**0E+00**	**0**
	Libby Admin. Building	0	8	210	25	0.068	**0E+00**	**0**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:

Conc. - concentration
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-9
Exposure Parameters for the Search and Rescue Building in OU1
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						Time-weighting Factor [TWF]**
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Indoor Air	Search and Rescue Volunteer	Indoor Activities	RME	3.2	[1]	147	[1]	52	[2] a.1	0.040
			CTE	1.7	[1]	72	[1]	22	[2] a.1	0.0044

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] Questionnaires for search and rescue volunteers (see **Appendix H.1**). RME is equal to the 95th percentile; CTE is equal to the mean across all respondents.
[2] ATSDR. 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.
[3] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a.1 Assumes volunteers are Libby residents. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

Notes:

CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
RME - reasonable maximum exposure
SRC - Syracuse Research Company
TWF - time-weighting factor

TABLE 7-10

Air Summary Statistics and Estimated Risks from Exposure to LA in Indoor Air at the Search and Rescue Building in OU1

Libby Asbestos Superfund Site

Panel A: Summary Statistics for Clearance Air Samples

Operable Unit	Exposure Location	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU1	Office	2	2	0.00033	0.00038	0.00024
	Garage	3	3	0.00022	0.00028	0.00024

Panel B: Risk Estimates Based on RME Exposure Parameters

Exposure Location	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Office	Active (high-end)	0.00033	3.2	147	52	0.040	**2E-06**	**0.1**
Garage	Active (high-end)	0.00022	3.2	147	52	0.040	**1E-06**	**0.1**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Exposure Location	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Office	Active (high-end)	0.00033	1.7	72	22	0.0044	**2E-07**	**0.02**
Garage	Active (high-end)	0.00022	1.7	72	22	0.0044	**2E-07**	**0.01**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:

cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-11
Exposure Parameters for Indoor Air in Buildings in OU5
Libby Asbestos Superfund Site

Building Description	Parameter Type	Exposure Scenario	Exposure Parameters [1]			
			Exposure Time [ET]	Exposure Frequency [EF]	Exposure Duration [ED]	Time-weighting Factor (TWF)**
			Value (hours/ day)	Value (days/ year)	Value (years)	
Occupied Buildings						
B+C Packaging	RME	Active Behaviors	1	300	5	0.0024
		Passive Behaviors	*100% of time assumed to be active for RME*			
	CTE	Active Behaviors	6.2	180	2	0.0036
		Passive Behaviors	*100% of time assumed to be active for CTE*			
Bioreactor Building	RME	Active Behaviors	6.4	250	25	0.065
		Passive Behaviors	1.6	250	25	0.016
	CTE	Active Behaviors	4	219	10	0.014
		Passive Behaviors	4	219	10	0.014
CDM Smith Main Office	RME	Active Behaviors	6.4	250	25	0.065
		Passive Behaviors	1.6	250	25	0.016
	CTE	Active Behaviors	0.4	250	10	0.0016
		Passive Behaviors	7.6	250	10	0.031
Central Maintenance Building	RME	Active Behaviors	8	319	27	0.11
		Passive Behaviors	*100% of time assumed to be active for RME*			
	CTE	Active Behaviors	2.55	146	11	0.0067
		Passive Behaviors	0.45	146	11	0.0012
Fire Hall	RME	Active Behaviors	6.4	250	25	0.065
		Passive Behaviors	1.6	250	25	0.016
	CTE	Active Behaviors	4	219	10	0.014
		Passive Behaviors	4	219	10	0.014
Log Yard Truck Scale House	RME	Active Behaviors	0.083	10	25	0.000034
		Passive Behaviors	*100% of time assumed to be active for RME*			
	CTE	Active Behaviors	0.07	9	13	0.000013
		Passive Behaviors	*100% of time assumed to be active for CTE*			
Luck EG Electric Motor Shed	RME	Active Behaviors	0.33	300	15	0.0024
		Passive Behaviors	*100% of time assumed to be active for RME*			
	CTE	Active Behaviors	0.22	*280*	*8*	0.00080
		Passive Behaviors	*100% of time assumed to be active for CTE*			
Office/Laboratory	RME	Active Behaviors	6.4	250	25	0.065
		Passive Behaviors	1.6	250	25	0.016
	CTE	Active Behaviors	4	219	10	0.014
		Passive Behaviors	4	219	10	0.014
Vacant Buildings						
All buildings	RME	Active (high-end)	8	250	25	0.082
	CTE	Active (high-end)	8	219	10	0.029

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] All occupied building exposure parameters are based on building-specific surveys. See **Appendix H.3** for survey results. Vacant building exposure parameters are based on default worker parameters (EPA 1991, 2002).

[2] EPA 1991. *Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors".* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[3] EPA 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.

Notes:

CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor
% - percent

TABLE 7-12

Summary Statistics for Indoor ABS at Buildings in OU5

Libby Asbestos Superfund Site

Building	ABS Type	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)*		Mean Achieved Sensitivity (cc^{-1})
				Mean	Maximum	
Occupied Buildings						
B+C Packaging	Active	4	1	0.000094	0.00038	0.0060
	Passive	1	0	0	All ND	0.00049
Bioreactor Building	Active	2	1	0.00023	0.00047	0.00061
	Passive	1	0	0	All ND	0.00049
CDM Smith Main Office	Active	5	3	0.0013	0.0049	0.0039
	Passive	2	0	0	All ND	0.00049
Central Maintenance Building	Active	4	1	0.0010	0.0041	0.014
	Passive	1	1	0.00021	0.00021	0.00053
Fire Hall	Active	2	0	0	All ND	0.0059
	Passive	1	0	0	All ND	0.00049
Log Yard Truck Scale House	Active	6	3	0.0065	0.016	0.060
	Passive	1	0	0	All ND	0.00050
Luck EG Electric Motor Shed	Active	3	3	0.0025	0.0042	0.0024
	Passive	1	0	0	All ND	0.00045
Office/Laboratory	Active	2	1	0.00025	0.00049	0.00084
	Passive	1	0	0	All ND	0.00049
Vacant Buildings						
Chemical Storage Building	Active*	5	0	0	All ND	0.00049
Diesel Fire Pump House	Active*	5	2	0.00011	0.00037	0.00083
Electric Pump House	Active*	5	2	0.00034	0.00085	0.0021
Intermediate Injection Building	Active*	5	0	0	All ND	0.00048
LTU Leachate Building #1	Active*	5	1	0.000039	0.00019	0.00049
LTU Leachate Building #2	Active*	5	0	0	All ND	0.00049
Pipe Shop	Active*	5	0	0	All ND	0.0022
Power house/office	Active*	5	0	0	All ND	0.00091
Shed 12	Active*	5	0	0	All ND	0.00039
Tank Farm Building	Active*	5	0	0	All ND	0.00049

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

* Samples collected following active disturbances with a leaf-blower.

Notes:

ABS - activity-based sampling

cc^{-1} - per cubic centimeter

Conc. - concentration

OU - operable unit

LA - Libby amphibole asbestos

N - number

ND - non-detect

PCME - phase contrast microscopy - equivalent

s/cc - structures per cubic centimeter

TABLE 7-13
Estimated Risks from Exposure to LA from Indoor Air in OU5
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Occupied Buildings								
B+C Packaging	Active Behaviors	0.000094	1	300	5	0.0024	**4E-08**	**0.003**
	Passive Behaviors	0	*100% of time assumed to be active for RME*					
Bioreactor Building	Active Behaviors	0.00023	6.4	250	25	0.065	**3E-06**	**0.2**
	Passive Behaviors	0	1.6	250	25	0.016	**0E+00**	**0**
CDM Smith Libby Field Office	Active Behaviors	0.0013	6.4	250	25	0.065	**1E-05**	**1**
	Passive Behaviors	0	1.6	250	25	0.016	**0E+00**	**0**
Central Maintenance Building	Active Behaviors	0.0010	8	319	27	0.11	**2E-05**	**1**
	Passive Behaviors	0.00021	*100% of time assumed to be active for RME*					
Fire Hall	Active Behaviors	0	6.4	250	25	0.065	**0E+00**	**0**
	Passive Behaviors	0	1.6	250	25	0.016	**0E+00**	**0**
Log Yard Truck Scale House	Active Behaviors	0.0065	0.083	10	25	0.000034	**4E-08**	**0.002**
	Passive Behaviors	0	*100% of time assumed to be active for RME*					
Luck EG Electric Motor Shed	Active Behaviors	0.0025	0.33	300	15	0.0024	**1E-06**	**0.07**
	Passive Behaviors	0	*100% of time assumed to be active for RME*					
Office/Laboratory	Active Behaviors	0.00025	6.4	250	25	0.065	**3E-06**	**0.2**
	Passive Behaviors	0	1.6	250	25	0.016	**0E+00**	**0**
Vacant Buildings								
Chemical Storage Building	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Diesel Fire Pump House	Active (high-end)	0.00011	8	250	25	0.082	**2E-06**	**0.1**
Electric Pump House	Active (high-end)	0.00034	8	250	25	0.082	**5E-06**	**0.3**
Intermediate Injection Building	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
LTU Leachate Building #1	Active (high-end)	0.000039	8	250	25	0.082	**5E-07**	**0.04**
LTU Leachate Building #2	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Pipe Shop	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Power house/office	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Shed 12	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Tank Farm Building	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**

TABLE 7-13
Estimated Risks from Exposure to LA from Indoor Air in OU5
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Occupied Buildings								
B+C Packaging	Active Behaviors	0.000094	6.2	180	2	0.0036	**6E-08**	**0.004**
	Passive Behaviors	0	*100% of time assumed to be active for CTE*					
Bioreactor Building	Active Behaviors	0.00023	4	219	10	0.014	**6E-07**	**0.04**
	Passive Behaviors	0	4	219	10	0.014	**0E+00**	**0**
CDM Smith Libby Field Office	Active Behaviors	0.0013	0.4	250	10	0.0016	**4E-07**	**0.02**
	Passive Behaviors	0	7.6	250	10	0.031	**0E+00**	**0**
Central Maintenance Building	Active Behaviors	0.0010	2.55	146	11	0.0067	**1E-06**	**0.08**
	Passive Behaviors	0.00021	0.45	146	11	0.0012	**4E-08**	**0.003**
Fire Hall	Active Behaviors	0	4	219	10	0.014	**0E+00**	**0**
	Passive Behaviors	0	4	219	10	0.014	**0E+00**	**0**
Log Yard Truck Scale House	Active Behaviors	0.0065	0.07	9	13	0.000013	**1E-08**	**0.001**
	Passive Behaviors	0	*100% of time assumed to be active for CTE*					
Luck EG Electric Motor Shed	Active Behaviors	0.0025	0.22	*280*	*8*	0.00080	**3E-07**	**0.02**
	Passive Behaviors	0	*100% of time assumed to be active for CTE*					
Office/Laboratory	Active Behaviors	0.00025	4	219	10	0.014	**6E-07**	**0.04**
	Passive Behaviors	0	4	219	10	0.014	**0E+00**	**0**
Vacant Buildings								
Chemical Storage Building	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Diesel Fire Pump House	Active (high-end)	0.00011	8	219	10	0.029	**5E-07**	**0.04**
Electric Pump House	Active (high-end)	0.00034	8	219	10	0.029	**2E-06**	**0.1**
Intermediate Injection Building	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
LTU Leachate Building #1	Active (high-end)	0.000039	8	219	10	0.029	**2E-07**	**0.01**
LTU Leachate Building #2	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Pipe Shop	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Power house/office	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Shed 12	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Tank Farm Building	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:

Conc. - concentration	LA - Libby amphibole asbestos
CTE - central tendency exposure	OU - operable unit
ED - exposure duration	PCME - phase contrast microscopy - equivalent
EF - exposure frequency	RME - reasonable maximum exposure
EPC - exposure point concentration	s/cc - structures per cubic centimeter
ET - exposure time	TWF - time-weighting factor
HQ - hazard quotient	% - percent

TABLE 8-1
Exposure Parameters For Outdoor Air During Wood-Related Activities
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Tree Bark Disturbance Activities	Resident	Local Wood Harvesting (e.g., cutting and hauling)	RME	10	[3] a.4	15	[3] b.4	40	[5] c.5	0.0098
			CTE	5	a.2	5	[3]	20	[5] c.5	0.00082
	Outdoor Worker	Commercial Logger - Hand-felling	RME	8	[3]	24	[3] b.7	6	[6]	0.0019
			CTE	8	[3]	8	[3] b.8	6	[6]	0.00063
		Commercial Logger - skidding/mechanical processing/site restoration	RME	10	[3]	24	[3] b.7	12	[6]	0.0047
			CTE	8	[3]	8	[3] b.8	12	[6]	0.0013
		Landfill workers- wood-chipping & OU5 worker-pile disturbances	RME	4	[2] a.1	135	[2] b.1	25	[2] c.1	0.022
			CTE	4	[2] a.1	135	[2] b.1	7	[1] c.2	0.0062
		USFS Forest Maintenance	RME	8	[3]	30	[3]	10	[3]	0.0039
			CTE	4	a.2	15	b.2	5	[3] c.3	0.00049
Outdoor Air During Woodchip/Mulch Disturbance Activities	Resident	Gardening/ Landscaping	RME	2.0	[4] a.3	40	[4] b.3	52	[7] c.4	0.0068
			CTE	1.0	a.2	20	b.2	22	[7] c.4	0.00072
Indoor Air During Woodstove Ash Disturbance Activities	Resident	Woodstove Ash Removal	RME	0.25	[5] a.6	48	[5] b.6	52	[7] c.4	0.00102
			CTE	0.25	[5] a.6	24	b.2	22	[7] c.4	0.00022
Outdoor Air During Wildfires	Outdoor Worker (firefighter)	Air while fighting wildfires	RME	15	[3]	14	[3]	25	[3]	0.0086
			CTE	8	a.2	8	[3]	25	[3]	0.0026
	Resident	Ambient Air at Residence Impacted by Smoke	RME	24	a.5	5	[3] b.5	52	[7] c.4	0.0102
			CTE	24	a.5	3	[3] b.5	22	[7] c.4	0.0026

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.

[2] EPA 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.

[3] Personal communication with United States Forest Service (USFS); email dated 6/24/14.

[4] Professional judgment using site specific considerations.

[5] Interviews with residents that use wood-burning stoves for home heating (CDM Smith. 2012. *Sampling and Analysis Plan/Quality Assurance Plan: Wood-Burning Stove Ash Removal Activity-Based Sampling, Libby Asbestos Site, Operable Unit 4.* Revision 0 – November 2012).

[6] Input from local commercial logging operators in the Kootenai Valley. (CDM Smith. 2012. *Sampling and Analysis Plan/Quality Assurance Project Plan. 2012 Commercial Logging Activity-Based Sampling.* August 2012.)

[7] ATSDR 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana*. A Report to the Community. August 23, 2001.

[8] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 The default of 8 hours/day was adjusted by a factor of 0.5 assuming that a worker would not spend the entire day wood chipping.

a.2 Hours/day for CTE is assumed to be 1/2 RME value.

a.3 Hours/day performing landscaping are based on professional judgment [4].

a.4 Hours/day harvesting wood are site-specific values based on information from USFS [3]. CTE assumes 1/2 RME value.

a.5 Hours/day where smoke from a fire in OU3 reaches the community is a default value of 24 hours/day.

a.6 Hours/day cleaning woodstoves are based on interviews with residents that use wood burning stoves for heating; residents spend about 15 minutes per event.

TABLE 8-1
Exposure Parameters For Outdoor Air During Wood-Related Activities
Libby Asbestos Superfund Site

b) Exposure Frequency [EF]

b.1 Default exposure frequency estimates of 219 days/yr (CTE) or 225 days/year (RME) for outdoor workers were adjusted to account for days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (i.e., November to March) (225 days - 90 days (18 weeks for 5 days/week)=135 days).

b.2 Days/year for CTE is assumed to be 1/2 RME value.

b.3 Days/year gardening is based on professional judgment considering site-specific conditions [4] - assumes garden work will take place during warmer months mainly between May and September for 1-2 days/week (total 20 to 40 days/year).

b.4 Days/year harvesting wood are site-specific based on input from USFS [3].

b.5 Days/year where smoke from a fire in OU3 reaches the community is based on input from USFS [3].

b.6 Days/year removing ash from woodstove are site specific based on interviews with residents [5].

b.7 RME days/year adjusted to account for an area use factor of 0.1 (i.e., 10% of logging time is spent within OU3).

b.8 CTE days/year adjusted to account for an area use factor of 0.05 (i.e., 5% of logging time is spent within OU3).

c) Exposure Duration [ED]

c.1 ED (years) is recommended default for workers in EPA (2002).

c.2 ED (years) is recommended mean value for workers in EPA (2011).

c.3 ED (years) for CTE is 1/2 of the RME value.

c.4 ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

c.5 Years spent harvesting wood are site-specific based on input from with USFS [3]. CTE assumes 1/2 RME value.

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - environmental protection agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 8-2
Summary Statistics for Studies During Disturbances of Wood-Related Materials
Libby Asbestos Superfund Site

ABS Description	Wood Source*	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Achieved Sensitivity (cc^{-1})
				Mean	Maximum	
Panel A: ABS Results During Residential Wood Harvesting						
Felling trees, de-limbing, cutting, stacking firewood	Forest, near	---	---	---	---	---
	Forest, intermed.	40	13	0.0011	0.0060	0.0075
	Forest, far	22	1	0.00014	0.0030	0.011
Panel B: ABS Results During Commercial Logging Activities						
Hand-felling trees	~1 mile from mine	3	3	0.0034	0.0050	0.0012
Hooking/skidding	~1 mile from mine	5	5	0.105	0.16	0.0101
Mechanical Processing	~1 mile from mine	1	1	0.002	0.002	0.0015
Site restoration	~1 mile from mine	2	2	0.032	0.055	0.0036
Simulated milling (chipping)	~1 mile from mine	2	2	0.0068	0.0090	0.0017
Hand Felling	~4 miles from mine	3	1	0.0022	0.0065	0.0065
Skidding/Hooking	~4 miles from mine	4	1	0.00065	0.0026	0.0063
Mechanical Processing	~4 miles from mine	4	0	0	All ND	0.0064
Cutting slabs (pre-milling)	~4 miles from mine	8	0	0	All ND	0.0063
Simulated milling (chipping)	~4 miles from mine	8	0	0	All ND	0.0062
Site Restoration	~4 miles from mine	2	1	0.0040	0.0079	0.0065
Panel C: ABS Results During Wood Chipping Activities						
Chipping wood waste piles	various	6	0	0	All ND	0.0021
Panel D: ABS Results During Forest Maintenance Activities						
Road maintenance, tree thinning, forest surveying	Forest, near	---	---	---	---	---
	Forest, intermed.	60	5	0.00032	0.0064	0.012
	Forest, far	30	2	0.00020	0.0030	0.013
Panel E: ABS Results During Woodchip Disturbance Activities						
Woodchip/waste bark piles	various	16	0	0	All ND	0.0012
Digging/raking in woodchips	various	15	0	0	All ND	0.00060
Panel F: ABS Results During Woodstove Ash Disturbance Activities						
Emptying woodstove ash after burning firewood	~1 mile from mine	3	3	0.14	0.34	0.013
	Flower Creek	3	3	0.0074	0.018	0.0056
	Bear Creek	3	1	0.0029	0.0087	0.013

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
--- = no ABS data available from within two miles of the mine for this scenario
*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine.
Forest, far: greater than or equal to six miles from the mine
Flower Creek: approximately six miles from the mine
Bear Breek: approximately 10 miles from the mine

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
PCME - phase contrast micrscopy-equivalent
s/cc - structures per cubic centimeter

TABLE 8-3
Exposure Parameters For Outdoor Air During Fire-Related Activities
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Fires	Outdoor Worker (firefighter)	While fighting wildfires	RME	15	[3]	39	[4] b.1	25	[4]	0.0239
			CTE	8	a.1	17.5	[4] b.1	25	[4]	0.0057
		During prescribed understory burns	RME	3	[4]	7	[4] b.2	25	[4]	0.00086
			CTE	1.5	a.1	2	[4] b.2	25	[4]	0.00012
		During understory mop-up activities	RME	2	[4]	7	[4] b.2	25	[4]	0.00057
			CTE	1	a.1	2	[4] b.2	25	[4]	0.000082
	Outdoor Worker (USFS worker)	Generating slashpiles	RME	8	[4]	10	[4] b.3	10	[3]	0.0013
			CTE	4	a.1	5	[4] b.3	5	[3]	0.00016
		During slashpile burns	RME	4	[4]	10	[4] b.3	10	[3]	0.00065
			CTE	2	a.1	5	[4] b.3	5	[3]	0.000082
		During slashpile mop-up activities	RME	2	[4]	10	[4] b.3	10	[3]	0.00033
			CTE	1	a.1	5	[4] b.3	5	[3]	0.000041
	Resident	Ambient air at local residence impacted by wildfire smoke	RME	24	a.2	8	b.4	52	[5] c.1	0.016
			CTE	24	a.2	4	b.4	22	[5] c.1	0.0034

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA 2011. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-090/052F. September 2011.

[2] EPA 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.

[3] Personal communication with United States Forest Service (USFS); email dated 6/24/14.

[4] Personal communication with United States Forest Service (USFS); email dated 11/3/15.

[5] ATSDR 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

[6] EPA. 1989. *Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day for CTE is assumed to be 1/2 RME value.

a.2 Hours/day where smoke from a fire in OU3 reaches the community is a default value of 24 hours/day.

b) Exposure Frequency [EF]

b.1 Based on highest (RME) and average (CTE) number of 0.1-acre fires that have occurred within the NPL boundary in a single year (1986-2014); assumes each fire lasts one day (on average).

b.2 Based on highest (RME) and average (CTE) number of 0.1-acre fires that have occurred within the OU3 Study Area in a single year (1986-2014).

b.3 Assumes half of all slashpile burns within the NPL occur within the OU3 Study Area; RME is based on high-end estimate (0.5 * 20 days/year) and CTE is based on typical estimate (0.5 * 10 days/year).

b.4 Based on professional judgment. Assumes 20% of all wildfires within the NPL boundary would have smoke that reaches the nearby community. RME = 39 fires * 20% = 7.8 (rounded up to 8 days/year); CTE = 17.5 * 20% = 3.5 (rounded up to 4 days/year).

c) Exposure Duration [ED]

c.1 ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - environmental protection agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 8-4
ABS Air Summary Statistics During Fire-Related Activities
Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Exposure Area	Wood Source	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
						Mean	Maximum	
Outdoor air, during simulated burning activities	Outdoor Worker (firefighter during understory burn)	During burn (personal air)	~1 mile from mine	8	8	0.078	0.15	0.0052
		During dry mop-up	~1 mile from mine	4	4	0.75	1.5	0.072
		During wet mop-up	~1 mile from mine	4	4	0.18	0.41	0.018
	Resident (during understory burn)	During burn (200-ft monitor)	~1 mile from mine	3	1	0.00052	0.0016	0.0019
	Outdoor Worker (USFS worker during slashpile burn)	Building slashpile	~1 mile from mine	2	2	0.12	0.19	0.0055
		During burn (personal air)	~1 mile from mine	10	8	0.011	0.028	0.0039
		During dry mop-up	~1 mile from mine	2	2	0.13	0.17	0.0055
		During wet mop-up	~1 mile from mine	4	4	0.068	0.14	0.0043
	Resident (during slashpile burn)	During burn (200-ft monitor)	~1 mile from mine	8	1	0.00047	0.0038	0.0038
Outdoor air, during authetic wildfire	Resident	Downwind stations during wildfire	Souse Gulch	2	0	0	All ND	0.00070
	Outdoor Worker (firefighter)	Ground-based firefighter activities	Souse Gulch	15	2	0.00031	0.0031	0.0017
		Air-based wildfire suppression**	Souse Gulch	1	0	0	All ND	0.0024

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
**Monitor was placed in the cockpit of the responding helicopter

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
NPL - National Priority List
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 8-5
Estimated Risks from Exposure to LA During Disturbances of Wood-Related Materials
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Exposure Media	Receptor Population	Exposure/Disturbance Description*	Wood Source	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, during bark disturbances	Resident	Wood harvesting (Felling trees, de-limbing, cutting, stacking firewood)	Forest, near	---	---	---	---	---	---	---
			Forest, intermed.	0.0011	10	15	40	0.0098	**2E-06**	**0.1**
			Forest, far	0.00014	10	15	40	0.0098	**2E-07**	**0.01**
	Outdoor Worker (commercial logger)	Hand-felling trees	~1 mile from mine	0.0034	8	24	6	0.0019	**1E-06**	**0.07**
		Hooking/skidding, processing timber	~1 mile from mine	0.105	10	24	12	0.0047	**8E-05**	**5**
		Mechanical Processing	~1 mile from mine	0.002	10	24	12	0.0047	**1E-06**	**0.08**
		Site restoration	~1 mile from mine	0.032	10	24	12	0.0047	**3E-05**	**2**
		Simulated milling (chipping)	~1 mile from mine	0.0068	10	24	12	0.0047	**5E-06**	**0.4**
		Hand Felling	~4 miles from mine	0.0022	8	24	6	0.0019	**7E-07**	**0.05**
		Skidding/Hooking	~4 miles from mine	0.00065	10	24	12	0.0047	**5E-07**	**0.03**
		Mechanical Processing	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
		Cutting slabs (pre-milling)	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
		Simulated milling (chipping)	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
		Site Restoration	~4 miles from mine	0.0040	10	24	12	0.0047	**3E-06**	**0.2**
	Outdoor Worker (at landfill)	Chipping wood waste piles	various	0	4	135	25	0.022	**0E+00**	**0**
	Outdoor Worker (USFS worker)	Forest management (Road maintenance, tree thinning, forest surveying)	Forest, near	---	---	---	---	---	---	---
			Forest, intermed.	0.00032	8	30	10	0.0039	**2E-07**	**0.01**
			Forest, far	0.00020	8	30	10	0.0039	**1E-07**	**0.009**
Outdoor air, during woodchip/ mulch disturbances	Outdoor Worker (at OU5)	Woodchip/waste bark pile disturbances	various	0	4	135	25	0.022	**0E+00**	**0**
	Resident	Woodchip/mulch disturbances during gardening	various	0	2	40	52	0.0068	**0E+00**	**0**
Indoor Air, during wood-derived ash disturbances	Resident	Emptying woodstove ash after burning firewood	~1 mile from mine	0.14	0.25	48	52	0.00102	**2E-05**	**2**
			Flower Creek	0.0074	0.25	48	52	0.00102	**1E-06**	**0.08**
			Bear Breek	0.0029	0.25	48	52	0.00102	**5E-07**	**0.03**

TABLE 8-5
Estimated Risks from Exposure to LA During Disturbances of Wood-Related Materials
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Exposure Media	Receptor Population	Exposure/Disturbance Description	Wood Source	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, during bark disturbances	Resident	Wood harvesting (Felling trees, de-limbing, cutting, stacking firewood)	Forest, near	---	---	---	---	---	---	---
			Forest, intermed.	0.0011	5	5	20	0.00082	**1E-07**	**0.01**
			Forest, far	0.00014	5	5	20	0.00082	**2E-08**	**0.001**
	Outdoor Worker (commercial logger)	Hand-felling trees	~1 mile from mine	0.0034	8	8	6	0.00063	**4E-07**	**0.02**
		Hooking/skidding, processing timber	~1 mile from mine	0.105	8	8	12	0.0013	**2E-05**	**1**
		Mechanical Processing	~1 mile from mine	0.002	8	8	12	0.0013	**3E-07**	**0.02**
		Site restoration	~1 mile from mine	0.032	8	8	12	0.0013	**7E-06**	**0.4**
		Simulated milling (chipping)	~1 mile from mine	0.0068	8	8	12	0.0013	**1E-06**	**0.1**
		Hand Felling	~4 miles from mine	0.0022	8	8	6	0.0006	**2E-07**	**0.02**
		Skidding/Hooking	~4 miles from mine	0.00065	8	8	12	0.0013	**1E-07**	**0.009**
		Mechanical Processing	~4 miles from mine	0	8	8	12	0.0013	**0E+00**	**0**
		Cutting slabs (pre-milling)	~4 miles from mine	0	8	8	12	0.0013	**0E+00**	**0**
		Simulated milling (chipping)	~4 miles from mine	0	8	8	12	0.0013	**0E+00**	**0**
		Site Restoration	~4 miles from mine	0.0040	8	8	12	0.0013	**8E-07**	**0.06**
	Outdoor Worker (at landfill)	Chipping wood waste piles	various	0	4	90	25	0.015	**0E+00**	**0**
	Outdoor Worker (USFS worker)	Forest management (Road maintenance, tree thinning, forest surveying)	Forest, near	---	---	---	---	---	---	---
			Forest, intermed.	0.00032	4	15	5	0.00049	**3E-08**	**0.002**
			Forest, far	0.00020	4	15	5	0.00049	**2E-08**	**0.001**
Outdoor air, during woodchip/mulch disturbances	Outdoor Worker (at OU5)	Woodchip/waste bark pile disturbances	various	0	4	135	7	0.0062	**0E+00**	**0**
	Resident	Woodchip/mulch disturbances during gardening	various	0	1	20	22	0.00072	**0E+00**	**0**
Outdoor Air, during wood-derived ash disturbances	Resident	Emptying woodstove ash after burning firewood	~1 mile from mine	0.14	0.25	24	22	0.00022	**5E-06**	**0.3**
			Flower Creek	0.0074	0.25	24	22	0.00022	**3E-07**	**0.02**
			Bear Breek	0.0029	0.25	24	22	0.00022	**1E-07**	**0.007**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)
--- = No ABS air samples have been collected within two miles from the mine for this scenario

*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine.
Forest, far: greater than or equal to six miles from the mine
Flower Creek: approximately six miles from the mine
Bear Breek: approximately 10 miles from the mine

Notes:
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 8-6
Estimated Risks from Exposure to LA During Fire-Related Activities
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Exposure Media	Receptor Population	Exposure/Disturbance Description	Wood Source	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, during simulated burning activities	Outdoor Worker (firefighter during understory burn)	During burn (personal air)	~1 mile from mine	0.078	3	7	25	0.00086	**1E-05**	**0.7**
		During dry mop-up	~1 mile from mine	0.75	2	7	25	0.00057	**7E-05**	**5**
		During wet mop-up	~1 mile from mine	0.18	2	7	25	0.00057	**2E-05**	**1**
	Resident (during understory burn)	During burn (200-ft monitor)	~1 mile from mine	0.00052	24	8	52	0.016	**1E-06**	**0.09**
	Outdoor Worker (USFS worker during slashpile burn)	Building slashpile	~1 mile from mine	0.12	8	10	10	0.0013	**3E-05**	**2**
		During burn (personal air)	~1 mile from mine	0.011	4	10	10	0.00065	**1E-06**	**0.08**
		During dry mop-up	~1 mile from mine	0.13	2	10	10	0.00033	**7E-06**	**0.5**
		During wet mop-up	~1 mile from mine	0.068	2	10	10	0.00033	**4E-06**	**0.2**
	Resident (during slashpile burn)	During burn (200-ft monitor)	~1 mile from mine	0.00047	24	8	52	0.016	**1E-06**	**0.09**
Outdoor air, during authetic wildfire	Resident	Downwind stations during wildfire	Souse Gulch	0	24	8	52	0.016	**0E+00**	**0**
	Outdoor Worker (firefighter)	Ground-based firefighter activities	Souse Gulch	0.00031	15	39	25	0.024	**1E-06**	**0.08**
		Air-based wildfire suppression**	Souse Gulch	0	15	39	25	0.024	**0E+00**	**0**

Panel B: Risk Estimates Based on CTE Exposure Parameters

Exposure Media	Receptor Population	Exposure/Disturbance Description	Wood Source	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, during burning activities	Outdoor Worker (firefighter during understory burn)	During burn (personal air)	~1 mile from mine	0.078	3	2	25	0.00024	**3E-06**	**0.2**
		During dry mop-up	~1 mile from mine	0.75	2	2	25	0.00016	**2E-05**	**1**
		During wet mop-up	~1 mile from mine	0.18	2	2	25	0.00016	**5E-06**	**0.3**
	Resident (during understory burn)	During burn (200-ft monitor)	~1 mile from mine	0.00052	24	3	22	0.0026	**2E-07**	**0.01**
	Outdoor Worker (USFS worker during slashpile burn)	Building slashpile	~1 mile from mine	0.12	8	5	5	0.00033	**7E-06**	**0.4**
		During burn (personal air)	~1 mile from mine	0.011	4	5	5	0.00016	**3E-07**	**0.02**
		During dry mop-up	~1 mile from mine	0.13	2	5	5	0.000082	**2E-06**	**0.1**
		During wet mop-up	~1 mile from mine	0.068	2	5	5	0.000082	**9E-07**	**0.06**
	Resident (during slashpile burn)	During burn (200-ft monitor)	~1 mile from mine	0.00047	24	3	25	0.0029	**2E-07**	**0.02**
Outdoor air, during authetic wildfire	Resident	Downwind stations during wildfire	Souse Gulch	0	24	3	22	0.0026	**0E+00**	**0**
	Outdoor Worker (firefighter)	Ground-based firefighter activities	Souse Gulch	0.00031	8	8	25	0.0026	**1E-07**	**0.009**
		Air-based wildfire suppression**	Souse Gulch	0	8	8	25	0.0026	**0E+00**	**0**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)
**Monitor was placed in the cockpit of the responding helicopter

<u>**Notes:**</u>

Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 10-1

Illustration of Poisson Uncertainty

Libby Asbestos Superfund Site

Panel A: Probability of Observing a Specified Number of Structures if λ is 3.72

N Structures Observed	Probability
0	2.4%
1	9.0%
2	16.8%
3	20.8%
4	19.3%
5	14.4%
6	8.9%
7	4.7%
8	2.2%
9	0.9%
10+	0.5%

Panel B: Example Calculations of Lower and Upper Bounds on Structure Counts and Concentration

Sample	Achieved Sensitivity (cc^{-1})	N Structures Observed	Air Conc. (s/cc)	LB – UB on Count*	LB – UB on Conc.(s/cc)
A-02987	0.01	0	0	0 – 1.92	0 – 0.019
B-19880	0.005	5	0.025	2.29 – 9.83	0.011 – 0.049

*Based on 90% confidence interval (see Section 10.1.1 for equations)

Notes:

cc^{-1} – per cubic centimeter
Conc. – concentration
LB – lower bound
N – number
s/cc – structures per cubic centimeter
UB – upper bound
% - percent

TABLE 10-2
Examples of Estimated Risks Based on Upper-Bound Concentrations
Libby Asbestos Superfund Site

Panel A: During Yard Soil Disturbances at Properties in OU4

Soil Concentration[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Yards (Mowing, Raking, Digging)											
Bin A	**high intensity**	0.0040	0.0062	0.3	60	52	0.0015	1E-06	2E-06	0.07	0.1
	typical intensity	0.00011	0.0014	6.3	60	52	0.032	6E-07	8E-06	0.04	0.5
							TOTAL	**2E-06**	**9E-06**	**0.1**	**0.6**
Bin B1	**high intensity**	0.061	0.064	0.3	60	52	0.0015	2E-05	2E-05	1	1
	typical intensity	0.0024	0.0036	6.3	60	52	0.032	1E-05	2E-05	0.9	1
							TOTAL	**3E-05**	**4E-05**	**2**	**2**
Bin B2/C	**high intensity**	0.21	0.21	0.3	60	52	0.0015	5E-05	5E-05	4	4
	typical intensity	0.0080	0.0082	6.3	60	52	0.032	4E-05	4E-05	3	3
							TOTAL	**1E-04**	**1E-04**	**7**	**7**

Panel B: During Soil Disturbances in OU2

Receptor	Exposure Scenario	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor Worker	Mowing Hwy 37 ROW	0	0.018	1	5	15	0.00012	0E+00	4E-07	0	0.02
Recreational Visitor	Hiking along Kootenai River	0	0.0048	2	10	52	0.0017	0E+00	1E-06	0	0.09

Panel C: During Recreational Visitor Soil Disturbances in OU3

Exposure Scenario	Exposure Area	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Hiking	Rainy Creek	0.0093	0.011	3.6	20	52	0.006	1E-05	1E-05	0.6	0.8
	Forest, near	0.00050	0.0042	8	50	52	0.034	3E-06	2E-05	0.2	2
	Forest, intermed.	0.00065	0.0056	8	50	52	0.034	4E-06	3E-05	0.2	2
	Forest, far	0.00023	0.0052	8	50	52	0.034	1E-06	3E-05	0.09	2
ATV-riding	Forest, near	0.0014	0.0065	4	50	52	0.0170	4E-06	2E-05	0.3	1
	Forest, intermed.	0.00050	0.0062	4	50	52	0.0170	1E-06	2E-05	0.09	1
	Forest, far	0.00022	0.0060	4	50	52	0.0170	6E-07	2E-05	0.04	1
Campfire building/ burning	Forest, near	0.0024	0.0072	2	50	52	0.0085	3E-06	1E-05	0.2	0.7
	Forest, intermed.	0.0022	0.0064	2	50	52	0.0085	3E-06	9E-06	0.2	0.6
	Forest, far	0.00046	0.0060	2	50	52	0.0085	7E-07	9E-06	0.04	0.6
Driving	Forest, near	---	---	---	---	---	---	---	---	---	---
	Forest, intermed.	0	0.025	3	50	52	0.0127	3E-07	5E-05	0.02	4
	Forest, far	0	0.024	3	50	52	0.0127	0E+00	5E-05	0	3
Fishing/ boating	Kootenai River	0	0.00031	8	60	52	0.041	0E+00	2E-06	0	0.1

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[a] Non-detect samples are evaluated at zero.
[b] Non-detect samples are evaluated at the achieved sensitivity.
--- = No ABS air samples have been collected within two miles from the mine for this scenario

Notes:

ABS - activity-based sampling
ATV - all-terrain vehicle
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
ROW - right-of-way
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 10-3
Illustration of Impact of Supplemental Analysis for Several OU3 Forest ABS Scenarios
Libby Asbestos Superfund Site

			Based on Original Analysis					Based on Supplemental Analysis				
ABS Scenario	ABS Area	RME TWF	Mean Sensitivity (cc^{-1})	EPC (PCME LA s/cc)[+]		RME Non-cancer HQ		Mean Pooled Sensitivity (cc^{-1}) [c]	EPC (PCME LA s/cc)[+]		RME Non-cancer HQ	
				Mean [a]	Estimated Upper-Bound [b]	Mean [BE]	Upper-bound [UB]		Pooled Mean [a,c]	Estimated Upper-Bound [b]	Mean [BE]	Upper-bound [UB]
Hiking	ABS-02	0.034	0.0060	0	0.0060	0	**2**	0.00053	0	0.00053	0	0.2
	ABS-07	0.034	0.0060	0	0.0060	0	**2**	0.00053	0	0.00053	0	0.2
	ABS-10	0.034	0.0060	0	0.0060	0	**2**	0.00053	0	0.00053	0	0.2
Driving to and from harvest area	ABS-02	0.013	0.030	0	0.030	0	**4**	0.0027	0	0.0027	0	0.4
	ABS-07	0.013	0.036	0	0.036	0	**5**	0.0027	0	0.0027	0	0.4
	ABS-06'	0.013	0.033	0	0.033	0	**5**	0.0027	0.0009	0.0027	0.1	0.4
Cutting and hauling firewood	ABS-02	0.0098	0.0127	0	0.013	0	1	0.0025	0	0.0025	0	0.3
	ABS-07	0.0098	0.0071	0.0029	0.011	0.3	1	0.0026	0.0012	0.0041	0.1	0.4
	ABS-06'	0.0098	0.0089	0.00037	0.0089	0.04	1	0.0026	0.0002	0.0026	0.02	0.3
Cutting firelines by hand (Pulaski)	ABS-02	0.0023	0.0087	0.0076	0.013	0.2	0.3	0.0062	0.0050	0.0099	0.1	0.3
	ABS-07	0.0023	0.011	0.012	0.031	0.3	0.8	0.0062	0.012	0.027	0.3	0.7
	ABS-06'	0.0023	0.013	0	0.013	0	0.3	0.0063	0	0.0063	0	0.2

[+]Concentrations have been adjusted to account for preparation method (see Section 2.3.4)
[a] Non-detect samples are evaluated at zero.
[b] Non-detect samples are evaluated at the achieved sensitivity.
[c] "Pooled" indicates that the results for the original analysis and the supplemental analysis have been combined.

Note:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
EPC - exposure point concentration
HQ -hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 10-4
Effect of Changing the High Intensity Disturbance Frequency Assumption on Estimated Risks
Libby Asbestos Superfund Site

Panel A: High intensity disturbances account for 5% of yard disturbance time

Exposure Location (Scenario)	Soil Concentration[1]	Yard ABS Script Intensity	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4 Yards (Mowing, Raking, Digging)	Bin A	high intensity	0.0040	0.3	60	52	0.0015	**1E-06**	**0.07**
		typical intensity	0.00011	6.3	60	52	0.032	**6E-07**	**0.04**
							TOTAL	**2E-06**	**0.1**
	Bin B1	high intensity	0.061	0.3	60	52	0.0015	**2E-05**	**1**
		typical intensity	0.0024	6.3	60	52	0.032	**1E-05**	**0.9**
							TOTAL	**3E-05**	**2**
	Bin B2/C	high intensity	0.21	0.3	60	52	0.0015	**5E-05**	**4**
		typical intensity	0.0080	6.3	60	52	0.032	**4E-05**	**3**
							TOTAL	**1E-04**	**7**

Panel B: High intensity disturbances account for 20% of yard disturbance time

Exposure Location (Scenario)	Soil Concentration[1]	Yard ABS Script Intensity	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4 Yards (Mowing, Raking, Digging)	Bin A	high intensity	0.0040	1.3	60	52	0.0066	**4E-06**	**0.3**
		typical intensity	0.00011	5.3	60	52	0.027	**5E-07**	**0.03**
							TOTAL	**5E-06**	**0.3**
	Bin B1	high intensity	0.061	1.3	60	52	0.0066	**7E-05**	**4**
		typical intensity	0.0024	5.3	60	52	0.027	**1E-05**	**0.7**
							TOTAL	**8E-05**	**5**
	Bin B2/C	high intensity	0.21	1.3	60	52	0.0066	**2E-04**	**20**
		typical intensity	0.0080	5.3	60	52	0.027	**4E-05**	**2**
							TOTAL	**3E-04**	**20**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[1] PLM-VE Bin:
- A - ND
- B1 - Tr
- B2 - <1
- C - ≥ 1

Notes:
- ABS - activity-based sampling
- Conc. - concentration
- ED - exposure duration
- EF - exposure frequency
- EPC - exposure point concentration
- ET - exposure time
- HQ - hazard quotient
- LA - Libby amphibole asbestos
- OU - operable unit
- PCME - phase contrast microscopy - equivalent
- PLM-VE - polarized light microscopy - visual area estimation
- RME - reasonable maximum exposure
- s/cc - structures per cubic centimeter
- TWF - time-weighting factor
- % - percent

APPENDIX A

SCREENING LEVEL ASSESSMENT OF RISKS FROM ORAL EXPOSURE TO LIBBY AMPHIBOLE ASBESTOS

1.0 HEALTH EFFECTS OF ORAL EXPOSURE TO ASBESTOS

The U.S. Environmental Protection Agency (EPA) and Agency for Toxic Substances and Disease Registry (ATSDR) reviewed studies and reviews that have been performed to evaluate the health effects of oral exposure to asbestos. The following sections, adapted from EPA (1988) and ATSDR (2001), summarize the main findings.

1.1 Non-Cancer Effects

Studies in humans and animals indicate that ingestion of asbestos causes little or no risk of non-carcinogenic injury. Because ingested asbestos fibers are poorly absorbed, the tissue most highly exposed to ingested asbestos is the gastrointestinal tract epithelium. A few studies reported some histological or biochemical changes in gastrointestinal tract cells of rats chronically exposed to oral doses of asbestos, but, in an extensive series of lifetime dietary exposure studies in rats and Syrian hamsters, comprehensive microscopic evaluation of tissues and organs found no excess non-neoplastic lesions in the gastrointestinal epithelium or in other tissues or organs in animals exposed to daily doses as high as 500 to 830 milligrams of asbestos per kilogram body weight per day (mg/kg/day). The weight of evidence indicates that asbestos ingestion does not cause any significant non-carcinogenic effects in the gastrointestinal tract or other tissues.

1.2 Cancer Effects

A number of epidemiological studies of workers exposed to asbestos fibers in workplace air suggest that, in addition to increased risk of lung cancer and mesothelioma, workers may also have an increased risk of gastrointestinal cancers. Because the main route of exposure is inhalation, it is usually assumed that any effect of asbestos on the gastrointestinal tract is a consequence of mucociliary transport of fibers from the respiratory tract to the gastrointestinal tract. Because of these findings, a number of researchers have investigated the carcinogenic risk (especially the risk of gastrointestinal cancer) in humans and animals when exposure to asbestos occurs by the oral route.

1.2.1 Human Studies

A number of epidemiological studies have been conducted to determine if human cancer incidence is higher than expected in geographical areas where asbestos levels in drinking water are elevated (usually in the range of 1 to 300 million fibers per liter [MFL]). Most of these studies have detected increases, some of which were statistically significant, in cancer death or incidence rates at one or more tissue sites (mostly gastrointestinal) in populations exposed to elevated levels of asbestos in their drinking water. However, the magnitudes of the increases in cancer incidence are usually rather small and may be related to other risk factors such as smoking. In a review of data from eight independent epidemiological studies, it was concluded that the number of positive findings for neoplasms of the esophagus, stomach, pancreas, and prostate were unlikely to have been caused by chance alone (Marsh 1983). Similarly, Kanarek (1989) noted that there were relatively consistent findings for increased stomach and pancreatic cancer among the studies. Cantor (1997) reviewed the published studies and concluded that results from epidemiologic studies of populations exposed to high concentrations of asbestos in drinking water are inconsistent and are not adequate to evaluate cancer risk from asbestos in drinking water, although some of the results are suggestive of elevated risks for gastric, kidney, and pancreatic cancer.

1.2.2 Animal Data

Early animal studies on gastrointestinal cancer from ingested asbestos were mostly negative, although some studies yielded increases in tumor frequency that were not statistically significant. More recently, a series of large scale, lifetime feeding studies were performed by the National Toxicology Program (NTP). These studies investigated the effects of several different types of asbestos, as summarized below.

Summary of NTP Oral Exposure Studies in Animals

Asbestos Type	Animal	NTP Conclusion	Citation
Amosite	Rat	Not carcinogenic	NTP 1990b
	Syrian hamster	Did not cause a carcinogenic response	NTP 1983
Crocidolite	Rat	Did not cause a carcinogenic response	NTP 1988
Tremolite	Rat	Did not cause a carcinogenic response	NTP 1990c
Chrysotile (short-range)	Rat	No evidence of carcinogenicity	NTP 1985
	Syrian hamster	Not carcinogenic	NTP 1990a
Chrysotile (intermediate-range)	Rat	Some evidence of carcinogenicity	NTP 1985
	Syrian hamster	Not carcinogenic	NTP 1990a

As shown, of 8 studies performed, seven were negative, including all studies of amphibole asbestos (amosite, crocidolite, tremolite). The only neoplastic response that was considered to be treatment related was an increase in the frequency of benign intestinal polyps in male rats (but not female rats or Syrian hamsters) exposed to intermediate-range chrysotile fibers (65 percent [%]) of fibers were longer than 10 micrometers [μm]). This effect was not observed following exposure to short-range chrysotile fibers (98% of fibers were shorter than 10 μm). Overall, the data were interpreted as providing "some evidence" of carcinogenicity for intermediate range chrysotile fibers.

2.0 QUANTITATIVE CANCER TOXICITY FACTORS

Three basic strategies are available for estimation of the oral slope factor for asbestos.

1. Epidemiological studies of cancer risk associated with exposure to asbestos in drinking water. However, as discussed above, none of the available epidemiological studies of cancer risk in humans exposed to asbestos in drinking water are suitable for estimating quantitative dose-response relationships (EPA 1988; ATSDR 2001).

2. Extrapolation from studies of workers exposed by inhalation. Both EPA and the National Academy of Sciences sought to estimate the risk of gastrointestinal cancer after oral exposure by extrapolating dose-response data from occupational studies (EPA 1980; NAS 1983). However, these potency estimates are rather uncertain because of uncertainty both in the level of inhalation exposure and in the extent of transfer of fibers from the lung to the gastrointestinal

(GI) tract, and this method for quantification of oral risk is not considered to be reliable (EPA 1988).

3. Extrapolation from animal studies. EPA (1988) determined that the most reliable study for estimation of oral cancer risk was the data on benign intestinal polyps in male rates exposed to intermediate length chrysotile (NTP 1985). Based on the data from this study, EPA (1988) calculated an upper bound on slope (q1*) of 1.4E-13 (TEM fibers per liter [f/L])$^{-1}$. Based on this, ingestion of 2 liters per day (L/day) of drinking water containing 1.0 MFL would result in an increased cancer risk to humans of about 1.4E-07. This corresponds to an oral slope factor (oSF) of 7.0E-08 per million fibers ingested.

The carcinogenic response in male rats exposed to intermediate range chrysotile was used by EPA to derive the maximum contaminant level (MCL) for asbestos in water (EPA 1985, 1991). Because the intermediate range chrysotile was composed mainly of fibers longer than 10 μm, and because no carcinogenic response was observed in animals exposed to short range chrysotile (98% were less than 10 μm in length), EPA defined the MCL for asbestos as 7.1 million fibers longer than 10 μm per liter of water. This concentration is associated with an increased lifetime cancer risk of 1E-06.

It is important to note that the oSF derived from the intermediate range chrysotile study has not been approved for use at Superfund sites, and EPA's Integrated Risk Information System[1] (IRIS) does not identify any quantitative value for evaluation of oral exposure to asbestos. Nevertheless, this value and the associated MCL are judged to provide the most reliable basis for performing a screening level risk evaluation of oral exposures. It is considered likely that this oSF will overestimate any risks associated with oral exposure to Libby amphibole asbestos (LA), since no carcinogenic response was observed following exposure to any type of amphibole asbestos.

3.0 EXPOSURE AND RISK ASSESSMENT

There are a number of potential pathways by which individuals at the Libby Asbestos Superfund Site (Site) might be exposed to LA by the oral pathway, including the following:

- Ingestion surface water from area streams, ponds, or rivers
- Ingestion in groundwater from area wells
- Ingestion of fish caught from area streams or rivers
- Ingestion of meat from game animals harvested from the Site
- Incidental ingestion of contaminated soil or duff

The following sections provide screening level evaluations of these oral exposure pathways. In all cases, exposure concentrations are based on LA structures longer than 10 μm (designated as "LA>10").

[1] http://www.epa.gov/iris/subst/0371.htm

3.1 Exposure and Risk from Ingestion of Surface Water

LA Concentration in Surface Water

EPA has measured the concentration of LA in a number of surface water samples for streams, ponds, and rivers at the Site. **Table A-1** presents data on LA concentrations in surface water at various Site locations. As shown, LA structures are consistently observed in creeks and ponds near the former vermiculite mine (Operable Unit 3 [OU3]), including Carney Creek, Fleetwood Creek, lower Rainy Creek, and the on-site ponds and impoundments, but are rarely observed in upper Rainy Creek, the Kootenai River or its tributaries, or in reference streams/ponds. The overall mean concentration of LA>10 for surface water from the lower portion of the Rainy Creek drainage is 3.9 MFL, and is 0.01 MFL or less for the Kootenai River downstream of Rainy Creek and Kootenai River tributaries.

Surface Water Ingestion Rates

The streams and ponds of the lower Rainy Creek drainage are unlikely to be used for drinking water on a regular basis, but might occasionally be ingested by recreational visitors or workers. However, to be conservative, an intake rate of 2.5 L/day was assumed. This is the default reasonable maximum exposure (RME) drinking water intake rate used for evaluating adult residential exposures (EPA 2014).

Estimated Cancer Risk from Surface Water Ingestion

Based on an exposure concentration of 3.9 MFL (lower Rainy Creek drainage) and a conservative intake rate of 2.5 L/day, the estimated excess cancer risk is 7E-07. This indicates that risk from ingestion of LA in lower Rainy Creek surface water is of low concern. Risk from ingestion of surface water from other areas, such as the Kootenai River and its tributaries, is substantially lower (surface water concentrations of LA are more than 300 times lower than in the lower Rainy Creek drainage).

3.2 Exposure and Risk from Ingestion of Groundwater

LA Concentration in Groundwater

EPA has measured the concentration of LA in a number of existing wells in OU3. **Table A-2** presents data on LA concentrations in groundwater for wells in OU3. As shown, LA>10 is only occasionally observed, usually at concentrations of 3 MFL or lower. The mean value across all wells is 0.7 MFL. However, for screening purposes, the highest concentration detected (3.0 MFL) is used to provide a conservative estimate of potential risks from hypothetical future ingestion of groundwater.

A total of 62 groundwater samples have been collected in OU4. The majority of these samples (N = 55) have been collected from the Lincoln County Landfill as part of the semiannual groundwater monitoring activities, while the remaining seven samples were collected from private residences. No groundwater samples collected in OU4 had LA structures detected that were longer than 10 μm.

Groundwater Ingestion Rates

Under present conditions, none of the groundwater wells in OU3 are used for drinking, but it is plausible that one or more might be used for drinking in the future. As with surface water, the most likely scenario is occasional ingestion by recreational visitors or workers. However, to be conservative, the default RME adult residential intake rate of 2.5 L/day was assumed (EPA 2014).

Estimated Cancer Risk from Groundwater Ingestion

Based on an exposure concentration of 3.0 MFL and a conservative intake rate of 2.5 L/day, the estimated excess cancer risk is 5E-07. This indicates that risk from ingestion of LA in groundwater from wells in OU3 is of low concern.

3.3 Exposure and Risk from Ingestion of Fish

LA Concentration in Fish

Fish that reside in streams or rivers that are contaminated with LA may tend to take up fibers from the water or the sediment into their tissues, and ingestion of the fish might lead to exposure of area residents who catch and eat the fish. In order to investigate this possibility, EPA collected seven trout from the Mill Pond located near the mine. This site was selected because it is considered likely that tissue concentrations in fish from this location will be at the high-end of the concentration range, both because fish in the Mill Pond are relatively large (old), and because the concentration of LA in water and sediment in the Mill Pond contain higher levels of LA. Consequently, it is considered likely that tissue levels in these fish provide a conservative (high-end) estimate of what may occur in fish from other locations. These data are summarized in **Table A-3**. As indicated, the mean concentration of LA>10 in fish tissue from the Mill Pond was 4.2E+04 fibers per gram (wet weight) of tissue (f/g ww).

Fish Ingestion Rates

EPA's *Exposure Factors Handbook* (EPA 2011) provides data that may be used to estimate intake rates of fish by area residents. The recommended long-term average value for ingestion of fish caught by freshwater anglers is 5-12 grams (wet weight) per day (g ww/day), with 95% upper-bound values of 13-39 g ww/day (EPA 2011; Table 10-84). Based on this, an RME fish tissue intake rate of 39 g ww/day is assumed. Note that this is likely to be a conservative value because it assumes that 100% of all locally caught fish come from the lower Rainy Creek drainage. This is considered to be unlikely, and that only a small fraction of locally caught fish will come from this area.

Estimated Cancer Risk from Fish Ingestion

Based on an exposure concentration of 4.2E+04 f/g ww and a conservative intake rate of 39 g ww/day, the estimated excess cancer risk is 1E-07. This indicates that risk from ingestion of fish caught in the lower Rainy Creek drainage is of low concern. Risk from ingestion of fish from the Kootenai River is expected to be lower.

3.4 Exposure and Risk from Ingestion of Game

LA Concentration in Game

Game animals that reside at the Site may tend to take up fibers from environmental media into their tissues, and ingestion of the meat might lead to exposure of area residents who harvest the game animals. In order to investigate this possibility, EPA harvested a deer from near the mine area in OU3 and analyzed a number of tissue samples from this animal. As shown in **Table A-4**, no LA structures (of any size) were detected in any samples of muscle or organ tissue.

Game Ingestion Rates

EPA's *Exposure Factors Handbook* (EPA 2011) provides data that may be used to estimate intake rates of game by area residents. The recommended 95th percentile of game ingestion by people who hunt is 2.9 grams of tissue (wet weight) per gram of body weight per day (EPA 2011; Table 13-41). Assuming a default adult body weight of 80 kilograms (EPA 2014), this is equivalent to an average daily intake of about 232 g ww/day. Assuming a typical meal includes about 0.75 pounds of game, this equates to an average of about five meals of game per week for a lifetime.

Estimated Cancer Risk from Game Ingestion

Because no LA was detected in any sample of deer meet, the best estimate of excess cancer risk is zero. If it were conservatively assumed that the average concentration of LA fibers was just below the mean achieved analytical sensitivity, the upper-bound LA>10 concentration estimate would be 8.4E+03 f/g ww, which would correspond to an excess cancer risk of 1E-07. Based on this, it is concluded that risk from ingestion of game harvested in OU3 is of low concern. Risk from ingestion of game harvested from outside OU3 is expected to be even lower.

3.5 Exposure and Risk from Ingestion of Soil

LA Concentration in Soil

At the Site, soil samples are usually analyzed for LA using polarized light microscopy (PLM), and results are reported as mass percent (%). As illustrated in **Figure A-1**, LA concentrations greater than 1% in soil and waste materials have been observed within the mined area, but outside the immediate mine areas the maximum observed value is Bin B2 (interpreted as an LA concentration between 0.2% and 1%), and many values are Bin B1 (interpreted as an LA concentration less than 0.2%) or Bin A (non-detect). Outside of OU3, soil concentrations are generally less than 1% (as this level has been used as a trigger for conducting soil removal actions [EPA 2003]). For the purposes of performing a screening level evaluation of soil ingestion exposures, a conservative mean soil exposure concentration of 1% is assumed.

Because risk is calculated from an estimate of ingested LA>10 fibers, it is necessary to convert a concentration of 1% in soil to units of LA>10 fibers per gram of soil (f/g). The first step is to convert soil concentrations from mass percent to total[2] LA f/g, using the empiric relationship described by Januch *et al.* (2013):

Csoil (as f/g) = Csoil (as mass percent) · 3.6E+07

Thus, a concentration of 1% LA in soil is estimated to correspond to 3.7E+07 total LA f/g.

The second step is to estimate the fraction of the total LA fibers that are longer than 10 µm. The most reliable estimate of this fraction is derived from transmission electron microscopy (TEM) analyses of duff samples from OU3. For these duff samples, approximately 5% of all the LA structures recorded have a length greater than 10 µm (see **Figure A-2**). To be conservative, it was assumed that 10% of LA structures are longer than 10 µm. Based on this, the soil exposure concentration for LA>10 is 3.7E+06 f/g.

Soil Ingestion Rate

Most people do not intentionally ingest soil, but incidental intake may occur, mainly *via* hand to mouth contact. However, no site-specific data are available on the rate of soil ingestion that may occur by individuals at the Site. Default soil intake rate values used by EPA in human health risk assessments are as follows:

Default Soil Intake Rates Used in Human Health Risk Assessment

Exposed Population	Default RME Soil Intake Rate (mg/day)	
	Value	Source
Resident, child	200	EPA (2014)
Resident, adult	100	EPA (2014)
Outdoor worker	100	EPA (2014)
Construction worker	330	EPA (2002)

RME = reasonable maximum exposure
mg/day = milligrams of soil per day

The maximum default soil intake rate – 330 milligrams of soil per day (mg/day), based on a construction worker exposure scenario – is assumed. Based on an assumed exposure frequency of 50 days per year and an exposure duration of 50 years, this corresponds to a lifetime average intake rate of:

$$\text{Lifetime average soil intake rate} = 330 \text{ mg/day} \cdot (50 \text{ days}/365 \text{ days}) \cdot (50 \text{ years} /70 \text{ years})$$
$$= 32 \text{ mg/day}$$

Risk from Ingestion of Soil

Based on an estimated lifetime average soil intake rate of 32 mg/day and an estimated soil concentration of 3.7E+06 LA>10 f/g, the estimated excess cancer risk is 2E-08. Based on this, it is concluded that risk from ingestion of soils with an LA concentration of 1% is of low concern; risk from ingestion of soils with LA concentrations less than 1% would be even lower.

[2] "Total" is defined as structures longer than 0.5 µm with an aspect ratio (length:width) of 3:1 or greater.

3.6 Exposure and Risk from Ingestion of Duff

LA Concentration in Duff

EPA has measured the concentration of LA in duff (forest litter) from numerous locations in OU3 and along the National Priorities List (NPL) boundary. As shown in **Figure A-3**, LA concentrations in duff near the mine may range as high as about 3E+09 f/g (total LA), but rapidly decline as a function of distance from the mine. To be conservative, a value of 3E+09 total LA fibers per gram (dry weight) of duff (f/g dw) is assumed, even though actual exposures in locations further from the mine would be much lower. As noted above, to be conservative, it was assumed that 10% of LA structures are longer than 10 µm (see **Figure A-2**). Based on this, the conservative estimate of LA>10 in duff is 3E+08 f/g dw.

Duff Ingestion Rate

Similar to soil, it is assumed that most people do not intentionally ingest duff, but that incidental ingestion may occur. However, no data are available on the ingestion rate of duff. In the absence of data, the duff intake rate is assumed to be equal to that for soil (32 mg/day).

Risk from Ingestion of Duff

Based on an estimated lifetime average duff intake rate of 32 mg/day and an estimated duff concentration of 3E+08 LA>10 f/g dw, the estimated excess cancer risk is 7E-07. Based on this, it is concluded that risk from ingestion of duff near the mine is of low concern; risk from ingestion of duff in locations further from the mine would be even lower.

4.0 SUMMARY

Based on conservative estimates of oral cancer potency and human exposure, screening level estimates of excess cancer risks from oral exposure to LA in surface water, groundwater, fish, game, soil, and duff are all below 1E-06 (see below), which is generally considered to be sufficiently low to be insignificant.

Exposure Scenario	RME Excess Cancer Risk
Ingestion of surface water	7E-07
Ingestion of groundwater	5E-07
Ingestion of fish	1E-07
Ingestion of game	1E-07
Ingestion of soil	2E-08
Ingestion of duff	7E-07

RME = reasonable maximum exposure

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Table A.1
LA Concentrations in Surface Water

Location	Sampling Station	LA Water Concentration (LA>10 MFL)	
		Mean by Station	Overall Mean
Upper Rainy Creek	URC-1 URC-1A URC-2	0 (non-detect) 0.0038 0.39	0.24
Lower Rainy Creek	LRC-1 LRC-2 LRC-3 LRC-4 LRC-5 LRC-6	1.1 1.8 0.79 3.4 4.3 7.3	3.9
Carney Creek/Pond	CC-1 CC-2 CC-POND	0.26 2.7 1.8	2.2
Fleetwood Creek/Pond	FC-1 FC-2 FC-POND	0.34 0.45 17	10
Tailings Pond	TP TP-OVERFLOW TP-TOE1 TP-TOE2 UTP	6.7 0.19 0.35 0.40 1.9	4.5
Mill Pond	MP	1.2	1.2
Kootenai River	Upstream of Rainy Creek Downstream of Rainy Creek	0.0085 0.0062	0.0066
Kootenai River tributaries	Granite Creek Libby Creek Flower Creek Pipe Creek Fisher River Callahan Creek	0.01 0.01 0 (non-detect) 0 (non-detect) 0 (non-detect) 0 (non-detect)	0.0036
OU3 Reference Creeks/Ponds+	Bobtail Creek tributary Noisy Creek Banana Lake Tepee Pond 1 Bobtail Pond	0 (non-detect) 0.0040 0.022 0 (non-detect) 0 (non-detect)	0.0048

+ These creeks and ponds have been used as reference locations in the ecological assessments conducted for OU3
MFL = million fibers per liter
LA>10 = Libby amphibole asbestos fibers longer than 10 µm

Table A.2
LA Concentrations in Groundwater

Well ID	Sampling Event	Achieved Analytical Sensitivity (1/L)	LA Water Concentration (LA>10 MFL)
Well A	Round 1	2.5E+06	2.5
	Round 2	8.0E+05	0 (non-detect)
	Round 3	5.0E+04	0 (non-detect)
Well C	Round 1	5.0E+04	0 (non-detect)
	Round 2	5.0E+04	0 (non-detect)
	Round 3	5.0E+04	0 (non-detect)
Well D	Round 1	8.0E+05	0 (non-detect)
	Round 2	4.0E+05	0 (non-detect)
	Round 3	5.0E+04	0 (non-detect)
Well E	Round 1	1.0E+06	2.0
	Round 2	1.0E+06	3.0
	Round 3	5.0E+04	0.15
Well H	Round 1	1.3E+06	2.7
	Round 2	--	--
	Round 3	2.0E+05	0.20

MFL = million fibers per liter
LA>10 = Libby amphibole asbestos fibers longer than 10 μm
1/L = per liter
-- = not available

Table A.3
LA Concentrations in Fish Tissue

Sample ID	Species	Length (inches)	Weight (grams)	LA Tissue Concentration (LA>10 f/g ww)
MP-Fish-1	Rainbow Trout	9.6	140	3.5E+04
MP-Fish-2	Cutbow Trout	11.4	280	0 (non-detect)
MP-Fish-3	Cutthroat Trout	14.6	540	2.3E+04
MP-Fish-4	Cutbow Trout	14.6	560	3.5E+04
MP-Fish-5	Rainbow Trout	14.2	550	1.9E+05
MP-Fish-6	Cutbow Trout	13.0	450	1.2E+04
MP-Fish-7	Cutbow Trout	15.2	595	0 (non-detect)
	Mean	13.2	445	**4.2E+04**

f/g ww = fibers per gram of tissue (wet weight)
LA>10 = Libby amphibole asbestos fibers longer than 10 µm

Table A.4
LA Concentrations in Deer Tissue

Sample Description	Achieved Analytical Sensitivity (1/g ww)	LA Tissue Concentration (LA>10 f/g ww)
Heart	9.4E+03	0 (non-detect)
Kidney, Sample #1	2.5E+03	0 (non-detect)
Kidney, Sample #2	9.4E+03	0 (non-detect)
Inside Shoulder Muscle	9.4E+03	0 (non-detect)
Diaphragm, Sample #2	9.4E+03	0 (non-detect)
Diaphragm, Sample #1	9.4E+03	0 (non-detect)
Backstrap Muscle, Sample #1	9.4E+03	0 (non-detect)
Backstrap Muscle, Sample #2	9.4E+03	0 (non-detect)
Lung, Sample #1	2.5E+03	0 (non-detect)
Lung, Sample #2	2.5E+03	0 (non-detect)
Liver, Sample #1	9.4E+03	0 (non-detect)
Liver, Sample #2	1.9E+04	0 (non-detect)
Mean	**8.4E+03**	**0 (non-detect)**

f/g ww = fibers per gram of tissue (wet weight)
1/g ww = per gram of tissue (wet weight)
LA>10 = Libby amphibole asbestos fibers longer than 10 µm

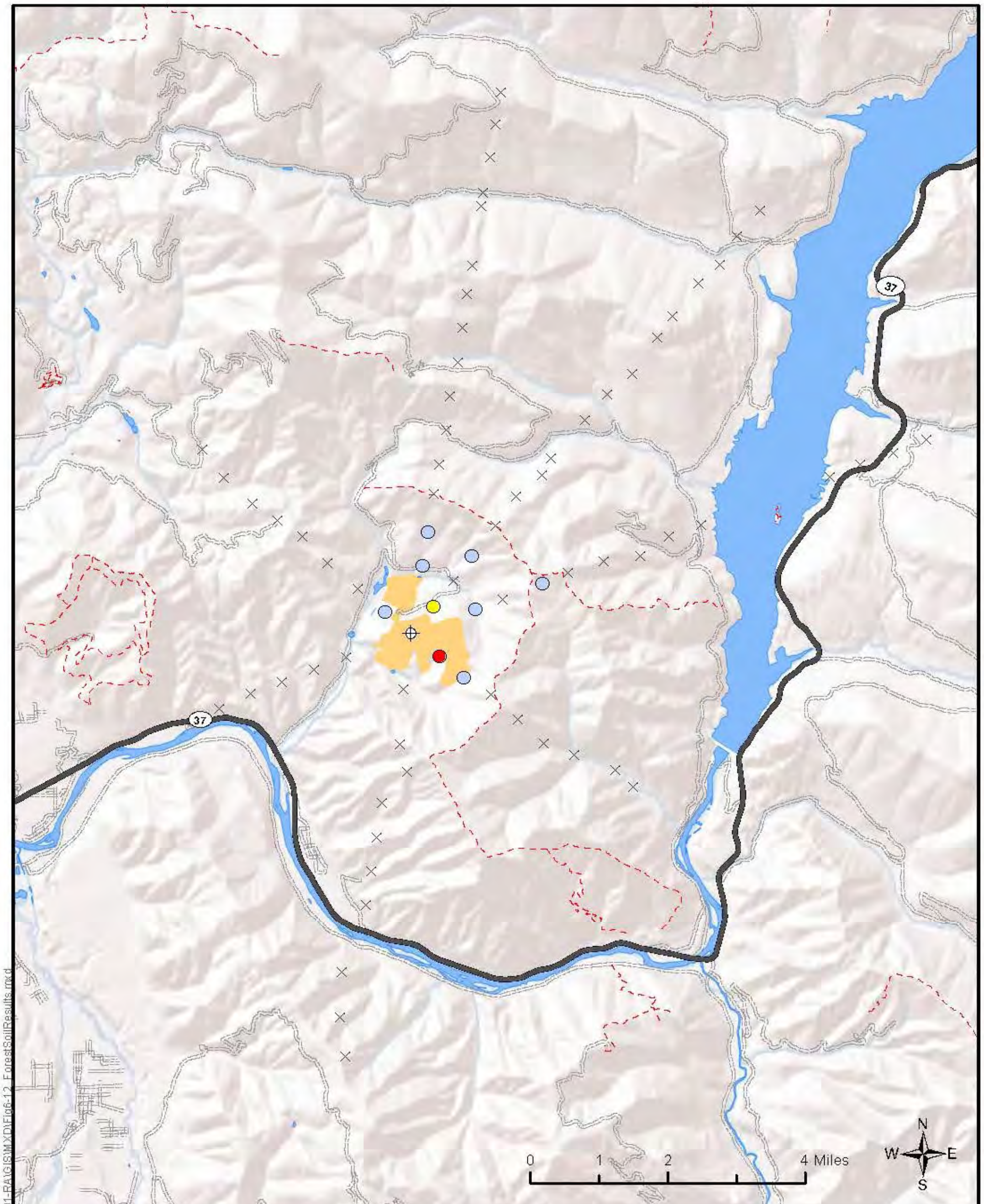
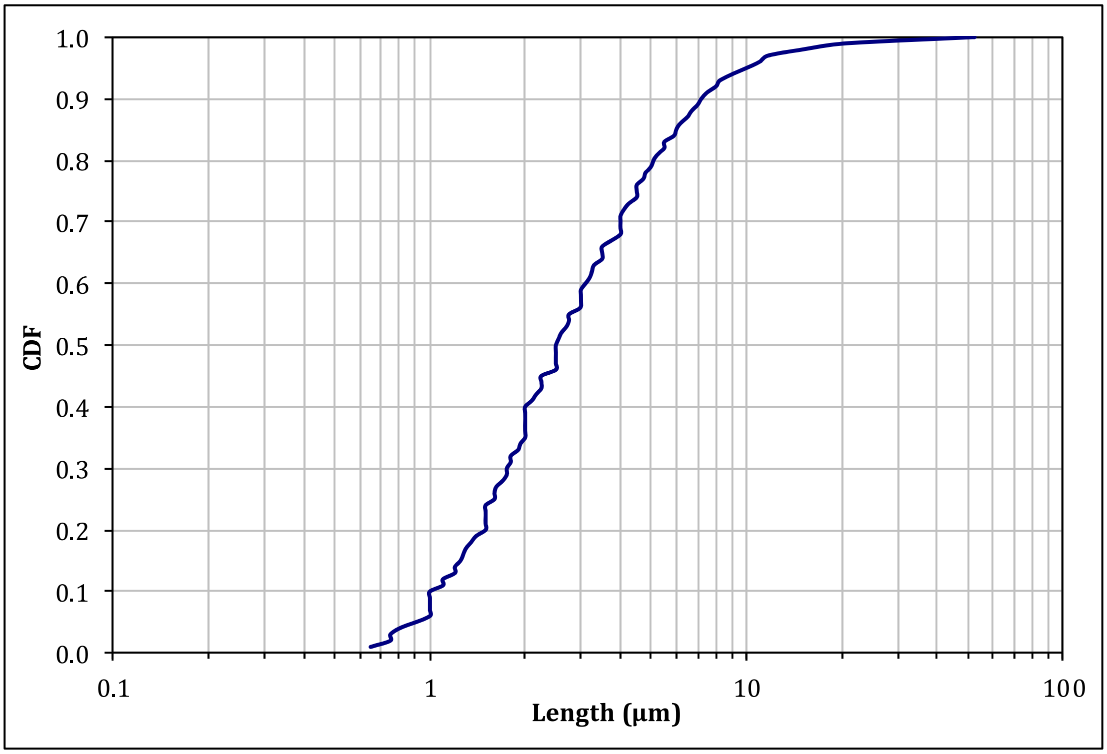


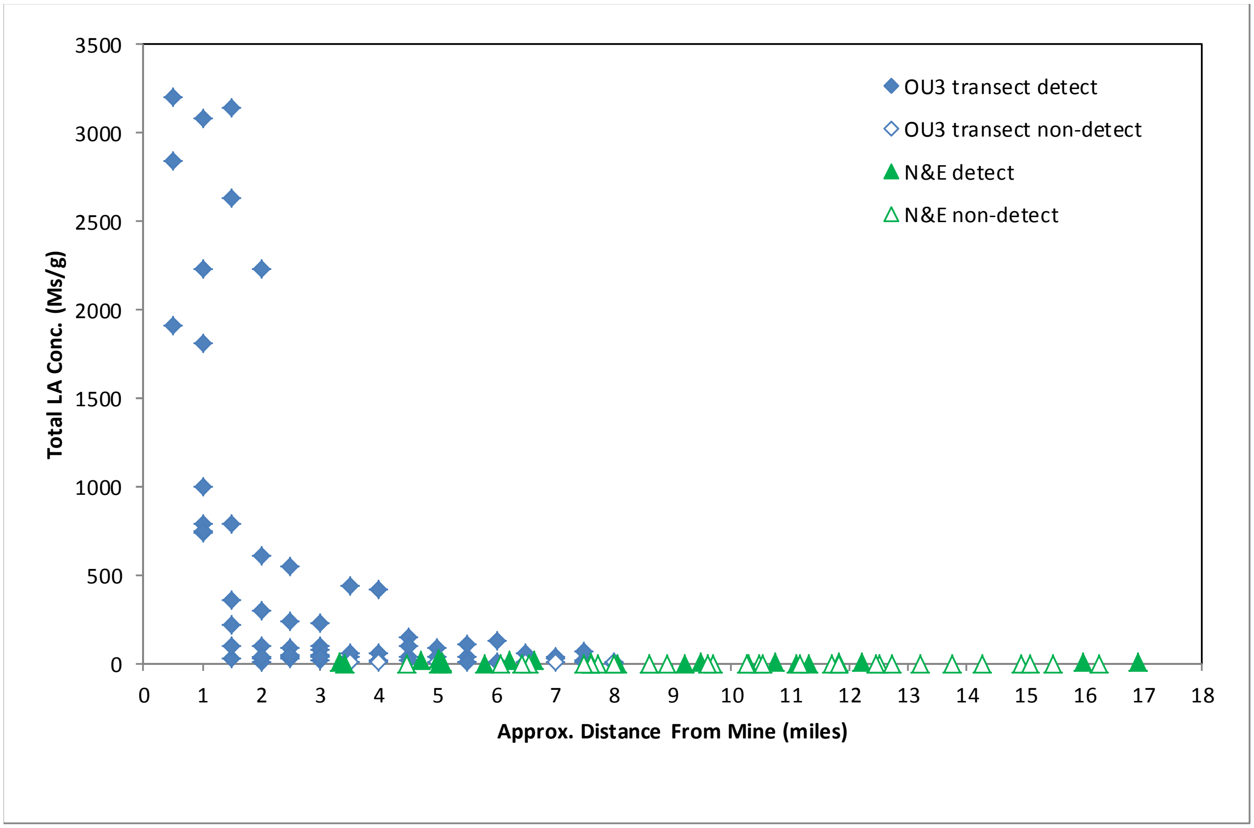
Figure A-1
Asbestos Concentrations in Forest Soil, Phase I

Figure A.2
Size Distribution of LA Structures Observed in Duff Samples from OU3



Graph is based on 1,547 total LA structures recorded for duff samples collected in OU3.

Figure A.3
Duff Concentrations as a Function of Distance from the Mine



LA = Libby amphibole
Ms/g = million structures per gram of duff
N&E = Nature & Extent Forest Study
OU3 = Operable Unit 3 Phase I Study

APPENDIX B

BASIC CONCEPTS OF ASBESTOS SAMPLING, ANALYSIS, AND DATA REDUCTION FOR RISK ASSESSMENT PURPOSES

1.0 INTRODUCTION

In many ways, the issues associated with sampling and analysis of asbestos in air are the same as for other analytes in other media. However, there are a number of issues that are unique to asbestos, and understanding these issues is key to proper use and interpretation of data for site characterization and risk assessment at asbestos-contaminated sites. This appendix provides basic information that explains how to interpret and utilize data on asbestos concentrations in air that are collected during site investigations.

2.0 BASICS OF ASBESTOS AIR SAMPLING AND ANALYSIS

The concentration of asbestos in air is usually estimated by drawing a known volume of air through a filter and counting the number of asbestos structures[1] on the filter using some appropriate microscopic technique. The concentration is then calculated as follows:

$$C = N_t / V_t \qquad \textbf{[Eqn. 1]}$$

where:

- C = Concentration of asbestos in the air drawn through the filter (structures per cubic centimeter, s/cc)
- N_t = Total number of asbestos structures on filter (structures, s)
- V_t = Total volume of air drawn through filter (cubic centimeter, cc)

Counting structures on the filter may be achieved using several different types of microscope, but the U.S. Environmental Protection Agency (EPA) generally recommends using transmission electron microscopy (TEM) because this technique has the ability to clearly distinguish asbestos from non-asbestos structures, and to classify different types of asbestos.

In air sampling for asbestos, the filter that is used is usually about 25-millimeters (mm) in diameter, and has an effective filter area (the area of filter through which air can pass) of about 360 to 385 square millimeters (mm^2), depending on the filter device. The filter is usually made of mixed cellulose ester (MCE) and can have effective pore sizes ranging from 0.2 to 0.8 micrometers (μm). In most cases, samples of air are collected using pore sizes of 0.45 or 0.8 μm to avoid excess backpressure on the filter.

After air is drawn through the filter, a wedge is cut from the filter and this is placed on a glass slide. This is referred to as "direct" preparation. In some cases, the filter may be too heavily loaded with particulate matter to allow a reliable "direct" examination of the filter. In such cases, the filter may be evaluated

[1] The basic physical unit of asbestos is a fiber. However, in some samples, fibers may occur in complex structures classified as bundles, clusters, or matrix particles. International Organization of Standardization (ISO) method 10312 provides rules for quantifying the contribution of these complex structures to concentration estimates. For simplicity, the term "structure" is used here to include both individual fibers as well as the more complex structures.

using an “indirect” preparation technique, where the material on the original (primary) filter is suspended in water, and a fraction of the water suspension is filtered through a new (secondary) filter.

The wedge of filter (either primary or secondary) is collapsed by exposure to a solvent (e.g., acetone), and the surface of the collapsed filter is etched to help expose the asbestos structures. This collapsed and etched filter is then carbon-coated, and several pieces of the carbon-coated material are transferred onto small copper grids. Each grid is about 3-mm in size (either round or square), and contains a very fine copper mesh in the center. The copper grid bars (usually about 20 μm wide) are opaque, but the areas between the grid bars (the grid openings [GOs]) are transparent. The size of each GO is usually about 0.1-mm x 0.1-mm, corresponding to an area of about 0.01 mm^2 (depending on manufacturer). During analysis, a number of GOs (selected at random) are examined in the TEM instrument, and the number of structures observed in each GO is recorded.

The raw data from each analysis consists of the number of asbestos structures observed and the number of GOs examined. From these data, the concentration of asbestos in the sample is calculated as follows:

$$C = N_{obs} \cdot EFA / (GOx \cdot Ago \cdot V_t \cdot 1000 \cdot F) \qquad \textbf{[Eqn. 2]}$$

where:

C	=	Asbestos concentration in air (s/cc)
N_{obs}	=	Number of structures observed in the analysis of the grid openings
EFA	=	Effective filter area (mm^2)
GOx	=	Number of grid openings examined
Ago	=	Area of one grid opening (mm^2)
V_t	=	Total volume of air drawn through the filter (liters [L])
1000	=	Conversion factor from L to cc
F	=	Fraction of the material on the primary filter applied to the secondary filter (if an indirect preparation was used). If a direct preparation was used, F = 1.0.

For convenience, Equation 2 is often written as:

$$C = N_{obs} \cdot S \qquad \textbf{[Eqn. 3]}$$

where S = analytical sensitivity, which has units of 1/cc (cc^{-1}). The value of S is given by:

$$S = EFA / (GOx \cdot Ago \cdot V_t \cdot 1000 \cdot F) \qquad \textbf{[Eqn. 4]}$$

Note that S is the inverse of the volume of air that passed through the area of filter analyzed:

$$S = 1/V_a$$

$$V_a = 1/S$$

where:

V_a = Volume of air that passed through the area of filter analyzed (cc)
$= V_t \cdot 1000 \cdot (GOx \cdot Ago \cdot F / EFA)$

Consequently, we may also express concentration as follows:

$$C = N_{obs} / V_a \qquad \textbf{[Eqn. 5]}$$

3.0 POISSON STATISTICS

If it were possible to actually examine the entire filter under the microscope, it would be possible to count exactly the total number of structures present on the filter. Hence, the true concentration in the air passed through the filter would be known with certainty, and there would be no need to consider any type of statistics. However, due to time and cost constraints, in a typical TEM analysis, only a tiny fraction of the filter is actually examined. For example, if a total of 50 GOs were examined, this would usually correspond to an area of about 0.5 mm^2, which is only a little more than 0.1 percent (%) of the total filter area.

This means that the number of structures that are observed during any specific analysis of a filter is a random sample of the whole population of all structures on the filter, and the sample observed in any one analysis may or may not be a good representation of the whole. This means we have to consider the *statistical uncertainty* in the results for that sample.

Perhaps the best way to understand the problem is to consider an example. Assume we draw a volume of 200 L (200,000 cc) of air through a filter. Assume the true concentration of asbestos in the air is 0.0030 s/cc. Based on these assumptions, the total number of structures on the filter is:

$$N_t = 0.0030 \text{ s/cc} \cdot 200{,}000 \text{ cc} = 600 \text{ structures}$$

Assuming an EFA of 360 mm^2, the structure loading on the filter is:

$$\text{Loading} = 600 \text{ structures} / 360 \text{ mm}^2 = 1.67 \text{ s/mm}^2$$

Assume we analyze a total of 25 GOs, each with an area of 0.01 mm^2. Under these conditions, the expected count (often indicated by λ, the Greek letter lambda) of asbestos structures is:

$$\lambda = (25 \text{ GO}) \cdot (0.01 \text{ mm}^2/\text{ GO}) \cdot (1.67 \text{ s/mm}^2) = 0.417 \text{ structures}$$

That is, if we analyze this filter several times by counting 25 GOs each time, on average we would expect to see 0.417 structures. However, it is obvious that in any one specific analysis we will never see 0.417 structures. Rather, we will see some integer number (0, 1, 2, 3, etc.). The relative probability of seeing any specified count "x" is given by the Poisson distribution:

Probability of seeing a count of "x" = Poisson (x, λ)

The following table gives the Poisson distribution for this particular example (λ = 0.417 structures):

Count	Probability
0	65.9%
1	27.5%
2	5.7%
3	0.8%
4	0.1%
5	0.01%

Thus, if we count 25 GOs selected at random, there is a 65.9% chance we will see zero structures, a 27.5% chance we will see one structure, a 5.7% chance we will see two structures, and less than a 1% chance we will see three or more structures.

Let's say that in our analysis of this sample we saw 1 structure in 25 GOs. Based on this, we would estimate the concentration to be:

$C = N_{obs} \cdot S$
$N_{obs} = 1$
$S = 360\ mm^2 / (25\ GO \cdot 0.01\ mm^2/GO \cdot 200\ L \cdot 1{,}000\ cc/L \cdot 1.0) = 0.0072\ (cc)^{-1}$
$C = 0.0072$ s/cc

Note that this value is substantially higher than the true concentration (0.0030 s/cc). Likewise, if we had seen a count of zero (a 66.2% chance), we would have said the concentration is zero (substantially lower than the true value). Based on this, it is clear that a measured (observed) estimate of concentration is unlikely to be identical with "truth", and the true concentration might be either higher or lower than our estimate. The following section discusses how to quantify the uncertainty around any particular concentration estimate.

4.0 CHARACTERIZING UNCERTAINTY IN INDIVIDUAL SAMPLES

There are a number of different statistical methods for estimating the confidence interval around a Poisson count. For example, the International Organization of Standardization (ISO) Method 10312:1995(E) (ISO 1995) calculates the bounds as follows:

5% Lower Bound on Count = $0.5 \cdot \text{CHISQ.INV}(0.05, 2 \cdot N_{obs})$
95% Upper Bound on Count = $0.5 \cdot \text{CHISQ.INV}(0.95, 2 \cdot N_{obs} + 2)$

where CHISQ.INV is the inverse chi-squared distribution function. Because this method tends to overestimate the confidence interval for small values of N_{obs}, EPA has selected the method recommended by Box and Tiao (1973) for use at the Libby Asbestos Superfund Site:

$$5\%\ \text{Lower Bound on Count} = 0.5 \cdot \text{CHISQ.INV}(0.05,\ 2 \cdot N_{obs} + 1) \qquad \textbf{[Eqn. 6]}$$
$$95\%\ \text{Upper Bound on Count} = 0.5 \cdot \text{CHISQ.INV}(0.95,\ 2 \cdot N_{obs} + 1) \qquad \textbf{[Eqn. 7]}$$

Table 1 shows the lower and upper bounds for a range of observed count values (N_{obs}), and **Figure 1** plots the ratio of the 5^{th} and 95^{th} uncertainty bounds to N_{obs} as a function of N_{obs}. As shown, relative uncertainty (lower or upper bound divided by N_{obs}) is highest for samples with small counts, and decreases as count increases.

In the example above (N_{obs} = 1 structure), the bounds on count based on Box and Tiao are:

5% Lower Bound on Count = 0.176 structures
95% Upper Bound on Count = 3.907 structures

Multiplying the bounds on count by the sensitivity (0.0072 cc^{-1}) yields the bounds on concentration:

5% Lower Bound on Concentration = 0.176 · 0.0072 = 0.0013 s/cc
95% Upper Bound on Concentration = 3.907 · 0.0072 = 0.0281 s/cc

That is, there is less than a 5% chance that the true concentration is lower than 0.0013 s/cc, and there is less than a 5% chance that the true concentration is higher than 0.0281 s/cc.

5.0 DETECT vs NON-DETECT

In general, a sample is ranked as a detect if there is high confidence that the analyte of concern is present in the sample. In the case of asbestos, this means that there must be high confidence that any structures observed during the analysis actually arose from the sample and were not attributable to "background".

Begin by considering the case where unused filters (i.e., blank filters) have no asbestos structures on them. That is, no matter how many GOs we count for blank filters, we will never see even one asbestos structure. In this case, if we see one structure in a field sample (a filter that has had air passed through it), the structure must be derived from the air, and the sample is a detect.

What if blank filters have a non-zero number of structures on them? This situation is addressed in ASTM 6620-06, *Standard Practice for Asbestos Detection Limit Based on Counts* (ASTM 2010). In this approach, a sample is declared to be a detect if the number of structures observed in the analysis of the field sample is higher than the high end of the number of structures that might be observed in any random examination of an equal area of a blank filter. This determination is performed as follows:

<u>Step 1.</u> Assemble the results for all relevant blank samples and compute the value of L_0, which is the average number of countable asbestos structures observed per mm^2 on filter blanks:

$$L_b = N_b / A_b \qquad \textbf{[Eqn. 8]}$$

where:

L_b = Background loading of countable structures (s/mm^2)
N_b = Total number of countable structures observed in the analysis of filter blanks (s)
A_b = Total area (mm^2) of filter blanks evaluated (=∑ GOs counted · Ago)

<u>Step 2.</u> Compute λ_0, which is the average number (count) of background asbestos structures that would be expected during examination of an area A_s (mm^2) from a field sample:

$$\lambda_0 = L_b \cdot A_s \quad \textbf{[Eqn. 9]}$$

Note that the value of A_s (and hence the expected count λ_0) may vary between field samples, depending on the total number of GOs counted and the area of the GOs (A_s = GOs counted · Ago).

<u>Step 3.</u> Based on the average count (λ_0) of background structures from Step 2, use the Poisson distribution to find x0, which is the count of background structures that would be observed in no more than 5% of a set of random observations of area A_s in field blanks. **Table 2** (taken from ASTM 6620-06) shows the value of x0 for average background counts (λ_0) ranging from zero up to about 2.6 structures.

<u>Step 4:</u> Compare the observed number (N_{obs}) of structures from area A_s of the field sample to x0. If N_{obs} > x0, conclude that the number of structures observed in the field sample is higher than background and rank the sample as a detect. If $N_{obs} \leq$ x0, then conclude that the observed number of structures in the field sample could be attributable to background, and rank the sample as a non-detect. Note that if the average expected count of background structures (λ_0) is small (≤ 0.05), then x0 is zero and any field sample with an observed count of one or more structures should be ranked as a detect.

EXAMPLE:

<u>Step 1:</u> Assume that we have analyzed 25 GOs in each of 100 filter blanks, and we have observed a total of 4 structures. Based on this:

N_b = 4 structures
A_b = 25 GO/blank · 100 blanks · 0.01 mm^2/GO = 25 mm^2
$L_b = N_b / A_b$ = 4 structures / 25 mm^2 = 0.16 s/mm^2

<u>Step 2:</u> Assume we have collected a field sample for which we have analyzed a total of 50 GOs. Based on this,

A_s = 50 GOs · 0.01 mm^2/GO = 0.5 mm^2
$\lambda_0 = L_b \cdot A_s$ = 0.16 s/mm^2 · 0.5 mm^2 = 0.08 structures

<u>Steps 3 and 4:</u> Using **Table 2**, we can see that x0 = 1 for all values of λ_0 between 0.05 and 0.35. Because our value of λ_0 is in this range, we conclude that there is less than a 5% chance we will

see more than 1 background structure in any random analysis of 50 GOs. Therefore, if we see two or more structures in our analysis of this field sample, we will rank the sample as a detect.

In the past, the occurrence of countable structures on blank filters was high enough that it could not be ignored. However, modern filters are manufactured in a way such that asbestos structures are quite rare when analysis is by TEM, since TEM can distinguish asbestos from other types of structures that might be present. Based on this, it is likely the value of L_b will be zero or very close to zero in most cases. For example, at the Libby Superfund site, more than 7,600 TEM analyses of blank filters have been performed (CDM Smith 2012, 2014), with the following results:

N_b = 12 s
A_b = 1,149 mm^2
L_b = 0.010 s/mm^2
x0 = 0

In this case (x0 = 0), any field sample with one or more observed asbestos structures is a detect, and the calculation of concentration can simply ignore any corrections for background contribution.

6.0 DETECTION LIMIT

In analytical chemistry, the detection limit (DL), also referred to as the limit of detection (LOD), is usually defined as a concentration that can be recognized with confidence to be greater than zero. This approach is based on the fact that most analytical instruments have a non-zero signal when a sample blank is analyzed, and that this non-zero signal is variable. The DL is a concentration that consistently generates a signal that is higher than the high-end of the range of signals generated by blank samples. In asbestos analysis, the "signal" that is measured is not electronic, but is a count of asbestos structures observed during a visual examination of a filter through a microscope.

Let's begin by considering an example. Assume we pass 200 L (200,000 cc) of air through a clean filter (background loading = 0), and we analyze 10 GOs (a total of 0.10 mm^2 of filter). The red line in **Figure 2** shows the probability of observing one or more structures (i.e., of detecting the presence of asbestos) in our analysis as a function of the concentration in the air. As seen, we stand very little chance of detecting even one structure if the concentration is lower than about 0.001 s/cc, while we are nearly certain we will detect one or more structures if the concentration is 0.1 s/cc or higher. In the range between 0.001 and 0.1 s/cc (a 100-fold range), the probability of detection increases from low to high as concentration increases.

So, what is the "detection limit" in this example? To answer that, we have to specify some probability of detecting asbestos if it is present. For example, if we decide to define the detection limit as a concentration that will be detected 95% of the time, the detection limit in this case would be about 0.054 s/cc. Note that identifying 0.054 s/cc as the "detection limit" does not mean we cannot detect a sample whose concentration is lower than 0.054 s/cc. Indeed, we can detect samples up to 50-fold lower, although the probability of detection decreases as concentration decreases below the detection limit.

Now, let's re-analyze the sample, except this time we count 100 GOs rather than 10, as shown by the blue line in **Figure 2**. By increasing the number of GOs analyzed by a factor of 10, the detection frequency curve shifts left by a factor of 10. Now we can nearly always detect a concentration of 0.01 s/cc, and we may be able to occasionally detect samples as low as 0.0001 s/cc. The detection limit (95% detection probability) for this analytical strategy is 0.0054 s/cc (10-fold lower than before). This emphasizes the key point: *there is no inherent detection limit in asbestos analysis*. We can (at least in concept) achieve any detection limit of our choice, simply by analyzing more and more GOs (more and more volume).

Once a probability value is chosen to define the DL, and assuming the background loading on the filter is zero or negligible, the basic equation for calculating the DL is as follows:

$$DL = -S \cdot \ln(1 - \text{probability}) \qquad \textbf{[Eqn. 10]}$$

The following table shows the results for a series of alternative values of probability of detection:

Probability of Detection	DL/S
0.95	2.996
0.90	2.303
0.80	1.609
0.70	1.204
0.63	1.000
0.50	0.693

The actual DL of a sample is then computed by multiplying the appropriate value of DL/S in the table above by the sample-specific value of S (which in turn depends on volume of air drawn through the filter and the number of GOs analyzed).

As shown, if DL is defined as a concentration that will be detected at least 95% of the time, the value of the DL is equal to 2.996 times the analytical sensitivity (S). This is the approach recommended by ISO (1995)[2] as well as ASTM (2010). As noted above, this is the lowest concentration that can be detected in nearly every case. It does <u>not</u> mean that lower concentrations cannot be detected, or that samples with 3, 2, or 1 observed structures should be considered "non-detects" or qualified as being uncertain.

Also note that some people simply assume that the analytical sensitivity (S) of an asbestos analysis is the same as the DL for that sample. However, as shown in the table above, this is true only if we choose to define the DL as a concentration that will be detected 63% of the time.

[2] ISO 10312 states that the limit of detection is based on "the upper 95% confidence limit on the Poisson distribution for a count of zero structures. In the absence of background, this is equal to 2.99 times the analytical sensitivity." However, this description is somewhat misleading because it confuses the Poisson uncertainty around a count of zero with a concentration that has a 95% probability of yielding a count of 1 or more. Nevertheless, the value is correct.

7.0 DEALING WITH MULTIPLE SAMPLES

7.1 Overview

All of the text above has focused on dealing with *individual samples*. However, human exposure and health risk can almost never be reliably characterized based on a single sample. Rather, the concentration of asbestos in air that a person is exposed to is likely to vary from place to place and from time to time, and risk-management decisions are generally based on the risk associated with the *long-term average* exposure concentration, not the risk from any one specific exposure event. In order to estimate the long-term average exposure concentration, it is necessary to collect multiple samples that provide measures of concentration that are realistic and representative over space and time.

7.2 Deriving the Best Estimate of the Mean of an Asbestos Data Set

By analogy with the process that is usually followed for other (non-asbestos) chemicals, some people assume that when the mean of a data set is calculated, all "non-detects" (i.e., samples with a count of zero) should be assigned a surrogate value greater than zero to account for the fact that the true concentration in the sample is probably not a true zero. While it is correct that the true concentration of an asbestos sample with zero counts may be greater than zero (see Section 4, above), it is not correct to assign some surrogate value (e.g., S or ½ S) to non-detects when computing the best estimate of the sample mean. Rather, the best estimate is obtained when all non-detects are evaluated using a concentration of zero (Cameron and Pravin 2007; Haas *et al.* 1999; EPA 1999, 2008).

If any value greater than zero is assigned to these samples, this will cause the estimate of the sample mean to be biased high. This is illustrated in **Figure 3**. In this example (generated using Monte Carlo simulation), a set of 100 samples is drawn from a lognormal distribution and analyzed with a range of alternative analytical sensitivities that yield detection frequencies ranging from about 15% up to about 90%. For each data set, the sample mean is divided by the true mean to generate a ratio. The upper panel shows the average and range (minimum to maximum) of the ratio values that are obtained when non-detects are evaluated as zero. As seen, regardless of the detection frequency, the expected value of the ratio is 1.0 (i.e., the expected mean is equal to the true mean). That is, treatment of non-detects as zero does not bias the results low.

The lower panel shows what happens when non-detects are assigned a non-zero surrogate value. In this example, the surrogate assigned is 0.5 times the analytical sensitivity (½ S). As seen, for cases where a high fraction of the samples are non-detects, a strong and substantial bias towards overestimation of the mean occurs. As expected, the magnitude of the bias decreases as the fraction of non-detects decreases.

So, the principle is clear: *when calculating the mean of an asbestos data set, the best estimate is obtained by treating all non-detects as zero*. These are valid samples and must be utilized as such, without adjustment.

7.3 Estimating the Uncertainty Around a Sample Mean

Ideally, the mean concentration for a data set, calculated as described above, would be equal to the true long-term average exposure concentration. However, due to random variation in both sampling and analysis, the average across multiple samples might be either higher or lower than the true long-term average. For this reason, EPA generally recommends that exposure and risk be calculated using the 95% upper confidence limit (95UCL) on the sample mean rather than the sample mean itself. This helps ensure that there is no more than a 5% chance that the actual exposure concentration will be underestimated, which in turn helps limit the probability of making a false negative decision error (declaring a site safe when it is in fact not safe).

To help with this process, EPA has developed a software application (ProUCL) to assist with the calculation of 95UCL values (EPA 2013). However, the equations and functions in ProUCL are not designed for asbestos data sets and application of ProUCL to asbestos data sets is not recommended (EPA 2008). This is because the variability between samples depends both on sampling variability (authentic differences between different samples) as well as Poisson counting uncertainty in each sample (Brattin *et al.* 2012). Because of this, EPA (2008) recommends that, until a statistical method is selected and validated by EPA for estimation of the 95UCL of an asbestos data set, risks from exposure to asbestos be calculated based on the best estimate of the mean concentration, recognizing that the sample mean may be either higher or lower than the true long-term average exposure concentration.

Nevertheless, in the case of data sets that are dominated by non-detects, especially a data set consisting of all non-detects, it is rather dissatisfying to declare that the best estimate of concentration is zero (and hence risk is zero). For this reason, as part of the uncertainty analysis, it may be useful to calculate an "upper-bound" on the sample mean by assigning a surrogate value (½ S or S) to non-detects. This approach is not statistically rigorous, but does yield a concentration value that is likely to be higher than the true mean concentration for that data set (see **Figure 3**).

8.0 SUMMARY

There are a number of key concepts that must be understood in order to properly interpret and utilize data on asbestos concentrations in air. The most important are summarized below:

1. Because of how asbestos is measured (by counting structures under a microscope), the analytical measurement error for asbestos samples is usually higher than for most other (non-asbestos) analytes.

2. The uncertainty around any specific measurement of asbestos concentration is highest when structure counts are low (e.g., 0 to 5 structures), and diminishes as structure counts increase.

3. If samples are collected on filters that have a negligible occurrence of countable "background" asbestos structures, then the occurrence of even one asbestos structure ranks the sample as a detect. This is likely to be the case with most modern-day filters analyzed by TEM and is true for the Libby Asbestos Superfund Site.

4. The “detection limit” in asbestos analysis is a not a sharp cutoff value. Rather, the ability of an analysis to detect asbestos (i.e., observe one or more structures) spans a relatively wide range (about two orders of magnitude) of concentration values, with a high probability of detection at the high end and a low probability of detection at the low end.

5. The range of concentrations that can be detected in an analysis of a filter is not fixed, but depends on the number of GOs evaluated. The greater the number of GOs evaluated, the greater the ability of the analysis to detect the presence of asbestos. In concept, nearly any analytical sensitivity may be achieved by counting a large enough number of GOs.

6. Human health risk from inhalation exposure to asbestos is related to the long-term average exposure concentration in air, so it is necessary to base risk evaluations on the average of multiple air samples that are representative of exposure levels over time and space. The best-estimate of the long-term average for a specified scenario is equal to the average of the samples that represent that scenario, treating non-detects as zero. If a non-zero surrogate value (e.g., ½ S or S) is assigned to non-detects, the resulting estimate of the mean will tend to be biased high, but may provide a helpful indication of uncertainty, especially for data sets with a high fraction of non-detects.

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TABLE B.1
90% POISSON CONFIDENCE BOUNDS ON COUNTS

N_{obs}	ISO 10312 (ISO 1995)		Box and Tiao (1973)	
	0.05 LB	0.95 UB	0.05 LB	0.95 UB
0	[0]	2.996	0.002	1.921
1	0.051	4.744	0.176	3.907
2	0.355	6.296	0.573	5.535
3	0.818	7.754	1.084	7.034
4	1.366	9.154	1.663	8.459
5	1.970	10.513	2.287	9.838
6	2.613	11.842	2.946	11.181
7	3.285	13.148	3.630	12.498
8	3.981	14.435	4.336	13.794
9	4.695	15.705	5.059	15.072
10	5.425	16.962	5.796	16.335
11	6.169	18.208	6.545	17.586
12	6.924	19.443	7.306	18.826
13	7.690	20.669	8.076	20.057
14	8.464	21.886	8.854	21.278
15	9.246	23.097	9.640	22.493
16	10.036	24.301	10.433	23.700
17	10.832	25.499	11.233	24.901
18	11.634	26.692	12.037	26.096
19	12.442	27.879	12.848	27.286
20	13.255	29.062	13.663	28.471
25	17.382	34.916	17.800	34.335
30	21.594	40.691	22.019	40.116
40	30.196	52.069	30.631	51.505
50	38.965	63.287	39.407	62.729

LB = lower bound count
N_{obs} = number of structures observed
UB = upper bound count

TABLE B.2
VALUE OF x0 FOR VARIOUS VALUES OF λ_0

Expected Count from Background (λ_0)	Decision value (x0)
0.00 – 0.05	0
0.05 – 0.35	1
0.35 – 0.81	2
0.81 – 1.36	3
1.36 – 1.97	4
1.97 – 2.61	5

Notes:
x0 = the highest count than could reasonably arise from background

Source: ASTM 6620-06

FIGURE B.1
UNCERTAINTY AS A FUNCTION OF COUNT

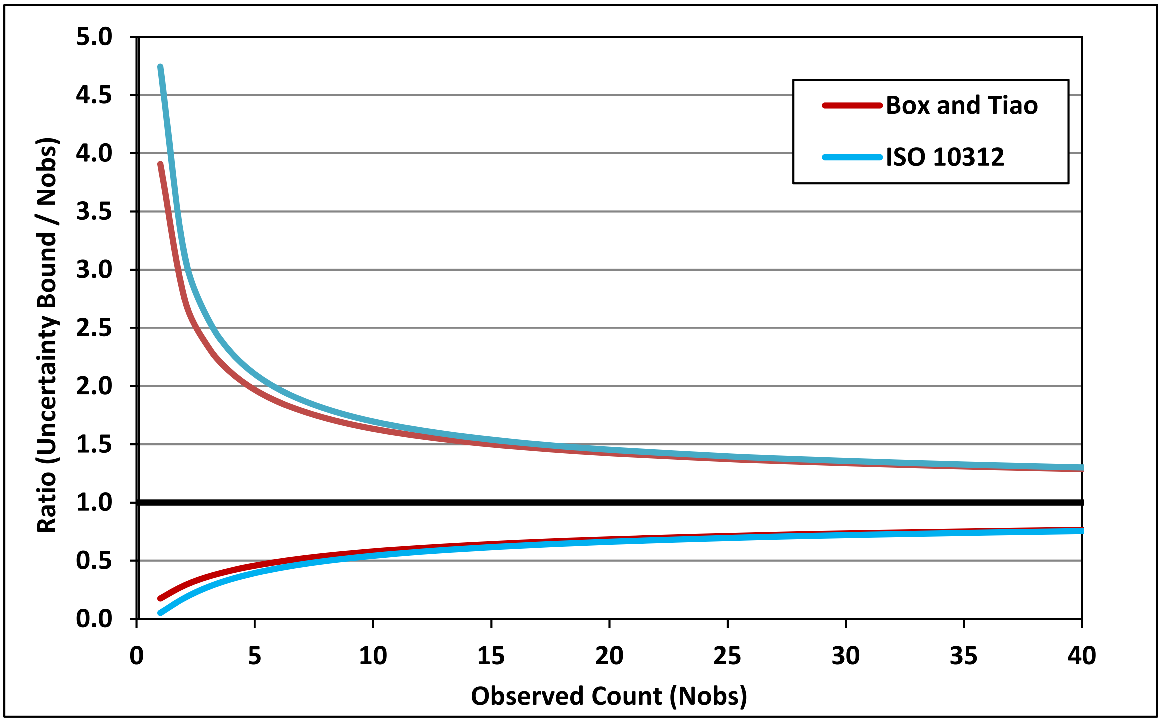


FIGURE B.2
PROBABILITY OF DETECTION AS A FUNCTION OF CONCENTRATION

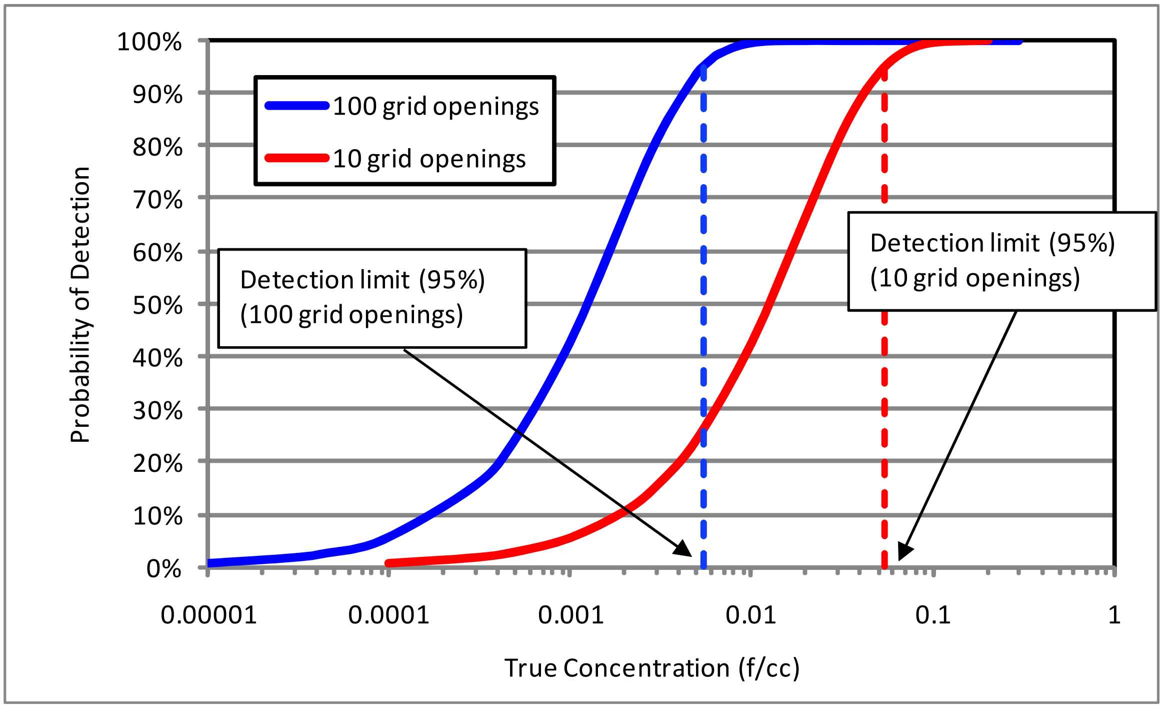
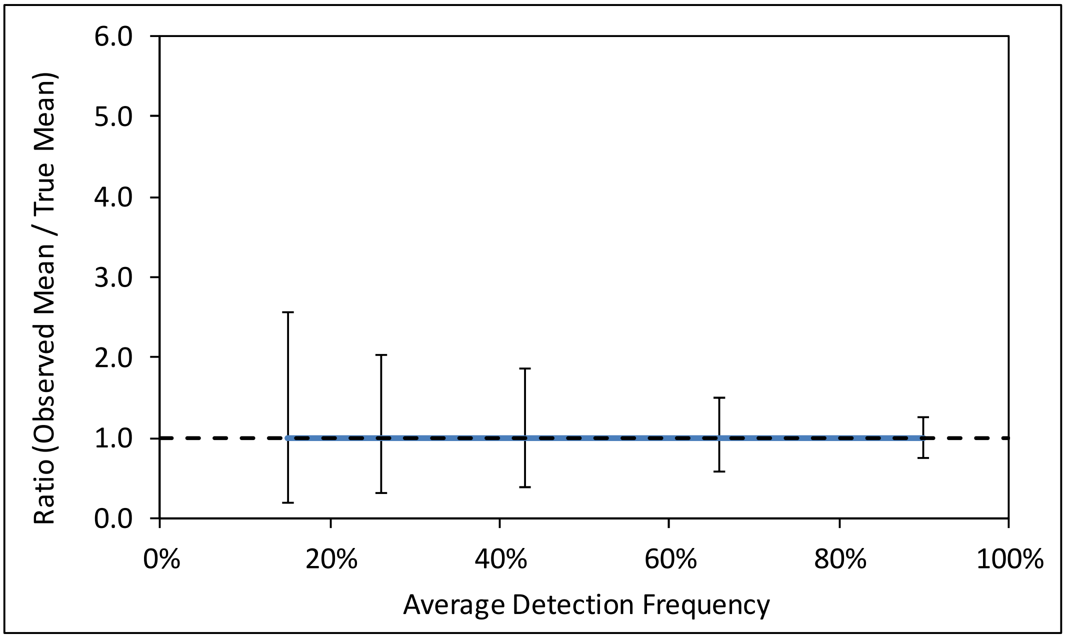
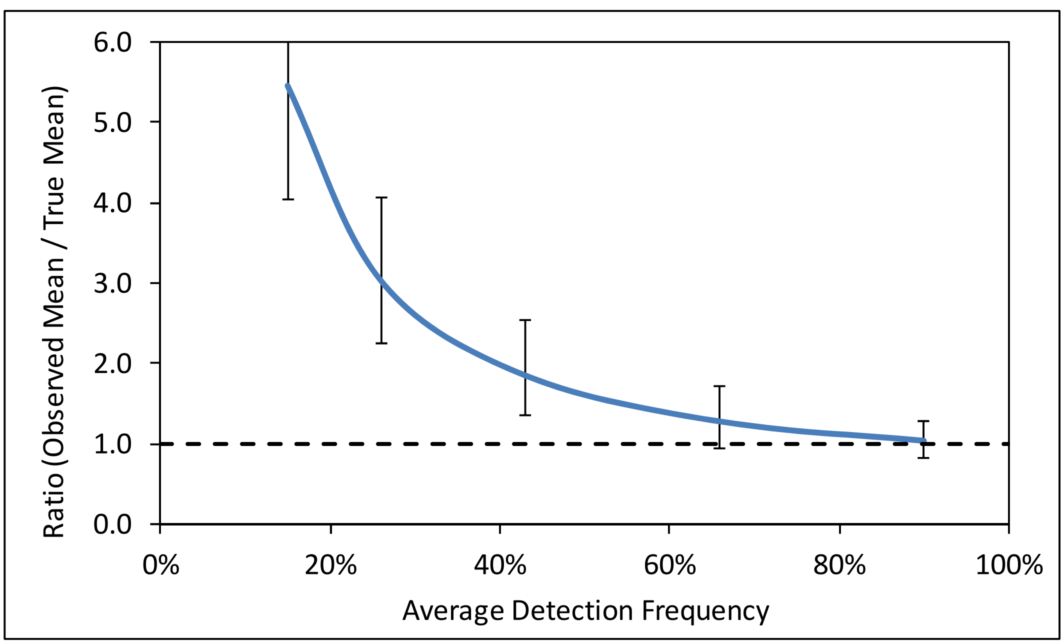


FIGURE B.3
BIAS INTRODUCED BY USING SURROGATE VALUES FOR NON-DETECTS

Panel A: Non-Detects Evaluated as Zero



Panel B: Non-Detects Evaluated at 1/2*S



APPENDIX C

DEFINITION OF PHASE CONTRAST MICROSCOPY-EQUIVALENT (PCME)

The Libby amphibole asbestos (LA)-specific toxicity factors were derived by fitting mathematical models to data that characterize the relationship between exposure to LA in workplace air and the occurrence of cancer or non-cancer effects in exposed workers. The studies that were used reported measures of asbestos concentration in workplace air that were obtained by phase contrast microscopy (PCM). Consequently, it is mandatory that risk estimates based on these toxicity factors be calculated using measures of concentration that are expressed in comparable units.

While analysis by PCM remains an option, the U.S. Environmental Protection Agency (EPA 2008) generally recommends that asbestos analyses at Superfund sites be performed using transmission electron microscopy (TEM). This is mainly because PCM cannot reliably distinguish between asbestos and non-asbestos fibers, while TEM can distinguish asbestos from non-asbestos and can also distinguish between asbestos mineral types. Consequently, when measures of concentration have been obtained by TEM, it is necessary to specify rules that allow identification of PCM-equivalent (PCME) structures that were observed in the TEM analysis.

The counting rules most likely followed by PCM microscopists at the time the workplace studies of LA exposure (1950s-1980s) were performed defined a fiber[1] as any visible structure with a length longer than 5 micrometers (µm) and an aspect ratio (length divided by width) of 3:1 or greater (National Institute for Occupational Safety and Health [NIOSH] 1977). No specific mention is made of any width resolution limit in NIOSH (1977). Based on a review of historical literature, it appears that the lower limit of width resolution by PCM varied between studies, depending upon the visual acuity of the analyst, optical performance of the microscope, and optical properties (refractive index) of the asbestos structures.

- Rendell and Skikne (1980) performed a study for the National Centre for Occupational Health in Johannesburg, South Africa in which known fibers, as determined by electron microscopy, were examined by PCM. They reported that 100 percent (%) of amosite fibers with a width greater than (>) 0.5 µm were visible by PCM, whereas 30% of fibers with a width of 0.2-0.4 µm and only 3% of fibers with a width less than (<) 0.2 µm were visible. Based on these results, the authors adopted a PCM limit of resolution of 0.4 µm.
- LeGuen *et al.* (1980) evaluated the effect of refractive index on fiber visibility and established a lower width detection limit of 0.2-0.25 µm for chrysotile, while Hwang and Gibbs (1981) estimated a lower limit of 0.21 µm for crocidolite.
- Rooker *et al.* (1982) performed a study of various fibrous materials, including several types of asbestos and man-made mineral fibers, to determine the variability and limits of fiber resolution under a range of analysis conditions. They found that "fibers of diameter 0.15 µm should be visible with good optics".
- Taylor *et al.* (1984) describes a study in which amosite and wollastonite fiber concentrations obtained by PCM and electron microscopy were compared for filters prepared using a fluidized

[1] In a PCM analysis, any particle (asbestos or non-asbestos) meeting the dimensional criteria is referred to as a "fiber". In a TEM analysis, particles are designated based on specific structure types (e.g., fibers, bundles, clusters). For simplicity, this document uses the term "structure" to refer to both PCM fibers and TEM PCME structures.

bed generator. According to the authors, "[t]he resolution limit of the phase contrast microscope was estimated to be 0.25 µm by observing reference slides…of known diameter".

- The World Health Organization identifies a lower width boundary of 0.25 µm for PCM, stating that "mineral fibres down to about 0.25 µm in diameter (lower for amphiboles than for chrysotile) are visible and countable" (International Programme on Chemical Safety [IPCS] 1986).

Based on these reports, it is concluded that the lower width boundary of detection by PCM likely varied from about 0.15 µm to 0.4 µm, depending upon the study, with the majority of studies supporting a value of about 0.25 µm. The lower width boundary of 0.25 µm is supported by the current NIOSH Method 7400 for PCM (NIOSH 1994), which states that "[f]ibers < ca. 0.25 µm diameter will not be detected by this method".

A related issue is whether there should be an upper bound on the thickness of PCME structures. Walton (1982) provides a comprehensive review of the PCM counting rules that have been applied historically, and notes that an upper width boundary of 3 µm for PCM counting was adopted internationally in 1971 based on findings by Timbrell *et al.* (1970) that amphibole fibers found in lung tissue had a maximum diameter of 3 µm. However, Walton (1982) indicates that the U.S. did not adopt this limit, and specifically states that the PCM methods used in the U.S. do not specify an upper diameter limit. Indeed, a review of the historical and current NIOSH methods for PCM (NIOSH 1977; 1994) shows that no upper diameter limit is imposed.

Based on this information, when estimating exposure point concentrations for air samples analyzed by TEM for use in the risk characterization, PCME structures are defined as follows:

- Length > 5 µm
- Width ≥ 0.25 µm (no upper limit)
- Aspect ratio ≥ 3:1

It is acknowledged that the width criterion that is used in the risk assessment differs from what is specified in EPA's *Framework for Investigating Asbestos-Contaminated Superfund Sites* (EPA 2008), which specifies an upper width limit of 3 µm. As illustrated in **Figure 2-4** (main text), very few (<1%) LA structures observed on air filters have a width > 3 µm.

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APPENDIX D

COMPARISON OF LA AIR CONCENTRATIONS RESULTING FROM DIRECT AND INDIRECT FILTER PREPARATION

Appendix D

Comparison of LA Air Concentrations Resulting from Direct and Indirect Filter Preparation Methods

Indirect filter preparation of air samples may be required in environmental settings where filters are overloaded with non-asbestos fibers or particles. The two studies described in the following sections support previous studies that indirect preparation may increase measured amphibole asbestos concentration values. In the case of amphibole asbestos from Libby, Montana, the increase appears to average about 3-4-fold, depending on counting rules. While this increase is considerably smaller than is often observed for chrysotile asbestos, the effect is sufficiently large that it may overestimate human exposure and risk from Libby amphibole asbestos in air. In a site-specific risk assessment that utilizes results of indirectly prepared air samples, this overestimation may be accounted for by application of a correction factor, or may be discussed as a source of uncertainty. The following sections provide supporting information for the correction factor used in the risk assessment for the Libby Asbestos Superfund Site.

1.0 Introduction

The concentration of asbestos in air is generally estimated by drawing a sample of air through a filter and examining the filter under a microscope for the presence of asbestos structures. In ideal cases, the filter is prepared for microscopic examination using "direct preparation" techniques, meaning that the original filter within the air sampling cassette is utilized. However, in cases where the air contains a significant level of dust, this can lead to overloading of the filter with dust particles, uneven deposition of material on the filter, and/or the presence of loose dust in the air sampling cassette. In any of these cases, the sample must be prepared for examination using an "indirect preparation" technique. Indirect preparation typically involves ashing the original filter, suspending and sonicating the ash residue in water, and applying an aliquot of the aqueous suspension to a new (secondary) filter (ISO 1999).

For chrysotile asbestos, indirect preparation can cause a substantial increase in the number of asbestos fibers counted during the analysis. The magnitude of the increase in the estimated air concentration due to indirect preparation is usually in the range of 2-100-fold, but may be as large as 1,000-2,000-fold (Kauffer *et al.* 1996; Hwang and Wang 1983; Sahle and Laszlo 1996; EPA 1990). The magnitude of the difference is often larger for short structures (e.g., length less than 5 micrometers [μm]) than for longer structures (Kauffer *et al.* 1996; Hwang and Wang 1983; Chatfield 1985). For amphibole asbestos, several reports show that the magnitude of the effect of indirect preparation is somewhat smaller (less than 10-fold) than for chrysotile (Sahle and Laszlo 1996; Bishop *et al.*1978; Goldade and O'Brien 2014).

Because indirect preparation may influence the estimate of asbestos structures in a sample, and because the magnitude of the effect may depend on the type of and source of asbestos, site-specific data on the effect of the indirect preparation may be valuable to support reliable estimation of airborne asbestos concentrations for use in human health risk assessment.

The Libby Asbestos Superfund Site is located in Libby, Montana near a large open-pit vermiculite mine that is known to be contaminated with several different mineralogical types of amphibole asbestos. The most common types are richterite and winchite, with lower frequencies of tremolite, edenite, magnesio-riebeckite, and magnesio-arfvedsonite (Meeker *et al.* 2003). Depending on the oxidation state of iron, some amphibole structures may also be classified as actinolite. For the purposes of investigations at the site, this amphibole mixture is referred to as Libby amphibole (LA). The United States Environmental Protection Agency (EPA) has performed several investigations at the Libby site to collect data on measured concentrations of LA in air during a variety of exposure scenarios for use in evaluating human health risks. In these investigations, indirect preparation has been used to prepare some air samples due to high particulate loading on the filter.

2.0 Methods

Two studies were conducted using air samples from the Libby site to investigate whether indirect preparation of air sample filters causes a significant change in estimated LA air concentrations compared to direct preparation of air sample filters.

2.1 Study 1

Study 1 was conducted using a set of 27 archived air sample filters that had previously been collected and analyzed using direct preparation and where LA structures were detected. For each of the 27 samples, half of the remaining filter was prepared using direct preparation in basic accordance with International Standards Organization (ISO) Method 10312:1995(E) (ISO 1995). The other half of the remaining filter was prepared using indirect preparation with ashing in basic accordance with ISO Method 13794:1999(E), but modifying the indirect preparation procedure to increase the total suspension volume from 40 milliliters (mL) to 100 mL to allow for the preparation of a series of secondary filters with a range of different application volumes (ISO 1999). The application of different volumes allowed the analyst to choose the secondary filter with the highest application volume that was not overloaded.

The resulting grids from each preparation method (direct and indirect) were then analyzed for LA by transmission electron microscopy (TEM) by the same analyst using the same microscope. ISO Method 10312:1995(E) structure counting and recording rules were used for all samples (ISO 1995). In brief, grids were examined under high magnification (20,000X) and all asbestos structures with a length longer than 0.5 μm and an aspect ratio (length:width) of 3:1 or greater were recorded. Asbestos structures were classified into three mineral types (LA, other amphibole, chrysotile) based on selective area electron diffraction (SAED) patterns and energy dispersive spectroscopy (EDS). If observed, complex structures were recorded enumerating their component structures (i.e., fibers and bundles that were part of disperse clusters and matrices were recorded and counted individually). Raw data from Study 1 are provided in **Attachment D-1**.

2.2 Study 2

At the Libby site, air sample collection is often performed using two sampling pumps operated at "high flow" and at "low flow" rates for the same location and sampling event. This results in two replicate filters, with each filter representing the same sample collection duration, but different total sample air volumes. In Study 2, the Libby site results database was queried to identify air samples collected during a residential activity-based sampling (ABS) investigation where the high flow filter had been analyzed using an indirect preparation, and where the particulate loading on the high flow filter was sufficiently small (as ascertained from the dilution factor used during the indirect preparation) that the corresponding low flow filter could be analyzed by a direct preparation. Based on this selection criterion, 52 samples were identified, including air samples collected from both indoor and outdoor settings under various ABS conditions. For each of the 52 air samples, the archived low flow filter was prepared using direct preparation and resulting grids were analyzed by TEM in basic accordance with ISO Method 10312:1995(E) using the same counting and recording rules as utilized in Study 1(ISO 1995). The TEM analysis of the low flow filter was usually performed by a different analyst in a different laboratory than the original analysis of the high flow filter. Raw data from Study 2 are provided in **Attachment D-2**.

3.0 Results and Discussion

Results of TEM analyses provide data on "total" LA. Using the raw structure data, which provides the length, width, and aspect ratio of each recorded LA structure, the number of phase contrast microscopy-equivalent (PCME) LA structures (i.e., structures longer than 5 μm with a width greater than or equal to 0.25 μm and an aspect ratio of 3:1 or greater) can be determined. Data on total LA air concentrations are used mainly to help characterize the nature and extent of contamination at the site, while data on PCME LA air concentrations are used to estimate human exposures for risk assessment purposes.

3.1 Effect of Indirect Preparation on Air LA Concentration Estimates

Figures D-1 and D-2 present the paired results (indirect vs. direct preparation) for estimated air concentrations in structures per cubic centimeter (s/cc) for Studies 1 and 2, respectively. In both figures, the upper panel compares the air concentration estimates for total LA, and the lower panel compares the air concentration estimates for PCME LA. The error bars for each sample indicate the 95% confidence interval resulting from random Poisson counting variability in the analysis. Each figure includes a dotted line to show the line of identity (1:1) and a dashed line to show an indirect:direct ratio of 5:1. Because concentrations are plotted on a log-scale, non-detects (analyses where no LA structures were observed) are shown at a concentration of 0.0001 s/cc. In both Studies 1 and 2, a clear tendency exists for total LA air concentration estimates based on indirect preparation to be higher than estimates based on direct preparation. The effect is similar, although somewhat smaller, for PCME LA (**Figures D-1 and D-2**, lower panel).

A comparison of the air concentration estimates for the direct preparation and indirect preparation was performed using two methods. The first method simply compared the reported air concentrations for each analysis. The second method performed a statistical comparison of the air concentrations using the Poisson ratio test (Nelson 1982). This test is based on the 95% confidence interval around the ratio of the two observed Poisson rates. **Table D-1** summarizes the number of samples where the indirect preparation analysis yielded higher air concentrations than the direct preparation analysis. Although some of the differences were not statistically significant, these data suggest that indirect preparation tends to increase the LA air concentration estimates.

The magnitude of the effect of indirect preparation on the air concentration estimate is generally less than a factor of about 10, with about 85-95% of the analysis pairs with detected levels of LA having a concentration ratio (indirect:direct) less than 5:1 for both total LA and PCME LA (**Table D-2**). When averaged across both studies, the mean indirect:direct concentration ratio is 3.5 for total LA and 2.5 for PCME LA (**Table D-2**).

3.2 Effect of Indirect Preparation on Structure Size Distribution

Figures D-3 and **D-4** compare the length, width, and aspect ratio cumulative distribution frequency of total LA structures observed for filters prepared using direct and indirect preparation methods for Studies 1 and 2, respectively. An apparent tendency exists for the length and width distributions for LA structures observed for indirect preparation filters to be somewhat left-shifted (shorter and thinner) compared to direct preparation filters.

3.3 Effect of Indirect Preparation on Structure Type

Table D-3 summarizes the frequency that total LA structures were observed to occur either as "free" fibers (F) (i.e., fibers not associated with matrices or clusters), bundles (B), fibers associated with matrix material (MF), or bundles associated with matrix material (MB) for direct and indirect preparations. Indirect preparation increased the relative frequency of free LA fibers for total LA in both Studies 1 and 2, while simultaneously decreasing the relative fraction of LA structures that were in bundles and/or associated with matrices. Results for PCME show a similar pattern (**Table D-4**).

4.0 Conclusions

The finding that indirect preparation causes an average increase of about 3-4-fold (depending on the structure type, total vs. PCME) for LA is generally consistent with reports for other types of amphibole asbestos (Sahle and Laszlo 1996; Bishop *et al.* 1978). This finding is also consistent with earlier investigations on the effect of indirect preparation methods on ABS air samples from Libby, which reported a 2-4-fold increase in the number of fibers recorded for air filters prepared using indirect methods versus direct preparation, as well as an increase in shorter fibers (length less than 5 μm), and fewer complex structures (Goldade and O'Brien 2014). Possible explanations for this increase include dissociation and dispersal of fibers present in complex structures, as well as breaking and/or splitting of some fibers. The increase in the frequency of free fibers, as well as the left-shift in structure length and width distributions, suggest both mechanisms may be occurring.

Regardless of the cause, the increase in apparent air concentration raises several issues with regard to exposure and risk assessment at the Libby site and other sites where amphibole asbestos is present. The first implication is that sampling and analysis plans should strive to collect air samples that are suitable for analysis using a direct preparation. However, this is not always possible, especially if the air samples are collected during an ABS disturbance scenario. In cases where the choice is to analyze samples following an indirect preparation or not analyze at all, collecting data from indirect preparations is clearly preferred.

In those cases where some or all samples in a data set are analyzed following an indirect preparation, it is necessary to account for the probable bias in the resulting air concentration estimates. For risk assessment purposes, two options are available. The simplest is to describe the probable bias in the uncertainty analysis, and state that risks based on indirectly prepared filters are likely to be higher than would have been obtained if the filters had been prepared directly. When reliable site-specific data are available, the risk assessor may also choose to include a semi-quantitative estimate of what the risks would be if all samples prepared indirectly were adjusted by an average correction factor (e.g., 2.5, in the case of PCME LA). The latter approach was employed in the risk assessment for the Libby Asbestos Superfund Site, in consultation with risk managers.

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TABLE D.1. Frequency that the Air Concentration was Higher for the Indirectly Prepared Filter
Libby Asbestos Superfund Site

Study	Total Number of Samples	Number (and Frequency) of Samples Where Indirect > Direct							
		Based on Concentration Comparison				Based on Poisson Ratio Comparison			
		Total LA		PCME LA		Total LA		PCME LA	
1	27	21	*78%*	15	*56%*	11	*41%*	2	*7%*
2	52	37	*71%*	26	*50%*	12	*23%*	1	*2%*
combined	79	58	*73%*	41	*52%*	23	*29%*	3	*4%*

Notes:

LA = Libby amphibole asbestos

PCME = phase contrast microscopy-equivalent

TABLE D.2. Evaluation of Indirect:Direct Air Concentration Ratios
Libby Asbestos Superfund Site

Study	Total LA			PCME LA		
	Number of detect:detect pairs	Mean indirect:direct ratio[A]	Frequency of indirect:direct ratios < 5:1	Number of detect:detect pairs	Mean indirect:direct ratio[A]	Frequency of indirect:direct ratios < 5:1
Study 1	21	3.0	20/21, 95%	13	2.5	13/13, 100%
Study 2	18	4.0	13/18, 72%	10	2.6	9/10, 90%
combined	39	3.5	33/39, 85%	23	2.5	22/23, 96%

[A] Based on detect:detect pairs only (i.e., both the indirect analysis and the direct analysis observed LA structures)

Notes:

LA = Libby amphibole asbestos

PCME = phase contrast microscopy-equivalent

TABLE D.3. Frequency of Total LA Structure Types Recorded for Filters Prepared by Direct and Indirect Methods
Libby Asbestos Superfund Site

Structure Type	Number (and Frequency) of Structures for each Structure Type							
	Study 1				Study 2			
	Direct		Indirect		Direct		Indirect	
F	128	*62%*	224	*84%*	20	*34%*	309	*56%*
B	2	*1.0%*	1	*0.4%*	15	*25%*	55	*10%*
MB	1	*0.5%*	0	*0%*	9	*15%*	18	*3.2%*
MF	75	*36%*	41	*15%*	15	*25%*	172	*31%*
Total	206		266		59		554	

Note: F=fiber, B=bundle, MB=matrix bundle, MF=matrix fiber

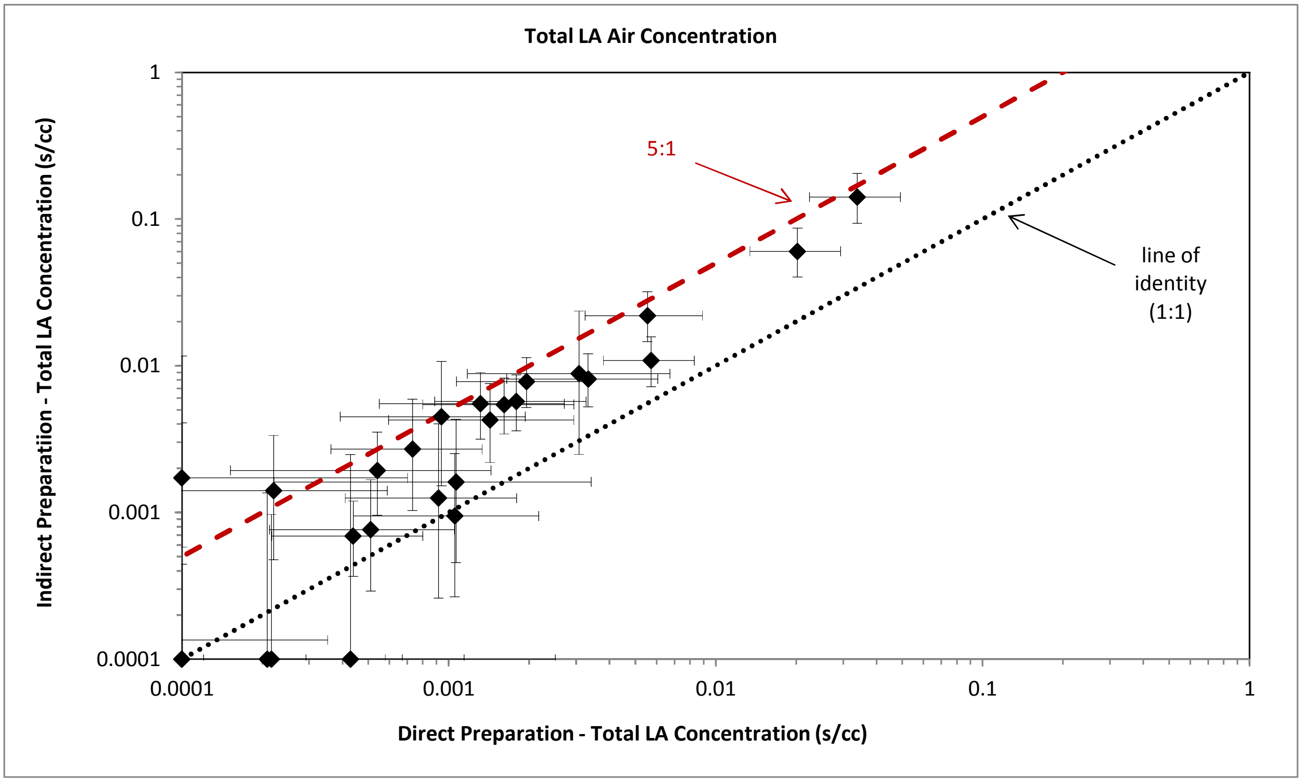
TABLE D.4. Frequency of PCME LA Structure Types Recorded for Filters Prepared by Direct and Indirect Methods
Libby Asbestos Superfund Site

Structure Type	Number (and Frequency) of Structures for each Structure Type							
	Study 1				Study 2			
	Direct		Indirect		Direct		Indirect	
F	73	*70%*	72	*84%*	12	*38%*	74	*53%*
B	1	*1.0%*	1	*1.2%*	11	*34%*	24	*17%*
MB	1	*1.0%*	0	*0%*	5	*16%*	6	*4.3%*
MF	30	*29%*	13	*15%*	4	*13%*	36	*26%*
Total	105		86		32		140	

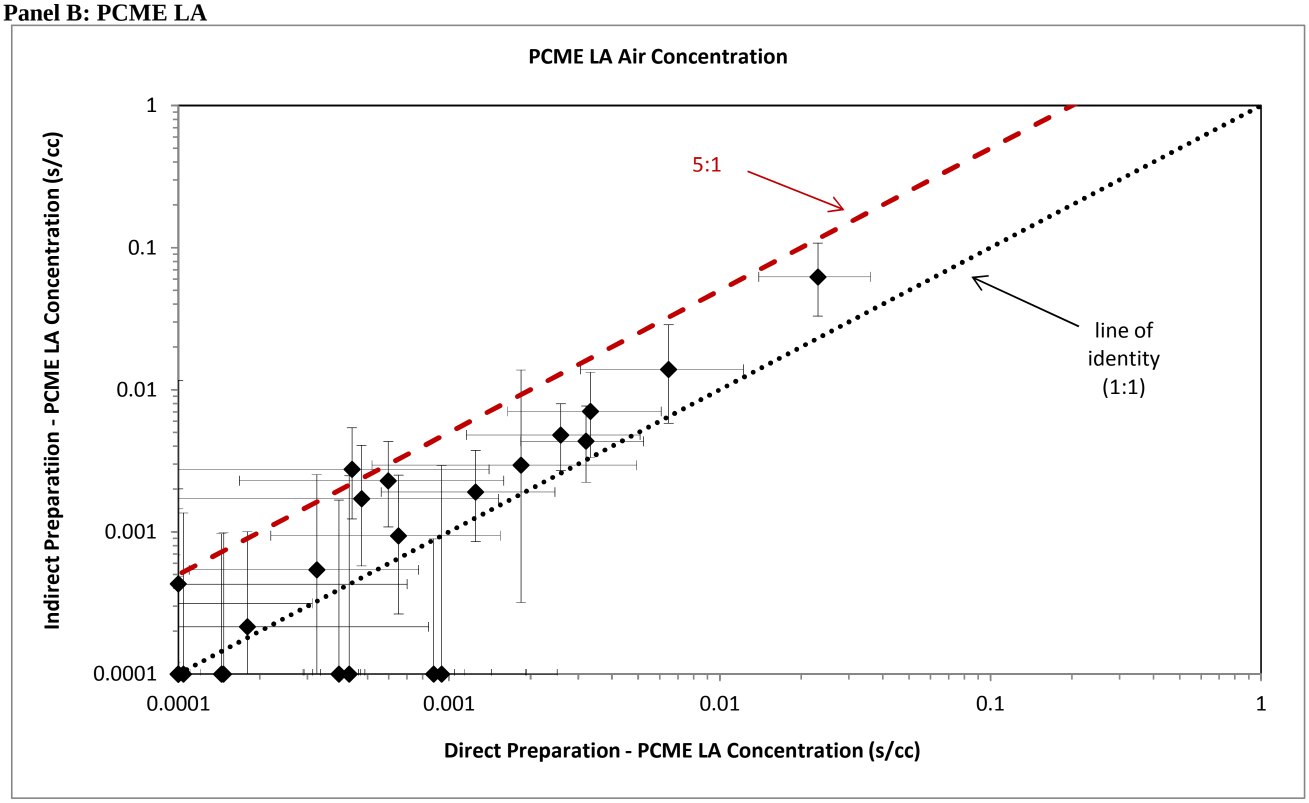
Note: F=fiber, B=bundle, MB=matrix bundle, MF=matrix fiber

Figure D.1. Study 1 Indirect Analysis vs. Direct Analysis

Panel A: Total LA



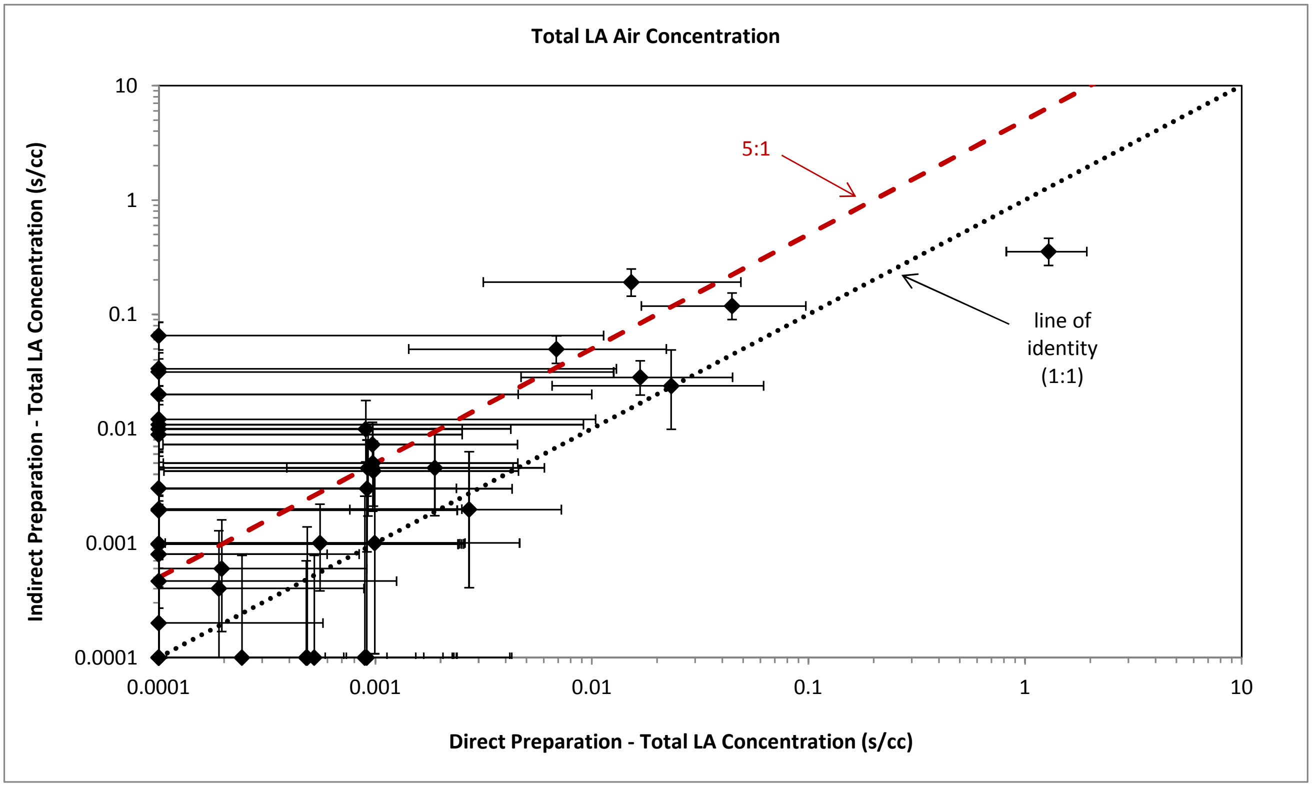
Panel B: PCME LA



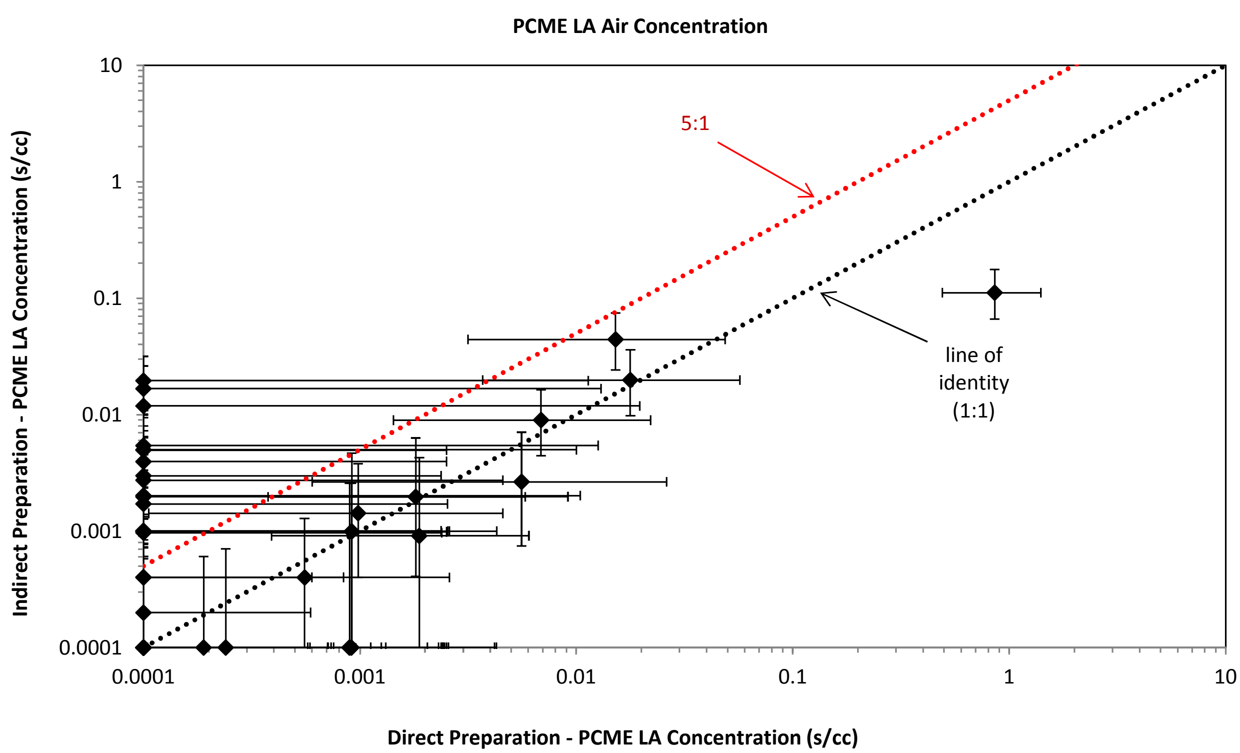
Non-detects are plotted at 1E-04 s/cc.

Figure D.2. Study 2 Indirect Analysis vs. Direct Analysis

Panel A: Total LA



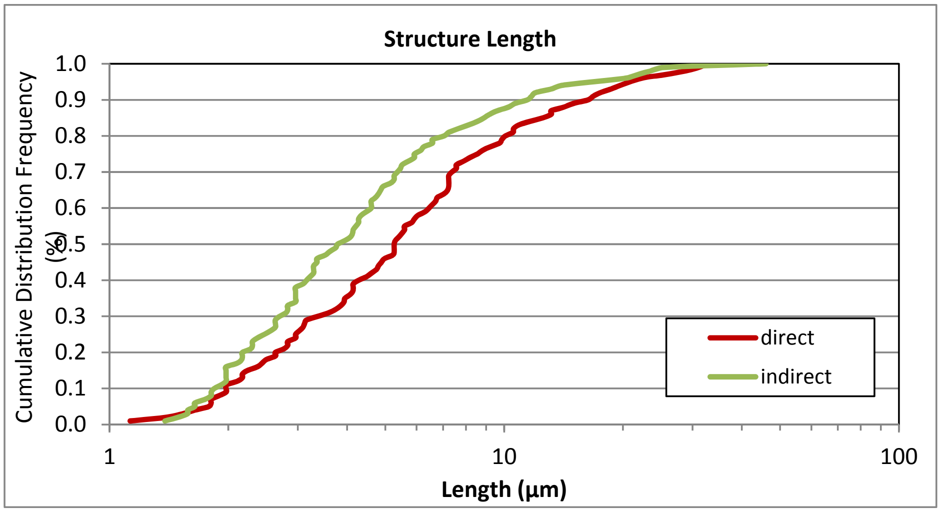
Panel B: PCME LA



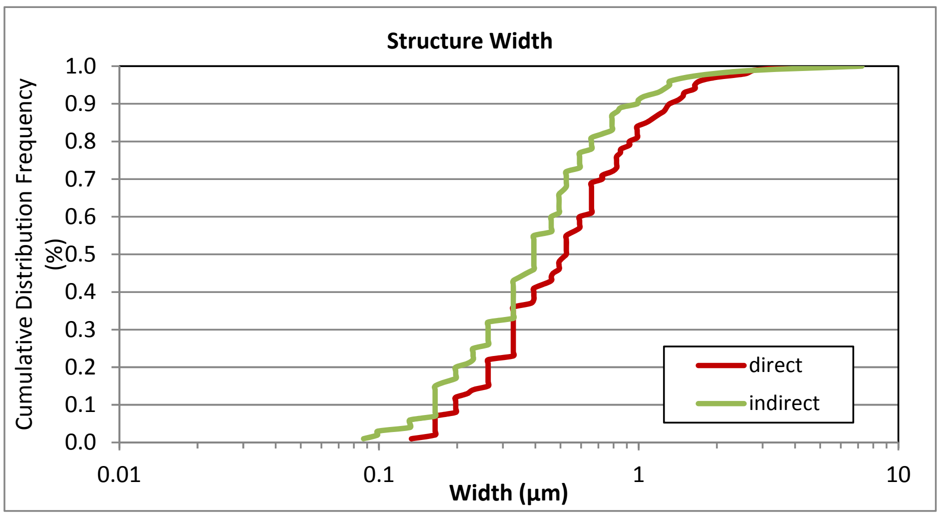
Non-detects are plotted at 1E-04 s/cc.

Figure D.3. Study 1: LA Particle Size Distribution

Panel A: Length



Panel B: Width



Panel C: Aspect Ratio

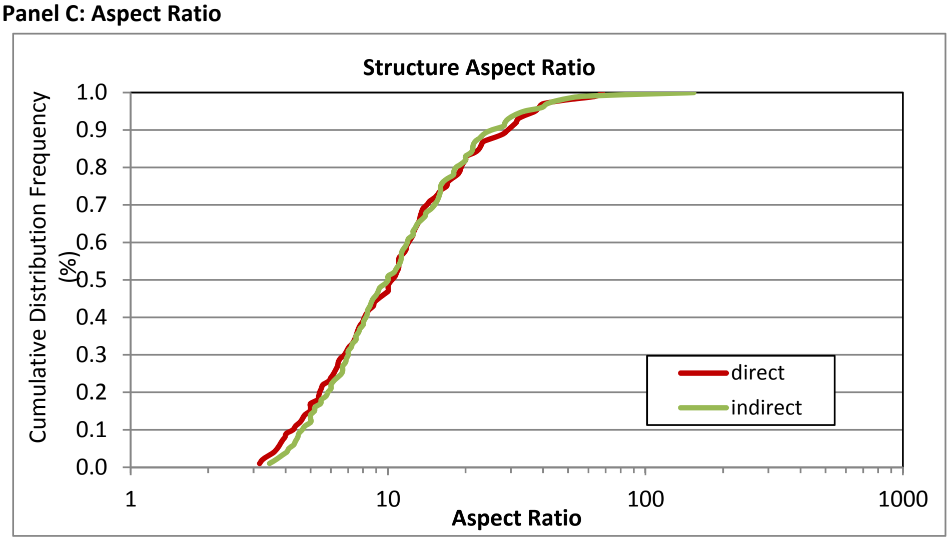
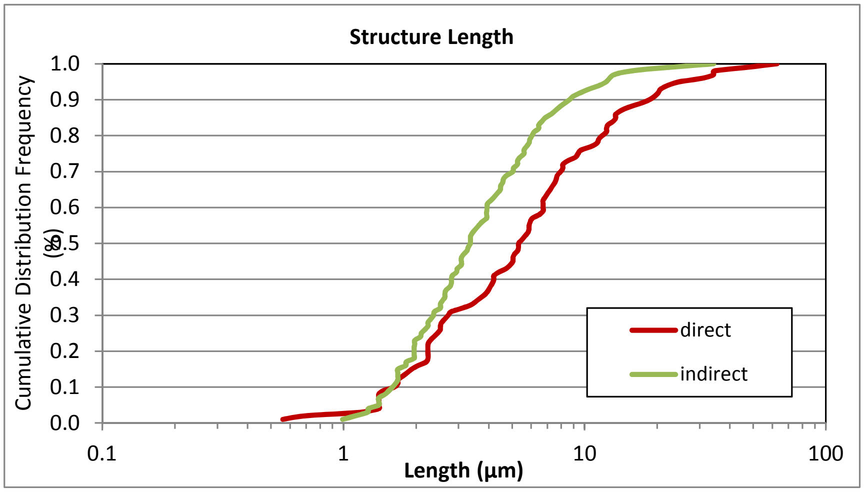
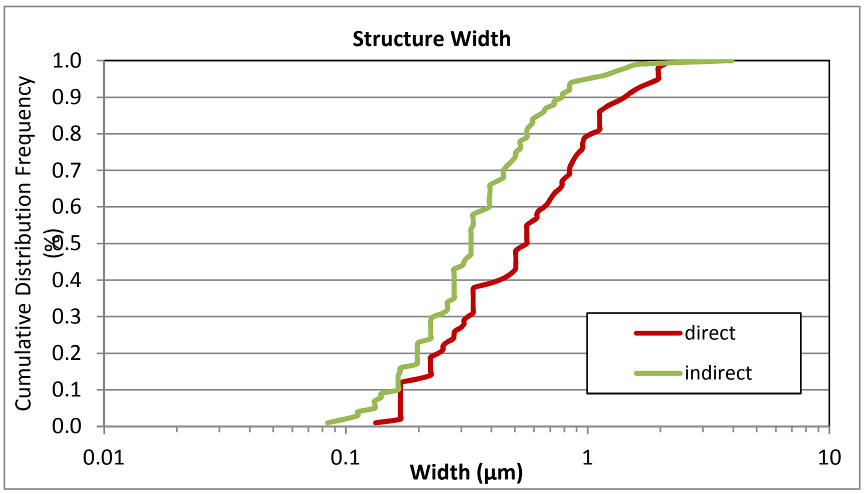


Figure D.4. Study 2: LA Particle Size Distribution

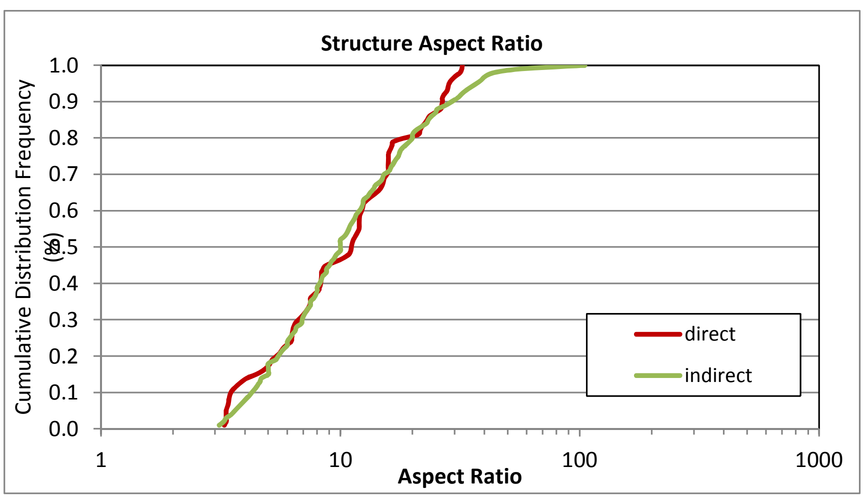
Panel A: Length



Panel B: Width



Panel C: Aspect Ratio



Attachment D.1a. Study 1: Summary of Direct Preparation and Indirect Preparation Results for PCME LA, Round 2
Libby Asbestos Superfund Site

Index ID	DIRECT (Original)				DIRECT (Round 2)				INDIRECT			
	GOs Counted	N PCME LA Struc	LA Sens	Conc (s/cc)	GOs Counted	N PCME LA Struc	LA Sens	Conc (s/cc)	GOs Counted	N PCME LA Struc	LA Sens	Conc (s/cc)
EX-01463	32	3	1.0E-03	3.0E-03	160	3	2.0E-04	6.0E-04	200	8	2.9E-04	2.3E-03
IN-00953	85	4	2.0E-04	8.0E-04	200	0	8.5E-05	0.0E+00	200	0	1.5E-04	0.0E+00
IN-02810	77	0	2.0E-04	0.0E+00	200	0	7.6E-05	0.0E+00	200	0	1.4E-04	0.0E+00
EX-01181	28	2	9.6E-04	1.9E-03	200	5	1.8E-04	8.8E-04	200	0	3.2E-04	0.0E+00
SQ-00690	100	6	7.1E-05	4.2E-04	145	2	4.9E-05	9.7E-05	202	5	6.3E-05	3.1E-04
SQ-00171	30	3	1.1E-03	3.2E-03	86	9	3.7E-04	3.3E-03	65	8	8.8E-04	7.0E-03
IN-00180	106	3	4.1E-04	1.2E-03	200	2	2.4E-04	4.8E-04	200	4	4.3E-04	1.7E-03
EX-01396	30	3	9.2E-04	2.8E-03	169	7	1.8E-04	1.3E-03	200	7	2.7E-04	1.9E-03
EX-00435	33	1	9.0E-04	9.0E-04	200	4	1.6E-04	6.5E-04	187	3	3.1E-04	9.4E-04
SL-70457	93	1	4.7E-04	4.7E-04	200	0	2.4E-04	0.0E+00	200	1	4.3E-04	4.3E-04
IN-02525	73	2	1.9E-04	3.7E-04	200	0	7.5E-05	0.0E+00	200	0	1.4E-04	0.0E+00
SQ-00344	32	6	9.3E-04	5.6E-03	89	7	3.7E-04	2.6E-03	160	13	3.7E-04	4.8E-03
SL-70486	81	1	4.9E-04	4.9E-04	200	2	2.2E-04	4.4E-04	200	7	3.9E-04	2.8E-03
SQ-00448	24	1	9.1E-04	9.1E-04	133	1	1.8E-04	1.8E-04	200	1	2.1E-04	2.1E-04
SQ-00375	33	8	1.1E-03	8.4E-03	43	8	8.1E-04	6.5E-03	27	6	2.3E-03	1.4E-02
SQ-00474	27	3	9.8E-04	2.9E-03	67	0	5.3E-04	0.0E+00	119	0	5.4E-04	0.0E+00
EX-01111	24	8	9.6E-04	7.7E-03	131	14	2.3E-04	3.2E-03	150	10	4.3E-04	4.3E-03
EX-00682	100	3	1.1E-03	3.2E-03	94	17	1.4E-03	2.3E-02	43	11	5.7E-03	6.2E-02
IN-00288	81	4	1.9E-04	7.5E-04	200	4	8.1E-05	3.2E-04	200	1	5.4E-04	5.4E-04
EX-01009	23	5	9.8E-04	4.9E-03	200	3	1.4E-04	4.3E-04	200	0	9.5E-04	0.0E+00
SL-70775	35	6	4.9E-03	2.9E-02	200	0	9.6E-04	0.0E+00	200	0	4.6E-03	0.0E+00
SL-70760	22	7	5.0E-03	3.5E-02	200	3	6.1E-04	1.8E-03	200	1	2.9E-03	2.9E-03
IN-02172	65	8	2.0E-04	1.6E-03	200	2	7.2E-05	1.4E-04	200	0	3.5E-04	0.0E+00
IN-01429	66	9	2.0E-04	1.8E-03	200	2	7.3E-05	1.5E-04	200	0	3.5E-04	0.0E+00
IN-01227	86	10	2.0E-04	2.0E-03	200	1	1.0E-04	1.0E-04	200	0	5.0E-04	0.0E+00
EX-00789	24	11	9.7E-04	1.1E-02	200	3	1.3E-04	3.9E-04	200	0	6.3E-04	0.0E+00
EX-00258	35	12	8.4E-04	1.0E-02	200	6	1.6E-04	9.4E-04	200	0	1.1E-03	0.0E+00

Notes:

cc = cubic centimeters

Conc. = concentration

GO = grid opening

ID = identification

LA = Libby amphibole asbestos

N = number

PCME = phase contrast microscopy-equivalent

s/cc = structures per cubic centimeter

Attachment D.1a. Study 1: Summary of Direct Preparation and Indirect Preparation Results for Total LA, Round 2

Libby Asbestos Superfund Site

Index ID	DIRECT (Original)				DIRECT (Round 2)				INDIRECT			
	GOs Counted	N LA Struc	LA Sens	Conc (s/cc)	GOs Counted	N LA Struc	LA Sens	Conc (s/cc)	GOs Counted	N LA Struc	LA Sens	Conc (s/cc)
EX-01463	32	4	1.0E-03	4.0E-03	160	9	2.0E-04	1.8E-03	200	20	2.9E-04	5.7E-03
IN-00953	85	5	2.0E-04	1.0E-03	200	6	8.5E-05	5.1E-04	200	5	1.5E-04	7.6E-04
IN-02810	77	2	2.0E-04	4.0E-04	200	0	7.6E-05	0.0E+00	200	0	1.4E-04	0.0E+00
EX-01181	28	2	9.6E-04	1.9E-03	200	6	1.8E-04	1.1E-03	200	3	3.2E-04	9.5E-04
SQ-00690	100	14	7.1E-05	9.9E-04	145	9	4.9E-05	4.4E-04	202	11	6.3E-05	6.9E-04
SQ-00171	30	7	1.1E-03	7.5E-03	86	15	3.7E-04	5.5E-03	65	25	8.8E-04	2.2E-02
IN-00180	106	5	4.1E-04	2.0E-03	200	6	2.4E-04	1.4E-03	200	10	4.3E-04	4.3E-03
EX-01396	30	4	9.2E-04	3.7E-03	169	9	1.8E-04	1.6E-03	200	20	2.7E-04	5.4E-03
EX-00435	33	2	9.0E-04	1.8E-03	200	12	1.6E-04	2.0E-03	187	25	3.1E-04	7.8E-03
SL-70457	93	2	4.7E-04	9.4E-04	200	0	2.4E-04	0.0E+00	200	4	4.3E-04	1.7E-03
IN-02525	73	3	1.9E-04	5.6E-04	200	1	7.5E-05	7.5E-05	200	1	1.4E-04	1.4E-04
SQ-00344	32	8	9.3E-04	7.5E-03	89	9	3.7E-04	3.3E-03	160	22	3.7E-04	8.1E-03
SL-70486	81	1	4.9E-04	4.9E-04	200	6	2.2E-04	1.3E-03	200	14	3.9E-04	5.5E-03
SQ-00448	24	4	9.1E-04	3.6E-03	133	3	1.8E-04	5.4E-04	200	9	2.1E-04	1.9E-03
SQ-00375	33	15	1.1E-03	1.6E-02	43	25	8.1E-04	2.0E-02	27	26	2.3E-03	6.0E-02
SQ-00474	27	11	9.8E-04	1.1E-02	67	2	5.3E-04	1.1E-03	119	3	5.4E-04	1.6E-03
EX-01111	24	2	9.6E-04	1.9E-03	131	25	2.3E-04	5.7E-03	150	25	4.3E-04	1.1E-02
EX-00682	100	16	1.1E-03	1.7E-02	94	25	1.4E-03	3.4E-02	43	25	5.7E-03	1.4E-01
IN-00288	81	5	1.9E-04	9.4E-04	200	9	8.1E-05	7.3E-04	200	5	5.4E-04	2.7E-03
EX-01009	23	2	9.8E-04	2.0E-03	200	3	1.4E-04	4.3E-04	200	0	9.5E-04	0.0E+00
SL-70775	35	1	4.9E-03	4.9E-03	200	0	9.6E-04	0.0E+00	200	0	4.6E-03	0.0E+00
SL-70760	22	1	5.0E-03	5.0E-03	200	5	6.1E-04	3.1E-03	200	3	2.9E-03	8.8E-03
IN-02172	65	2	2.0E-04	3.9E-04	200	3	7.2E-05	2.2E-04	200	0	3.5E-04	0.0E+00
IN-01429	66	2	2.0E-04	4.0E-04	200	3	7.3E-05	2.2E-04	200	4	3.5E-04	1.4E-03
IN-01227	86	3	2.0E-04	5.9E-04	200	2	1.0E-04	2.1E-04	200	0	5.0E-04	0.0E+00
EX-00789	24	1	9.7E-04	9.7E-04	200	7	1.3E-04	9.1E-04	200	2	6.3E-04	1.3E-03
EX-00258	35	2	8.4E-04	1.7E-03	200	6	1.6E-04	9.4E-04	200	4	1.1E-03	4.5E-03

Notes:

cc = cubic centimeters
Conc. = concentration
GO = grid opening
ID = identification
LA = Libby amphibole asbestos
N = number
Sens = sensitivity
s/cc = structures per cubic centimeter

Attachment D.2a. Study 2: Summary of High Volume Filter (Indirect Preparation) and Low Volume Filter (Direct Preparation) Results for PCME LA

Libby Asbestos Superfund Site

Location	Scenario	HV (Indirect)				LV (Direct)					
		Index ID	N PCME LA Struc	LA Sens	Conc (s/cc)	Index ID	Volume (L)	GOs Counted	N PCME LA Struc	LA Sens	Conc (s/cc)
Outdoor	Digging	EX-00877	12	3.7E-03	4.4E-02	EX-00876	384	12	2	7.6E-03	1.5E-02
	Digging	EX-01063	9	2.2E-03	2.0E-02	EX-01062	394	10	2	8.9E-03	1.8E-02
	Digging	EX-00119	17	9.8E-04	1.7E-02	EX-00120	379	18	0	5.1E-03	0.0E+00
	Digging	EX-00476	2	1.0E-03	2.0E-03	EX-00475	426	20	0	4.1E-03	0.0E+00
	Digging	EX-01331	3	9.9E-04	3.0E-03	EX-01332	391	99	0	9.0E-04	0.0E+00
	Digging	EX-01004	3	4.7E-04	1.4E-03	EX-01003	376	95	1	9.8E-04	9.8E-04
	Digging	EX-01242	2	9.8E-04	2.0E-03	EX-01241	391	99	2	9.0E-04	1.8E-03
	Digging	EX-01223	1	9.7E-04	9.7E-04	EX-01224	334	115	0	9.1E-04	0.0E+00
	Digging	EX-00832	0	8.2E-04	0.0E+00	EX-00833	392	115	0	7.8E-04	0.0E+00
	Digging	EX-01487	0	1.0E-03	0.0E+00	EX-01488	391	99	0	9.0E-04	0.0E+00
	Mowing	EX-01208	15	1.3E-03	2.0E-02	EX-01207	391	20	0	4.5E-03	0.0E+00
	Mowing	EX-00707	3	4.0E-03	1.2E-02	EX-00708	55	82	0	7.8E-03	0.0E+00
	Mowing	EX-00356	3	9.1E-04	2.7E-03	EX-00355	312	63	0	1.8E-03	0.0E+00
	Mowing	EX-01333	2	9.9E-04	2.0E-03	EX-01334	389	25	0	3.6E-03	0.0E+00
	Mowing	EX-01162	4	9.9E-04	4.0E-03	EX-01163	383	95	0	9.6E-04	0.0E+00
	Mowing	EX-01006	4	4.3E-04	1.7E-03	EX-01005	388	93	0	9.7E-04	0.0E+00
	Mowing	EX-00063	1	9.1E-04	9.1E-04	EX-00060	443	84	2	9.4E-04	1.9E-03
	Mowing	EX-01489	1	1.0E-03	1.0E-03	EX-01490	391	99	0	9.0E-04	0.0E+00
	Mowing	EX-00852	0	9.9E-04	0.0E+00	EX-00851	388	94	0	9.6E-04	0.0E+00
	Mowing	EX-00486	1	1.0E-03	1.0E-03	EX-00485	415	85	0	9.9E-04	0.0E+00
	Mowing	EX-01342	0	9.9E-04	0.0E+00	EX-01343	388	96	0	9.4E-04	0.0E+00
	Mowing	EX-01351	0	9.8E-04	0.0E+00	EX-01352	388	98	0	9.2E-04	0.0E+00
	Mowing	EX-01055	0	4.6E-04	0.0E+00	EX-01056	401	190	0	4.6E-04	0.0E+00
	Mowing	EX-01041	0	5.1E-04	0.0E+00	EX-00940	365	198	0	4.8E-04	0.0E+00
	Mowing	EX-01409	0	8.9E-04	0.0E+00	EX-01410	391	102	0	8.8E-04	0.0E+00
	Raking	EX-00600	16	7.0E-03	1.1E-01	EX-00599	52	11	14	6.1E-02	8.6E-01
	Raking	EX-01060	9	6.0E-04	5.4E-03	EX-01061	502	14	0	5.0E-03	0.0E+00
	Raking	EX-00375	3	8.8E-04	2.6E-03	EX-00374	392	16	1	5.6E-03	5.6E-03
	Raking	EX-00472	5	1.0E-03	5.0E-03	EX-00474	404	22	0	3.9E-03	0.0E+00
	Raking	EX-00514	5	9.9E-04	4.9E-03	EX-00513	364	100	0	9.6E-04	0.0E+00
	Raking	EX-01146	1	1.0E-03	1.0E-03	EX-01148	367	98	0	9.7E-04	0.0E+00
	Raking	EX-00349	0	9.1E-04	0.0E+00	EX-00348	364	104	0	9.2E-04	0.0E+00
	Raking	EX-01170	1	1.0E-03	1.0E-03	EX-01172	382	100	1	9.2E-04	9.2E-04
	Raking	EX-00116	0	9.8E-04	0.0E+00	EX-00117	376	95	0	9.8E-04	0.0E+00
	Raking	EX-01355	1	9.8E-04	9.8E-04	EX-01357	388	94	0	9.6E-04	0.0E+00
	Raking	EX-01290	0	9.8E-04	0.0E+00	EX-01289	427	89	0	9.2E-04	0.0E+00
	Raking	EX-01318	0	9.9E-04	0.0E+00	EX-01320	395	99	1	9.0E-04	9.0E-04
	Raking	EX-01383	0	9.9E-04	0.0E+00	EX-01384	391	98	1	9.1E-04	9.1E-04
	Raking	EX-01403	0	9.8E-04	0.0E+00	EX-01405	392	98	0	9.1E-04	0.0E+00

Attachment D.2a. Study 2: Summary of High Volume Filter (Indirect Preparation) and Low Volume Filter (Direct Preparation) Results for PCME LA

Libby Asbestos Superfund Site

Location	Scenario	HV (Indirect)				LV (Direct)					
		Index ID	N PCME LA Struc	LA Sens	Conc (s/cc)	Index ID	Volume (L)	GOs Counted	N PCME LA Struc	LA Sens	Conc (s/cc)
Indoor	Active	IN-01026	9	1.0E-03	9.0E-03	IN-01027	728	14	2	3.4E-03	6.9E-03
	Active	IN-00774	2	2.0E-04	4.0E-04	IN-00775	760	83	1	5.5E-04	5.5E-04
	Active	IN-01600	2	2.0E-04	4.0E-04	IN-01599	778	226	0	2.0E-04	0.0E+00
	Active	IN-01150	1	2.0E-04	2.0E-04	IN-01149	728	246	0	2.0E-04	0.0E+00
	Active	IN-01109	0	2.7E-04	0.0E+00	IN-01107	736	182	0	2.6E-04	0.0E+00
	Active	IN-01245	0	2.5E-04	0.0E+00	IN-01247	778	184	0	2.4E-04	0.0E+00
	Active	IN-01284	0	2.4E-04	0.0E+00	IN-01283	712	205	1	2.4E-04	2.4E-04
	Passive	IN-00975	2	2.0E-04	4.0E-04	IN-00976	728	163	0	2.9E-04	0.0E+00
	Passive	IN-00913	0	2.0E-04	0.0E+00	IN-00914	739	250	1	1.9E-04	1.9E-04
	Passive	IN-02785	0	2.0E-04	0.0E+00	IN-02787	723	257	0	1.9E-04	0.0E+00
	Passive	IN-00832	0	2.0E-04	0.0E+00	IN-00833	752	240	0	1.9E-04	0.0E+00
	Passive	IN-01013	0	2.7E-04	0.0E+00	IN-01015	760	190	0	2.4E-04	0.0E+00
	Passive	IN-01111	0	2.5E-04	0.0E+00	IN-01112	814	170	0	2.5E-04	0.0E+00

Notes:

cc = cubic centimeters

Conc. = concentration

GO = grid opening

HV = high volume

ID = identification

LA = Libby amphibole asbestos

LV = low volume

N = number

PCME = phase contrast microscopy-equivalent

s/cc = structures per cubic centimeter

Attachment D.2b. Study 2: Summary of High Volume Filter (Indirect Preparation) and Low Volume Filter (Direct Preparation) Results for Total LA

Libby Asbestos Superfund Site

Location	Scenario	HV (Indirect)				LV (Direct)					
		Index ID	N LA Struc	LA Sens	Conc (s/cc)	Index ID	Volume (L)	GOs Counted	N LA Struc	LA Sens	Conc (s/cc)
Outdoor	Digging	EX-00877	52	3.7E-03	1.9E-01	EX-00876	384	12	2	7.6E-03	1.5E-02
	Digging	EX-01063	54	2.2E-03	1.2E-01	EX-01062	394	10	5	8.9E-03	4.4E-02
	Digging	EX-00119	34	9.8E-04	3.3E-02	EX-00120	379	18	0	5.1E-03	0.0E+00
	Digging	EX-00476	12	1.0E-03	1.2E-02	EX-00475	426	20	0	4.1E-03	0.0E+00
	Digging	EX-01331	10	9.9E-04	9.9E-03	EX-01332	391	99	1	9.0E-04	9.0E-04
	Digging	EX-01004	9	4.7E-04	4.3E-03	EX-01003	376	95	1	9.8E-04	9.8E-04
	Digging	EX-01242	2	9.8E-04	2.0E-03	EX-01241	391	99	3	9.0E-04	2.7E-03
	Digging	EX-01223	2	9.7E-04	1.9E-03	EX-01224	334	115	0	9.1E-04	0.0E+00
	Digging	EX-00832	0	8.2E-04	0.0E+00	EX-00833	392	115	0	7.8E-04	0.0E+00
	Digging	EX-01487	0	1.0E-03	0.0E+00	EX-01488	391	99	0	9.0E-04	0.0E+00
	Mowing	EX-01208	50	1.3E-03	6.5E-02	EX-01207	391	20	0	4.5E-03	0.0E+00
	Mowing	EX-00707	6	4.0E-03	2.4E-02	EX-00708	55	82	3	7.8E-03	2.3E-02
	Mowing	EX-00356	22	9.1E-04	2.0E-02	EX-00355	312	63	0	1.8E-03	0.0E+00
	Mowing	EX-01333	11	9.9E-04	1.1E-02	EX-01334	389	25	0	3.6E-03	0.0E+00
	Mowing	EX-01162	10	9.9E-04	9.9E-03	EX-01163	383	95	0	9.6E-04	0.0E+00
	Mowing	EX-01006	17	4.3E-04	7.3E-03	EX-01005	388	93	1	9.7E-04	9.7E-04
	Mowing	EX-00063	5	9.1E-04	4.6E-03	EX-00060	443	84	2	9.4E-04	1.9E-03
	Mowing	EX-01489	3	1.0E-03	3.0E-03	EX-01490	391	99	0	9.0E-04	0.0E+00
	Mowing	EX-00852	2	9.9E-04	2.0E-03	EX-00851	388	94	0	9.6E-04	0.0E+00
	Mowing	EX-00486	1	1.0E-03	1.0E-03	EX-00485	415	85	1	9.9E-04	9.9E-04
	Mowing	EX-01342	1	9.9E-04	9.9E-04	EX-01343	388	96	0	9.4E-04	0.0E+00
	Mowing	EX-01351	1	9.8E-04	9.8E-04	EX-01352	388	98	0	9.2E-04	0.0E+00
	Mowing	EX-01055	1	4.6E-04	4.6E-04	EX-01056	401	190	0	4.6E-04	0.0E+00
	Mowing	EX-01041	0	5.1E-04	0.0E+00	EX-00940	365	198	1	4.8E-04	4.8E-04
	Mowing	EX-01409	0	8.9E-04	0.0E+00	EX-01410	391	102	0	8.8E-04	0.0E+00
	Raking	EX-00600	51	7.0E-03	3.5E-01	EX-00599	52	11	21	6.1E-02	1.3E+00
	Raking	EX-01060	52	6.0E-04	3.1E-02	EX-01061	502	14	0	5.0E-03	0.0E+00
	Raking	EX-00375	32	8.8E-04	2.8E-02	EX-00374	392	16	3	5.6E-03	1.7E-02
	Raking	EX-00472	20	1.0E-03	2.0E-02	EX-00474	404	22	0	3.9E-03	0.0E+00
	Raking	EX-00514	9	9.9E-04	8.9E-03	EX-00513	364	100	0	9.6E-04	0.0E+00
	Raking	EX-01146	5	1.0E-03	5.0E-03	EX-01148	367	98	1	9.7E-04	9.7E-04
	Raking	EX-00349	5	9.1E-04	4.5E-03	EX-00348	364	104	1	9.2E-04	9.2E-04
	Raking	EX-01170	3	1.0E-03	3.0E-03	EX-01172	382	100	1	9.2E-04	9.2E-04
	Raking	EX-00116	1	9.8E-04	9.8E-04	EX-00117	376	95	0	9.8E-04	0.0E+00
	Raking	EX-01355	1	9.8E-04	9.8E-04	EX-01357	388	94	0	9.6E-04	0.0E+00
	Raking	EX-01290	1	9.8E-04	9.8E-04	EX-01289	427	89	0	9.2E-04	0.0E+00
	Raking	EX-01318	0	9.9E-04	0.0E+00	EX-01320	395	99	1	9.0E-04	9.0E-04
	Raking	EX-01383	0	9.9E-04	0.0E+00	EX-01384	391	98	1	9.1E-04	9.1E-04
	Raking	EX-01403	0	9.8E-04	0.0E+00	EX-01405	392	98	0	9.1E-04	0.0E+00

Attachment D.2b. Study 2: Summary of High Volume Filter (Indirect Preparation) and Low Volume Filter (Direct Preparation) Results for Total LA

Libby Asbestos Superfund Site

Location	Scenario	HV (Indirect)				LV (Direct)					
		Index ID	N LA Struc	LA Sens	Conc (s/cc)	Index ID	Volume (L)	GOs Counted	N LA Struc	LA Sens	Conc (s/cc)
Indoor	Active	IN-01026	50	1.0E-03	5.0E-02	IN-01027	728	14	2	3.4E-03	6.9E-03
	Active	IN-00774	5	2.0E-04	1.0E-03	IN-00775	760	83	1	5.5E-04	5.5E-04
	Active	IN-01600	4	2.0E-04	8.0E-04	IN-01599	778	226	0	2.0E-04	0.0E+00
	Active	IN-01150	3	2.0E-04	6.0E-04	IN-01149	728	246	1	2.0E-04	2.0E-04
	Active	IN-01109	0	2.7E-04	0.0E+00	IN-01107	736	182	2	2.6E-04	5.2E-04
	Active	IN-01245	0	2.5E-04	0.0E+00	IN-01247	778	184	0	2.4E-04	0.0E+00
	Active	IN-01284	0	2.4E-04	0.0E+00	IN-01283	712	205	2	2.4E-04	4.8E-04
	Passive	IN-00975	4	2.0E-04	8.0E-04	IN-00976	728	163	0	2.9E-04	0.0E+00
	Passive	IN-00913	2	2.0E-04	4.0E-04	IN-00914	739	250	1	1.9E-04	1.9E-04
	Passive	IN-02785	1	2.0E-04	2.0E-04	IN-02787	723	257	0	1.9E-04	0.0E+00
	Passive	IN-00832	0	2.0E-04	0.0E+00	IN-00833	752	240	0	1.9E-04	0.0E+00
	Passive	IN-01013	0	2.7E-04	0.0E+00	IN-01015	760	190	1	2.4E-04	2.4E-04
	Passive	IN-01111	0	2.5E-04	0.0E+00	IN-01112	814	170	0	2.5E-04	0.0E+00

Notes:

cc = cubic centimeters

Conc. = concentration

GO = grid opening

HV = high volume

ID = identification

LA = Libby amphibole asbestos

LV = low volume

N = number

PCME = phase contrast microscopy-equivalent

s/cc = structures per cubic centimeter

APPENDIX E

DATA QUALITY ASSESSMENT

Investigations at the Libby Asbestos Superfund Site (Site) have generated a large amount of data on the Libby amphibole asbestos (LA) concentration in air, which were used in the risk assessment to quantify potential human exposures and risks. For most exposure scenarios, exposure estimates were based on measured LA concentrations in air. However, in some cases, soil data were also employed in the exposure estimates to group the air samples (e.g., exposures during yard soil disturbances [see **Table 6-3a**]) or to extrapolate exposure data to areas where air sampling was not performed. Thus, the focus of this data quality assessment (DQA) is on air and soil samples used in the risk assessment. The purpose of this appendix is threefold:

1) To describe the quality assurance (QA) procedures and quality control (QC) measures that have been established to govern the collection and analysis of air and soil samples at the Site;
2) To summarize the results for a variety of different types of QA/QC evaluations and analyses across the various sampling programs; and
3) To draw conclusions about the accuracy, precision, and reliability of reported results, and their suitability for use in risk assessment.

Information on specific QA/QC activities conducted for each investigation is provided in the investigation-specific data summary reports, which were cited in the main text. Detailed discussions of QA/QC for the Site are provided in a series of reports:

Site-wide Reports

- *QA/QA Summary Report for 1999-2009* (CDM Federal Programs Corporation [CDM Smith] 2012)
- *QA/QA Summary Report for 2010-2013* (CDM Smith 2014)
- *QA/QA Summary Report for 2014* (CDM Smith 2015)

Operable Unit 3 (OU3) Reports

- *Quality Assurance Support for RI/FS at the Libby Asbestos Site, OU3* (2007-2012) (CB&I Federal Services, LLC [CB&I] 2013a)
- *Quality Assurance Support for RI/FS at the Libby Asbestos Site, OU3* (2013) (CB&I 2015a)
- *Quality Assurance Support for RI/FS at the Libby Asbestos Site, OU3* (2014) (CB&I 2015b)

In addition, information pertaining to recent laboratory audits and data validation has also been summarized in a series of reports:

- *Quality Assurance Support for the Libby Asbestos Site* (2010-2012) (CB&I 2013b)
- *Annual Laboratory QA/QC Summary Report (2013)* (CB&I 2014)
- *Annual Laboratory QA/QC Summary Report (2014)* (CB&I 2015c)

A program-wide overview of QA activities for the field, soil preparation laboratory, and analytical laboratories is discussed below in Section E.1, Section E.2, and Section E.3, respectively. Section E.4 summarizes QC results, Section E.5 summarizes data management QA procedures and Section E.6 summarizes other data quality metrics that were evaluated to ensure results used in the risk assessment were of high quality.

E.1 Field Quality Assurance Activities

E.1.1 General

Field QA activities include processes and procedures to ensure that field samples are collected, handled, and documented properly, and that any issues/deficiencies associated with field data collection or sample processing are quickly identified and rectified. Detailed information on field QA activities can be found in the investigation-specific sampling and analysis plans (SAPs) and/or quality assurance project plans (QAPPs). These SAP/QAPPs were developed in general accordance with the U.S. Environmental Protection Agency (EPA) *Requirements for Quality Assurance Project Plans, EPA QA/R-5* (EPA 2001) and the *Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G4* (EPA 2006).

With the exception of Operable Unit 7 (OU7; Troy, Montana) and OU3 (the former mine site), activity-based sampling (ABS) and ambient air sampling programs at the Site were conducted by EPA contactors (e.g., CDM Smith, Tech Law, Inc. [Tech Law]). Because the Montana Department of Environmental Quality (DEQ) is the lead agency for OU7, investigations were conducted by the DEQ's contractor, Tetra Tech EM Inc. (Tetra Tech). For OU3, there is an Administrative Order on Consent between EPA and W.R. Grace and Company (Grace); therefore, sampling programs were conducted by Grace contractors in accordance with EPA-developed SAP/QAPPs.

The SAP/QAPPs were implemented by field contractors that were trained in asbestos sampling methodology. The following bullets summarize the components of the field QA program implemented at the Site:

- **Field Team Roles/Responsibilities** – There were a variety of field personnel involved in the sampling investigations conducted at the Site and each individual had assigned roles and responsibilities. The field team leader (FTL) oversaw all sample collection activities to ensure that governing documents were implemented appropriately. The field QA manager was responsible for ensuring that all field efforts were conducted in accordance with the governing SAP/QAPP and applicable QA requirements.

- **Field Team Training** – Individuals involved in the collection, packaging, and shipment of samples completed appropriate training, including Occupational Safety and Health Administration (OSHA) 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) and relevant 8-hour refresher updates, respiratory protection, and asbestos awareness training.

- **Orientation –** Field personnel were required to attend an orientation session with the field Health and Safety (H&S) manager, as well as an orientation session on sample collection techniques.

- **Investigation-Specific Documentation –** Field personnel were required to review and understand all applicable governing documents associated with the sampling investigation, including the SAP/QAPP, all associated standard operating procedures (SOPs), and the applicable Health and Safety Plan (HASP).

- **Readiness Reviews –** Meetings were conducted prior to beginning field sampling activities to discuss and clarify the objectives, equipment and training needs, field SOPs, QC samples, and H&S requirements for each investigation.

- **Field Documentation Review** – Field documentation was completed by field staff using Site-specific field forms. These field forms provided a standardized method of documenting sample information generated in the field. Field documentation was reviewed by the FTL on a regular basis to ensure the accuracy of the recorded sample information.

- **Equipment Maintenance/Calibration** – All field equipment was maintained in accordance with manufacturer specifications and Site-specific SOPs. For air samples, each air sampling pump was calibrated to the desired flow rate using a primary calibration standard prior to sample collection.

- **Equipment Decontamination** – Reusable equipment used in sample collection was decontaminated in accordance with Site-specific SOPs. Any disposable equipment or other investigation-derived waste (IDW) was handled in conformance with SOP requirements.

- **Sample Custody/Tracking** – All samples collected at the Site were tracked and managed in accordance with Site-specific SOPs for sample custody and tracking, using appropriate chain of custody (COC) forms.

- **Field QC Samples** – A variety of different types of field QC samples were collected as part of the investigations conducted at the Site. These QC samples provide information on potential contamination arising from sample collection methods, as well as information on result precision. (See Section E.4.1 for a detailed discussion of field QC results.)

- **Modification Documentation** – Major deviations from the SAP/QAPP that modified the sampling approach or associated guidance documents were recorded on a field record of modification (ROM) form. These ROMs were reviewed and approved by EPA.

E.1.2 Field Oversight

An important component of the field QA program is field oversight, which includes both field surveillances and field audits depending on the complexity of the investigation.

Field surveillances consist of periodic observations made to evaluate continued adherence to investigation-specific governing documents. Investigation-specific field surveillances were performed by the field contractor QA manager (or their designee). If not explicitly stated in contract requirements or the SAP/QAPP, the schedule for performing field surveillances was determined based on the duration of the investigation, frequency of execution, and magnitude of process changes. Typically, field surveillances were performed during the first week of a new field program to identify and mitigate issues early on, provide continuous improvement of processes and procedures, and facilitate mentoring/training. Thereafter, surveillances were conducted once a month or as necessary when field processes were revised or other QA/QC procedures indicated the possibility of deficiencies.

Field audits are broader in scope than field surveillances. Audits are evaluations conducted by qualified technical or QA staff that are independent of the activities audited. All aspects of data and sample collection, as well as sample documentation, handling, custody, and shipping are evaluated as part of a field audit. Field audits were conducted by field contractors, internal EPA staff, or EPA-contracted auditors in accordance with contract requirements or the investigation-specific SAP/QAPP. Like surveillances, field audits were typically conducted during the early stages of an investigation to identify and mitigate issues early on and provide for continuous improvement. Typically, at least one field audit was conducted for investigations with a project duration of one year.

There were numerous field surveillances and audits performed for the ABS and ambient air sampling programs. Detailed findings for each field surveillance/audit are documented in separate investigation-specific reports and are summarized in the *QA/QC Summary Reports* (CDM Smith 2012, 2014). The majority of the observations noted in the surveillances and audits pertained to adherence to field documentation processes (e.g., a visitor was not documented in the logbook); however, occasionally, deficiencies were noted (e.g., soil moisture content was not measured). To the extent possible, observations and deficiencies were addressed at the time they were discovered and in all cases, impacts were evaluated and improvements made to prevent recurrence. The impacts were determined to be minimal, such that they did not or were not likely to have negative impacts on Site data. This suggests that the field QA program has been effective in monitoring and ensuring field data quality and compliance with field requirements.

Information on field audits and surveillances for OU7 is not available.

E.2 Soil Preparation Laboratory Quality Assurance Activities

E.2.1 General

Soil or soil-like samples collected at the Site were sent to a soil preparation facility for drying, sieving, and grinding prior to analysis by the Site-specific polarized light microscopy (PLM) methods. From 2003 until about 2009, with the exception of OU7[1], all soil samples were prepared at the Close Support Facility (CSF) in Denver, Colorado, which was staffed by CDM Smith employees. Beginning in about 2009, all soil samples were sent to the Sample Preparation Facility (SPF) in Troy, Montana for preparation. The SPF is staffed by Tech Law employees.

The *CSF Soil Preparation Plan* (CDM Smith 2004) served as the guidance document for all activities at the CSF. The *SPF Soil Sample Preparation Work Plan* (Tech Law 2007) served as the guidance document for all activities at the SPF. The purpose of these soil preparation plans (SPPs) is to provide standard guidance on preparation methods to ensure that these procedures and resulting measurements were scientifically sound and of acceptable and documented quality. The following bullets summarize components of the QA procedures at the soil preparation laboratories:

- **Personnel Training** – Individuals involved in the processing of samples were required to have read and understood the SPP, all associated SOPs, as well as the facility HASP. In addition, personnel completed appropriate training, including OSHA 40-hour HAZWOPER and relevant 8-hour refresher updates.

[1] All soil samples collected from OU7 (Troy) were prepared at the SPF (including those collected prior to 2009).

- **Documentation Review** – Sample preparation documentation was completed by preparation laboratory staff using Site-specific forms. These forms provided a standardized method of documenting sample preparation information. This documentation was reviewed on a regular basis to ensure the accuracy of the recorded preparation information.

- **Equipment Maintenance/Calibration** – All weight scales, ventilation hoods, and drying ovens used in sample preparation were maintained and calibrated in accordance with manufacturer specifications. In addition, the plate grinder was calibrated daily to verify proper particle size and demonstrate that samples were not over-processed.

- **Equipment Decontamination** – Sample preparation equipment was decontaminated between each sample in accordance with the Site-specific sample preparation SOP.

- **Facility Contamination Monitoring** – The preparation laboratory performed regular contamination monitoring to evaluate worker safety, ensure laboratory cleanliness, and assess the potential for cross-contamination of samples submitted to the facility.

- **Sample Custody/Tracking** – All samples processed at the preparation laboratory were tracked and managed in accordance with COC requirements specified in the SPPs.

- **Preparation QC Samples** – A variety of different types of preparation QC samples were included in the preparation of samples collected as part of the investigations conducted at the Site. These QC samples provide information on potential cross-contamination arising from sample preparation methods as well as information on result precision. See Section E.4.2 for a detailed discussion of preparation QC results.

- **Modification Documentation** – Major deviations from the SPPs were recorded on a ROM form. These ROMs were reviewed and approved by EPA.

E.2.2 Audits

EPA's Quality Assurance Technical Support (QATS) contractor (CB&I, formerly Shaw Environmental, Inc. [Shaw]) performed an audit of the CSF in Denver in October 2008 and four audits of the SPF in Troy (in September 2008, August 2012, July 2013 and June 2014). Specific activities that were audited included the general laboratory facility, laboratory organization and personnel, general housekeeping, sample receipt and storage, sample preparation procedures, measurements and documentation, sample shipping procedures, and QA/QC procedures.

The 2008 CSF audit report was issued in March of 2009 (Shaw 2009). In brief, a total of 17 observed deficiencies were noted during the 2008 CSF audit. The majority of the observed deficiencies occurred within the following laboratory process area categories: sample preparation procedures (bulk drying), sample receipt, and QA/QC procedures (CB&I 2013b).

For the Troy SPF, a total of eight deficiencies were identified in 2008 and 10 deficiencies were identified in 2012. The laboratory process area categories in which the majority of the observed deficiencies occurred included preparation procedures (bulk drying, grinding, and splitting) and QA/QC procedures

(CB&I 2013b). A follow-up audit of the Troy SPF was performed in 2013 (CB&I 2014) to evaluate corrective actions taken by the laboratory to address deficiencies identified during the 2012 audit. The audit revealed that the laboratory had only completely addressed five, partially addressed one, and failed to address four of the ten deficiencies noted in the 2012 audit (CB&I 2014). The partially-addressed deficiency was identified for sample receipt and tracking (a final, complete, and signature-approved SOP for sample receiving, login, tracking, shipping, and archiving of samples was not available at the time). The deficiencies that were not addressed included a failure to calibrate and certify the balance on an annual basis by an outside vendor, a failure to accurately determine grinding recoveries, and a failure to weigh the dried portion, the fine fraction, and the coarse fraction to the nearest 0.1 gram of the sample. Corrective actions were recommended and were evaluated during the next audit in June 2014. This audit revealed that all previously identified deficiencies were addressed (CB&I 2015c). However, during this audit, two new deficiencies were noted in preparation procedures (the entire sample was not being homogenized and processed) and QA/QC procedures (grinding blanks were the first samples processed during the grinding process) (CB&I 2015c). Since the 2014 audit, processing procedures have been modified to address each of these deficiencies.

This suggests that the on-site audit program has been effective in monitoring and ensuring preparation laboratory data quality and compliance with preparation laboratory requirements. Although various deficiencies have been noted over time, most were minor in nature and did not impact data quality given the inherent uncertainty and variability associated with the PLM method itself (as demonstrated in Section E.4).

E.3 Analytical Laboratory Quality Assurance Activities

E.3.1 General

All laboratories selected for analysis of samples for asbestos were part of the Libby analytical laboratory team. These laboratories had demonstrated experience and expertise in analysis of LA in environmental media, and all were part of an ongoing Site-specific QA program designed to ensure accuracy and consistency of reported analytical results between laboratories. These laboratories were audited by EPA's QATS contractor and the National Institute of Standards and Technology (NIST)/National Voluntary Laboratory Accreditation Program (NVLAP) on a regular basis.

Laboratory QA activities include all processes and procedures designed to ensure that data generated by an analytical laboratory are of high quality and that any problems in sample preparation or analysis that may occur are quickly identified and rectified. The following bullets summarize the laboratory QA procedures that were required of each laboratory that analyzed samples from the Site.

- **Laboratory QA Management Plan** – Each laboratory developed a laboratory-specific *QA Management Plan* that provided a detailed description of the procedures and policies in place at their laboratory to ensure laboratory quality.

- **Certifications** – All analytical laboratories were subject to national, local, and project-specific certifications and requirements. Each laboratory was accredited by the NIST/NVLAP for the analysis of airborne asbestos by transmission electron microscopy (TEM) and/or analysis of bulk asbestos by polarized light microscopy (PLM). This included the analysis of NIST/NVLAP standard reference materials, or other verified quantitative standards, and successful participation in two proficiency rounds per year each of bulk asbestos by PLM and airborne asbestos by TEM supplied by NIST/NVLAP.

- **Team Training/Mentoring Program** – Laboratories were required to participate in a training/mentoring program to ensure they can demonstrate the ability to perform reliable analyses at the Site. The training process included a review of morphological, optical, chemical, and electron diffraction characteristics of LA using Site-specific reference materials, as well as training on Site-specific analytical methodology, documentation, and administrative procedures.

- **Technical Discussions/Conferences** – Laboratories participated in regular technical discussions with EPA and their contractors, as well as attended professional/technical conferences. These discussions enabled the laboratory and technical team members to have an ongoing exchange of information regarding all analytical and technical aspects of the project.

- **Analyst Training** – All TEM and PLM analysts were required to undergo method-specific training and understand the application of standard laboratory procedures and methodologies, including the Libby-specific analytical methods. Analysts familiarized themselves with the Site-specific method deviations, project-specific documents, and visual references.

- **Data Reporting** – Standardized benchsheets and data entry spreadsheets were developed specifically for the Site to ensure consistency between laboratories in the presentation and submittal of analytical data. All analysts were trained in the Site-specific reporting requirements and data reporting tools utilized in transmitting results.

- **Laboratory QC Samples** – A variety of different types of laboratory QC analyses were collected as part of the investigations conducted at the Site. These QC analyses provide information on potential contamination arising from laboratory preparation and analysis methods as well as information on result accuracy and precision. (See Section E.4.3 for a detailed discussion of analytical laboratory QC results.)

- **Laboratory Contamination Monitoring** – Each analytical laboratory performed regular contamination monitoring to evaluate worker safety and ensure laboratory cleanliness in compliance with their SOPs and certification requirements.

- **Modification Documentation** – Changes or revisions needed to improve or document specifics about analytical methods or laboratory procedures were documented using a laboratory ROM form. These ROMs were reviewed and approved by EPA.

E.3.2 Laboratory Audits

Each laboratory conducted internal audits of their specific operations on an annual basis using appropriate checklists in accordance with their laboratory-specific *QA Management Plan*. As noted above, the laboratories that were part of the Libby analytical laboratory team were also audited by EPA's QATS contractor on a regular basis to specifically evaluate adherence to all Libby-specific analytical requirements. On-site audits were used by EPA to verify that samples analyzed by their contract facilities were being processed in accordance with EPA requirements. Each on-site audit included a review of the general elements of preparation, on-site support, and report generation, which were modified as needed to fit the type of audit being performed.

The first series of laboratory audits was conducted in January of 2001. Because of performance concerns noted during this audit, one of the analytical laboratories was released from the Libby laboratory program. This laboratory did not analyze any of the ambient air or ABS air samples used in the risk assessment.

Nearly all of the air sample results that form the basis of the exposure assessment used in the risk characterization were analyzed from 2006 to 2015. A comprehensive series of laboratory audits was conducted in April-September 2008 to evaluate the TEM and PLM laboratories that support the Site. A second round of analytical laboratory audits was performed in June-August 2012. A third follow-up audits was performed in May-October 2013. A fourth round of laboratory audits was performed in March-September 2014. Detailed findings for each laboratory audit are documented in separate laboratory-specific audit reports. The overall conclusions of the laboratory audits are presented in CB&I (2013b, 2014, 2015c) and summarized below.

A total of 93 observed deficiencies, compiled from the completed summary on-site audit reports, were identified for six different analytical laboratories in 2008. The deficiencies identified in these laboratory audits were grouped into eight laboratory process areas. The laboratory process categories in which the majority of the observed deficiencies occurred included PLM, sample preparation, sample receiving, and QC/QA; whereas the laboratory process categories with the least frequently occurring deficiencies included TEM, facility, and data management. EPA requires that laboratories provide responses to on-site audit reports that include the laboratory's proposed corrective action to each of the identified audit deficiencies. Laboratory responses to the 2008 on-site audit reports were received from all the Libby team laboratories. The laboratory responses provided proposed corrective actions for the identified findings along with objective evidence as applicable. No findings were contested.

A total of 66 deficiencies were identified in the 2012 audits across eight analytical laboratories. An average number of 9.4 deficiencies per laboratory in 2012 represents a 39.4 percent (%) decrease from the 15.5 average number of deficiencies per on-site audit (for the same six laboratories) recorded in 2008. All six laboratories audited in 2008 and again in 2012 showed a significant reduction in the number of deficiencies, which indicates that all six laboratories applied effective corrective actions in response to their initial audits in 2008.

All of the analytical laboratories evaluated in 2012 were re-evaluated in 2013 to determine if the deficiencies identified in 2012 had been adequately addressed. In general, most of the deficiencies identified in 2012 were addressed. Also, the overall number of deficiencies (24) identified in 2013 was less than the number identified in 2012.

All of the analytical laboratories evaluated in 2013 were re-evaluated in 2014 to determine if the deficiencies identified in 2013 had been adequately addressed. Nearly every deficiency identified in 2013 was addressed; however, a total of 33 new deficiencies were identified in 2014. The laboratory auditor noted this increase was likely due to the more rigorous format of the audits performed in 2014 (2-day laboratory process audit) compared to 2013 (1-day follow-up audit) (CB&I 2015c). Laboratory responses to the deficiencies identified in the 2014 on-site audits provided appropriate corrective actions to adequately address each observed deficiency.

These audits demonstrate that the on-site audit program has been effective in monitoring and ensuring analytical laboratory quality and compliance with laboratory requirements. Although various deficiencies have been noted over time, most were minor in nature and did not impact data quality given the inherent uncertainty associated with the TEM method itself (as demonstrated in Section E.4).

E.4 Quality Control Results

As discussed above, a variety of field QC samples, preparation laboratory QC samples, and analytical laboratory QC analyses were included as part of the sampling investigations performed at the Site. A detailed review and discussion of the results for all QC samples and analyses is provided in the detailed Site-wide *QA/QC Summary Reports* (CDM Smith 2012, 2014, 2015) and the OU3-specific QA reports (CB&I 2013a, 2015a, 2015b). The following sub-sections summarize the overall conclusions from these reports.

E.4.1 Field Quality Control Samples

Various types of field-based QC samples have been collected for air and soil samples as part of investigations conducted at the Site. The investigation-specific SAP/QAPPs specified the field QC sample types and collection/analysis frequency required for each investigation. Field QC sample results are summarized briefly below.

<u>Lot Blanks</u>

A lot blank is an air filter cassette that has been taken from a new, unused box of filter cassettes. Lot blanks were collected to ensure that filters in unused cassettes do not have any asbestos contamination prior to their use in the field. Lot blanks were prepared by submitting unused cassettes for analysis prior to putting the cassette lot into use and were reviewed by designated field staff responsible for the project sample cassette inventory. Over 800 lot blank analyses were performed (typically, 10 grid openings are examined for each lot blank analysis). No asbestos structures were observed on any lot blank samples; therefore, it is concluded that the cassette lots were asbestos-free and usable for air sample collection at the Site.

<u>Field Blanks</u>

Field blanks were collected to evaluate potential contamination introduced during air sample collection, shipping and handling, or analysis. Air field blanks were collected by removing the end cap of the sample cassette to expose the filter in the same area where sample collection occurred for approximately 30 seconds before re-capping the sample cassette. The field blanks were analyzed for asbestos by the same method used for field sample analysis.

If asbestos was observed on the analyzed field blank, all other field blanks collected by that team during that week were submitted for analysis to determine the potential impact on the related sample results. If any asbestos was observed on a field blank, the FTL and/or laboratory manager was notified and appropriate measures taken (e.g., retraining) to ensure staff are employing proper sample handling and analysis techniques. In addition, a qualifier of “FB” is added to the related field sample results in the project database (see Section E.5.1) to denote that the associated field blank had asbestos structures detected.

More than 8,100 field blank samples have been collected and analyzed by TEM as part of the various air sampling programs at the Site. Typically, 10 grid openings are examined for each field blank analysis. Approximately 0.1% of these field blanks contained LA structures, with no field blank samples containing LA structures since 2002. On average, the total asbestos background filter loading rate across all field blanks was about 0.01 fibers per square millimeter (f/mm^2). When asbestos fibers were detected, in many cases, TEM results were also available for an additional field blank sample that was collected by the same field team at the same property on the same day as the field blank containing LA structures, and this additional field blank did not indicate detectable levels of LA. This suggests that contamination of air samples due to field sampling methods occurs rarely, and when detections are noted, they do not appear to be associated with systemic or large-scale field sampling issues. Based on the low frequency of detectable LA structures observed in field blanks, it is concluded that contamination of collected air samples due to field sampling methods is not a significant issue and impacts on reported LA air concentrations are negligible.

Field Duplicates[2]

Field duplicates were collected from the same sampling location at the same time as the parent field sample. Field duplicates were collected using the same collection technique as the parent sample. Field duplicates were analyzed by the same method as field samples and were blind to the analytical laboratories (i.e., the laboratory could not distinguish between field samples and field duplicates).

Field duplicates were not routinely collected for air, but were collected as part of several investigations. In order to be ranked as concordant, air field duplicate results must not be statistically different from the "parent" field sample at the 90% confidence interval (CI), as evaluated using the Poisson ratio test[3] (Nelson 1982). More than 200 air field duplicates have been collected, with almost 99% being ranked as concordant. These results show that air field duplicate results are reproducible and reliable.

For soil, field duplicates analyzed by PLM-VE were considered concordant if the reported PLM-VE "bin" result for the field duplicate was the same as the original sample. Results were ranked as "weakly discordant" if the field duplicate was within one bin of the parent field sample. Results were ranked as "strongly discordant" if the field duplicate was different by two bins. There are no concordance requirements established for soil field duplicates. Rather, concordance results are used to inform data users on result variability.

Results are available for approximately 2,400 soil field duplicates. The overall percentages on agreement are as follows:

[2] Historically (pre-2003), field splits for soil were also collected. A field split is an aliquot of a field sample that is taken after the soil sample (often a composite) has been collected and mixed. A field split helps to evaluate the precision of the subsequent laboratory preparation and analysis steps. However, more recent investigation only employ field duplicates. Concordance data include both field splits and duplicates.

[3] Laboratory ROM LB-000029 includes an Excel spreadsheet tool that can be used by the laboratory staff to make this statistical comparison.

- Concordant = 85%
- Weakly discordant = 14%
- Strongly discordant = 0.5%

When field duplicate results differed from the parent field sample, it was usually due to differences between Bin A (non-detect) and Bin B1 (trace; detected at levels less than 0.2% by mass). While field duplicate discordances may occur due to authentic field spatial heterogeneity, preparation variability and/or analytical uncertainty, the soil field duplicate results support the conclusion that estimates of soil concentration by PLM-VE were generally reproducible and reliable.

E.4.2 Preparation Laboratory Quality Control Samples

The preparation laboratory QC samples were collected to ensure that the preparation techniques utilized to process soil samples did not introduce potential contamination and to evaluate variability associated with preparation techniques. Two types of preparation laboratory QC samples were collected by the soil preparation facilities – preparation blanks (including grinding blanks and drying blanks) and preparation duplicates. Preparation laboratory QC sample results are summarized briefly below.

<u>Preparation Blanks</u>

A drying blank consists of approximately 100 to 200 grams of asbestos-free quartz sand that is processed with each batch of field samples that were dried together (usually there were approximately 125 samples per batch). Drying blanks are processed identically to field samples and determine if cross-contamination between samples is occurring during sample drying. More than 2,700 drying blanks have been analyzed and 99% have been reported as non-detect (Bin A) by PLM-VE. On the rare occasion that LA was detected in a drying blank, results were reported as trace (Bin B1).

A grinding blank consists of asbestos-free quartz sand that is processed along with the field samples on days that field samples are ground. Grinding blanks determine if decontamination procedures of laboratory soil processing equipment used for sample grinding and splitting were adequate to prevent cross-contamination. Grinding blanks are prepared at a frequency of one per grinding batch per grinder per day. More than 2,500 grinding blanks have been analyzed and 99% have been reported as non-detect (Bin A) by PLM-VE. When LA was detected, results were reported as trace (Bin B1).

These results indicate that inadvertent contamination during soil sample drying and grinding processes occurred rarely and is not expected to impact reported LA soil concentrations by PLM-VE.

<u>Preparation Duplicates</u>

Preparation duplicates are splits of field samples submitted for sample preparation. Preparation duplicates are used to evaluate the variability that arises during the soil preparation and analysis steps. After drying, but prior to sieving, a preparation duplicate is prepared by using a riffle splitter to divide the field sample (after an archive split has been created) into two approximately equal portions, creating a parent and duplicate sample. The variability between the preparation duplicate and the associated field sample reflects the combined variation due to sample preparation (sieving and grinding) and to PLM measurement error.

More than 3,300 preparation duplicates have been analyzed by PLM-VE. Preparation duplicate results were evaluated using the same methods as described above for field duplicates. Overall concordance results are as follows:

- Concordant = 87%
- Weakly discordant = 13%
- Strongly discordant = 0.2%

Preparation duplicate results are considered acceptable if the frequency of weak discordances is less than 20% and the frequency of strong discordances is less than 5%. As shown, the preparation duplicate results meet these acceptance criteria.

When preparation duplicate results differed from the parent sample, it was usually due to differences between PLM-VE Bin A (non-detect) and Bin B1 (trace). Slight differences between aliquots of the same sample are expected due the inherent heterogeneity of soil samples and the limitations of the PLM-VE method at the low levels observed at the Site. The results for preparation duplicates are generally similar to the results for field duplicates (see Section E.4.1). These results support the conclusion that the soil sample results are generally reproducible and reliable and were not greatly influenced by differences in soil preparation and analysis techniques.

E.4.3 Analytical Laboratory Quality Control Analyses

In the risk assessment, two types of air samples formed the basis of the exposure assessment – ABS air and ambient air. All ABS and ambient air samples were analyzed for asbestos using TEM. Soil samples were analyzed by the Site-specific PLM methods. Laboratory QC analyses and results for TEM and PLM are summarized briefly below.

E.4.3.1 TEM

The laboratory QC requirements for TEM analyses at the Site were patterned after the requirements set forth by NVLAP, and include:

- Laboratory blanks
- Repreparations
- Recounts (i.e., recount same, recount different, and verified analyses)
- Inter-laboratory analyses

Results for each type of TEM laboratory QC analysis are summarized briefly below.

Laboratory blanks

A laboratory blank is an analysis of TEM grids that are prepared from a new, unused filter which has been prepared and analyzed using same procedures as used for field samples. Laboratory blanks monitor overall laboratory cleanliness. More than 2,700 laboratory blank samples have been analyzed by TEM. Typically, 10 grid openings are examined for each laboratory blank analysis. No LA structures have been observed in any laboratory blank sample. Based on these results, it is concluded that the TEM preparation and examination procedures within the analytical laboratories have not introduced LA contamination.

Repreparations

A repreparation is an analysis of TEM grids that are prepared from a new section of the same field filter used to prepare the original grids. Typically, this is done within the same laboratory that performed the original analysis, but a different laboratory may also prepare grids from a new piece of the filter. If the repreparation is performed within the same laboratory, the repreparation and reanalysis is performed by a different analyst than performed the original analysis, whenever possible.

Repreparation analyses were evaluated by the analytical laboratory by comparing the results for the original and the repreparation analyses. In order to be ranked as concordant, the results must not be statistically different from each other at the 90% CI, as evaluated using the Poisson ratio test[4] (Nelson 1982). If the repreparation results were found to be statistically different from the original analysis results, a senior analyst investigated to see if this discordance was related to laboratory procedures, and took appropriate corrective action as needed (e.g., re-training in sample and filter preparation, counting rules, quantification of size, identification of types, etc.).

More than 800 repreparation analyses of air samples have been performed by the TEM laboratories. Repreparation analyses for air samples were statistically different at the 90% CI for approximately 5% of these analyses. This observed frequency (5%) is within the expected frequency (10%) based on random variation. Even when results were statistically different, LA air concentrations for repreparations were usually within a factor of 10 of the originally reported air concentration. These results indicate that TEM air concentrations have good precision and are not greatly influenced by differences in grid preparation techniques.

Recount Analyses

Recount analyses are a re-examination (or recount) of the original TEM grid openings that were evaluated in the initial analysis. This may be done in several different ways, as follows:

- ***Recount Same –*** This is an analysis in which the original TEM grid openings are re-examined by the same microscopist who performed the initial examination.

- ***Recount Different –*** This is an analysis in which the original TEM grid openings are re-examined by a different microscopist in the same laboratory than who performed the initial examination.

- ***Verified Analysis –*** This analysis is similar to a Recount Different but has more detailed requirements with regard to documentation. A verified analysis must be recorded in accordance with the protocol provided in NIST (1994).

[4] Laboratory ROM LB-000029 includes an Excel spreadsheet tool that can be used by the laboratory staff to make this statistical comparison.

- ***Inter-laboratory* –** This is an analysis in which a previously analyzed sample is re-prepared by the original laboratory and these TEM grid openings are re-examined by a microscopist in a different laboratory than the initial examination. Inter-laboratory analyses are selected post hoc by the QATS contractor or their designee. The list of samples selected for inter-laboratory analysis is provided to the LC, who coordinates with the analytical laboratories to ensure that selected samples are prepared and analyzed in accordance with the inter-laboratory procedures in laboratory ROM LB-000029.

Recount analysis results were evaluated based on grid opening- and structure-specific concordance criteria presented in laboratory ROM LB-000029. Results of the TEM laboratory QC analyses show that there have been some differences in structure counting and recording methods within and between the analytical laboratories, with within-laboratory precision being better than between-laboratory precision (CDM Smith 2012, 2014, 2015; CB&I 2013a, 2015a, 2015b). For example, concordance rates for the number of LA structures per grid opening were approximately 99% for recount same, recount different, and verified analyses (based on approximately 27,000 grid opening pairs), whereas concordance rates were 78% for inter-laboratory analyses (based on approximately 1,300 grid opening pairs).

Concordance rates for matched structures were about 99% for mineral class, 84-99% for structure length, and 88-100% for structure width for within-laboratory recounts; whereas between-laboratory concordance rates for matched structures were about 87-98% for mineral class, 84-93% for structure length, and 98-99% for structure width. These concordance rates primarily are in the "acceptable" to "good" range based on program-wide criteria specified in laboratory ROM LB-000029. Based on these results, the between-laboratory differences in structure counting and recording methods are not expected to be a large source of uncertainty in reported air concentrations.

E.4.3.2 PLM

Three types of laboratory-based QC analyses were performed for PLM-VE, including laboratory duplicates (both self-checks and cross-checks), inter-laboratory analyses, and performance evaluation (PE) standard analyses.

Laboratory Duplicates

A laboratory duplicate *self-check* is a repreparation of a soil sample slide by the same analyst. A laboratory duplicate *cross-check* is a reanalysis of a soil sample slide by a different analyst. More than 6,900 laboratory duplicate analyses have been performed. Laboratory duplicate results were evaluated using the same methods as described above for field duplicates.

Overall concordance was generally good for both laboratory duplicate self-check and cross-check analyses, with more than 96% of laboratory duplicate results ranked as concordant. When results were different between the original sample and the laboratory duplicate, they were usually only weakly discordant (i.e., results were within one bin). These results show that there was good within-laboratory reproducibility in PLM-VE LA results.

Inter-Laboratory Analyses

An inter-laboratory analysis is an examination of a second fine ground aliquot of the same soil sample by a PLM analyst at a different laboratory than completed the original analysis. Inter-laboratory results are evaluated using the same concordance evaluation methods as described above for laboratory duplicates.

To date, more than 650 PLM-VE inter-laboratory analyses have been performed. The overall concordance rate for inter-laboratory analyses tends to be lower than for laboratory duplicate analyses, with rates ranging from 53 to 68% (depending upon the time period). These inter-laboratory results show that there are differences between the analytical laboratories in reported LA PLM-VE bin results, mainly in the distinction between non-detect (Bin A) and trace (Bin B1) LA soil concentrations (CB&I 2012; CDM Smith 2012, 2014, 2015). In particular, prior to 2014, EPA's Environmental Services Assistance Team, Region 8 (ESATR8) laboratory had demonstrated proficiency in detecting the presence of trace levels (Bin B1) of LA in soil compared to other laboratories (CDM Smith 2014) (i.e., the ESATR8 laboratory is able to detect trace LA in soil samples ranked as non-detect [Bin A] by other PLM laboratories). However, PLM-VE inter-laboratory analyses performed in 2014, efforts taken in 2014 to improve between-laboratory consistency in PLM-VE analysis techniques appear to have been effective in addressing this bias (CDM Smith 2015).

In general, the majority of soil samples used to group the outdoor ABS air data were analyzed by the ESATR8 laboratory. Thus, there is less uncertainty in the PLM-VE results for the soil samples used in the risk assessment. However, the ESATR8 laboratory did not begin performing PLM-VE analyses until about 2008; thus, soil samples collected prior to this would have been analyzed by non-ESATR8 laboratories. Any extrapolation of the risk characterization results to properties and locations without outdoor ABS that is based on soil data must consider which PLM laboratory performed the soil analyses. Even for PLM analyses performed by the ESATR8 laboratory, all soil sample results have uncertainty due to the inherent variability in the analytical method.

Performance Evaluation Standard Analyses

The U.S. Geological Survey has prepared several different Site-specific reference materials for use during PLM-VE analyses (EPA 2008b). These reference materials were prepared by adding known aliquots of LA spiking material to uncontaminated[5] soils from Libby to obtain several different nominal LA concentrations (based on mass percent). Aliquots of these reference materials are utilized as performance evaluation (PE) standards to evaluate PLM-VE laboratory accuracy and precision. PE standard results are ranked as acceptable if the correct semi-quantitative bin is reported, as determined by the nominal concentration of the PE standard.

Over 200 PE standards, representing a range of nominal levels, have been analyzed by the PLM laboratories. In general, about 68% were ranked as concordant (meaning the reported bin was the same as the expected bin based on the nominal level). When results were discordant, they were usually only weakly discordant (i.e., within one bin) and tended to be biased low. Less than 5% of PE standards had results that were ranked as strongly discordant. PE standards with nominal LA levels near bin

[5] Recent analyses of "non-detect" PE standards, which were prepared using the unspiked soil (the uncontaminated Libby soils), have been shown to contain LA fibers when analyzed by TEM following preparation by fluidized bed. In all cases, the "non-detect" PE standards have been ranked as Bin A by PLM-VE. These results highlight the fact that PLM-VE is not able to reliably detect low levels (less than 0.05%) of LA in soil.

boundaries (i.e., 0.2%, 1%) were the most difficult to assign accurately. These results demonstrate that PLM-VE results are generally accurate but there are inherent uncertainties associated with reported binned results.

E.5 Data Management Quality Assurance Activities

E.5.1 Database

<u>Application</u>

Historically, there was a single standard query language (SQL) server database for the entire Libby project, referred to as the "Libby2 Database", which was used to manage and maintain most[6] sample information, analysis details, and analytical results for all samples collected at the Site. The Libby2 Database was also used to track property status information. As of December 2009, the Libby2 Database was decommissioned and archived on EPA's server at the Region 8 office in Denver, CO.

Beginning in January 2010, field and analytical Site data has been managed in Scribe. Scribe is a software tool developed by EPA's Environmental Response Team (ERT) to assist in the process of managing environmental data. A Scribe project is a Microsoft® Access database. Multiple Scribe projects can be stored and shared through Scribe.NET, which is a web-based portal that allows multiple data users controlled access to Scribe projects. Local Scribe projects are "published" to Scribe.NET by the entity responsible for managing the local Scribe project. External data users "subscribe" to the published Scribe projects *via* Scribe.NET to access data. Subscription requests have been managed by ERT.

All field-related data (e.g., sample information, location specifics, pump information) contained in the Libby2 Database, which included all investigative and H&S programs conducted at the Site from 1999-2009, have been migrated to Scribe. However, the analytical information and results have not and will not be migrated to Scribe. These data can be accessed in the historical Libby2 Database which is available upon request from EPA.

Due to the nature of asbestos analysis and other data reporting requirements, the project databases were developed iteratively, expanding in capabilities (and complexity) as project-specific needs evolved. In addition to providing new functionality, as needed, enhancements were made to accommodate data user needs and to incorporate various automated QA/QC procedures to improve data integrity.

Because data are continually being generated as a result of ongoing sampling and analysis at the Site, the project databases are dynamic. Each day, new sample, analysis, and results records are added and records are corrected, as appropriate. As a result, any database-generated queries, tables, figures, maps, and reports provide only a "snapshot" of the database on the day the output was created. All non-OU3 data summaries included in the risk assessment are based on a database snapshot dated July 20, 2015. All OU3 data summaries included in the risk assessment are based on a database snapshot dated November 13, 2015.

[6] Investigation samples from OU3 and OU7 were not maintained in the Libby2 Database. OU3 data is managed in an OU3-specific Microsoft Access® relational database and OU7 data has always been managed in OU7-specific Scribe projects.

Administration and Security

As noted above, Scribe subscription requests are managed by ERT. A data user cannot gain access to the Scribe databases without being provided subscription information, which includes a login and password specific to each Scribe project.

Data Entry Processes

The project databases have a variety of built-in QC functions that improve accuracy of data entry and help maintain data integrity. For example, field data entry forms utilize drop-down menus whenever possible. Drop-down menus allow the data entry personnel to select from a set of standard inputs. The use of drop-down menus prevents duplication and transcription errors and limits the number of available selections (e.g., valid media types).

The analytical laboratories were required to transmit results using Site-specific electronic data deliverable (EDD) spreadsheets. Each EDD contains a variety of built-in QC functions that improve the accuracy of data entry and help maintain data integrity. For example, data entry forms utilize drop-down menus whenever possible to standardize data inputs and prevent transcription errors. In addition, many data input cells are electronically checked in the EDD spreadsheet to highlight omissions, apparent inconsistencies, or unexpected values so that data entry personnel can check and correct any errors before submittal of the EDD. These spreadsheets also perform automatic computations of analytical sensitivity, dilution factors, and concentration, thus reducing the likelihood of analyst calculation errors.

The transmitted EDDs were uploaded directly into the project databases using "upload" procedures designed specifically for each type of EDD, which avoids potential errors related to manual entry of the results. Each upload procedure performed several integrity checks to ensure that records were consistent and complete prior to uploading the analytical data. For example, the project database allows a unique sample ID to only be entered once, thus ensuring that different samples cannot inadvertently be assigned the same sample number. If issues were identified, the analytical EDD was not uploaded until the issues were rectified.

E.5.2 Asbestos Data Verification

Prior to the preparation of any data summary reports, a cursory data review was performed on applicable data to identify potential omissions, unexpected values, or apparent inconsistencies. Because analytical laboratories utilized Site-specific EDD spreadsheets, data checking of reported analytical results began with automatic QC checks built into these spreadsheets (discussed above). In addition to these automated checks, as dictated by the governing investigation-specific SAP/QAPP, a more thorough data verification evaluation was also performed to ensure the consistency and quality of reported data.

Asbestos data verification included checking that results are transferred correctly from the original hand-written, hard copy field and analytical laboratory documentation to the project database. This data verification process utilized Libby-specific SOPs developed to ensure TEM and PLM results and field sample information in the database were accurate and reliable. The SOP for TEM verification (SOP EPA-LIBBY-09) and PLM verification (SOP EPA-LIBBY-10) describe the review of the laboratory benchsheets and verification of the transfer of results from the benchsheets into the project database. The SOP for field sample data sheet (FSDS) verification (SOP EPA-LIBBY-11) describes the steps for the verification of field sample information, based on a review of the FSDS form, and verification of the transfer of results from the FSDS forms into the project database. An FSDS review is performed on all samples selected for TEM or PLM data verification.

The goal of the data verification was to identify and correct data reporting errors. The frequency of data verification was specified in each investigation-specific SAP/QAPP; typically, a minimum of 10% of sample and analysis results were verified. This frequency increased if there were issues identified in the verification effort. For the purposes of the Libby residential sampling efforts, 100% of sample and analysis results were verified prior to the distribution of results to the property owner. For Troy, 20% of the sample and analysis results were verified[7].

In brief, most of the issues identified during these data verification efforts were non-critical in nature, meaning that they were typographical errors and inconsistencies that did not influence LA results or data interpretation. The frequency of critical errors (i.e., those that could influence LA results and data interpretation) was generally low. Error frequencies tended to be higher following particular programmatic changes in laboratory methods and data reporting requirements and at the beginning of sampling investigations.

All issues identified during the various data verification efforts were submitted to the field teams and/or analytical laboratories for resolution and rectification. All tables, figures, and appendices generated for this risk assessment reflect corrected data.

E.5.3 Asbestos Data Validation

Unlike asbestos data verification, where the goal was to identify and correct data reporting errors, the goal of asbestos data validation was to evaluate overall data quality and to assign data qualifiers, as appropriate, to alert data users to any potential data quality issues.

Until recently, formal data validation guidelines for asbestos did not exist. Thus, data validation efforts were performed by EPA technical contractors following the completion of each investigation and consisted primarily of a review and assessment of field and laboratory ROM forms, field QC data (e.g., field duplicates, field blanks), and laboratory QC data (e.g., recounts, repreparations) to identify potential data quality issues with respect to result precision, accuracy, representativeness, completeness, and comparability. No review of instrument calibration or control standard data was performed, as this type of information was included in the regular NVLAP certification process.

In late 2011, EPA released a draft of the *National Functional Guidelines (NFGs) for Asbestos Data Review* (EPA 2011b). These guidelines include review criteria and recommended data qualifiers for validation of TEM and PLM data. However, these draft asbestos NFGs have not been finalized. Consequently, EPA's QATS contractor (CB&I) developed Libby-specific SOPs for data validation of asbestos datasets based on the draft asbestos NFGs. CB&I performed formal data validation review of asbestos results for investigations conducted from 2007 to 2012 (CB&I 2013b), 2013 (CB&I 2014), and 2014 (CB&I 2015c). The conclusions of these reviews are summarized below.

[7] It should be noted that there were issues identified in the Troy residential sampling effort where additional verification may be desirable to support risk management decision-making.

More than 4,000 field samples from over 400 different laboratory jobs were selected for validation. Samples for validation were selected randomly (5% frequency), choosing samples that were representative across laboratory, analysis method, and media. Less than 0.5% of the selected analyses required qualification. No ambient air samples were qualified and only six ABS air samples were qualified (two were R-qualified and four were J-qualified[8]). When qualification was needed, it was usually due to the failure of the laboratory to perform and/or document daily calibration activities. No R-qualified analyses were used in the HHRA.

Based on the very low frequency of qualification, the data validation results support the conclusion that the reported air and soil concentrations used in the risk assessment are of high quality.

E.6 Other Data Quality Evaluation Metrics

Three additional data quality evaluation metrics were evaluated for air samples analyzed by TEM to ensure reported LA concentrations were of adequate quality and reliable to support risk management decision-making. This included the confirmation of the TEM analysis stopping rules (Section D6.1), a test of filter loading evenness (Section D6.2), and an assessment of the frequency and effect of indirect filter preparation methods (Section D6.3). Each are these metrics are discussed further below.

E.6.1 Confirmation of TEM Analysis Stopping Rules

Specific requirements for the TEM analysis of air samples are detailed in the governing SAP/QAPPs. These requirements include the TEM analysis stopping rules. In general, three alternative stopping rules are specified for TEM analyses to ensure resulting data are adequate:

1. The target analytical sensitivity (TAS) to be achieved
2. A maximum number of LA structures to be counted
3. A maximum area of filter to be examined

When one of these stopping rules is met, the TEM analyst can stop counting grid openings and the analysis is complete.

Target Analytical Sensitivity (TAS). As discussed in **Appendix B**, there is no “preset” lower limit of analytical sensitivity for TEM; in theory, the analytical sensitivity can be lowered simply by reading more and more grid openings. The level of analytical sensitivity needed to ensure that the analysis of an air sample will be adequate for use in risk assessment is derived by finding the concentration of LA in air that might be of potential concern, and then ensuring that if an air sample were encountered that had a true concentration equal to that level of concern, it would be quantified with reasonable accuracy. Thus, the TAS was determined for each investigation based on a back-calculated risk-based concentration (RBC) that was specific to the receptor and exposure scenario for each investigation to ensure the resulting achieved analytical sensitivities would be adequate to support Site-specific risk estimates and decision-making.

[8] R-qualified analyses are rejected due to data quality issues. J-qualified analyses are useable, but concentrations are considered estimates.

In general, most TEM analyses for ambient and ABS air samples used in the risk assessment achieved the TAS; however, for several of the earlier (pre-2011) ABS datasets, the specified TAS at the time was not adequate to support decisions based on the non-cancer endpoint. This is because earlier ABS programs were conducted prior to the development of the draft LA-specific reference concentration (RfC) and RBCs were derived to be protective of the cancer endpoint, which is not the most sensitive endpoint (see Section 4.2 in the main text). EPA has performed several supplemental[9] TEM analyses on datasets to achieve an improved sensitivity for specific ABS datasets, including a subset of 2010 Operable Unit 4 (OU4) ABS air samples during soil disturbances in yards, gardens, and driveways, a subset of the recreational and occupational ABS air investigations in forested areas surrounding OU3, and a subset of the OU4 outdoor schools ABS air samples.

Maximum Number of LA Structures. For filters that have high asbestos loading, reliable estimates of concentration may be achieved before achieving the TAS. This is because the uncertainty around a TEM estimate of asbestos concentration in a sample is a function of the number of structures observed during the analysis (see **Appendix B**). The goal was to specify a maximum number of structures such that the resulting Poisson uncertainty was not a substantial factor in the evaluation of method precision. For most investigations, the maximum number of LA structures was 25 structures (meaning that the analysis could stop if 25 structures were recorded regardless of the achieved sensitivity). As shown in **Figure 10-1** (see the main text), above about 25 structures, there is little change in the relative uncertainty due to Poisson uncertainty.

Few air samples utilized in the risk assessment achieved the maximum number of LA structures stopping rule; typically, most samples have lower structure counts (fewer than 10 structures). Because of this, and because there is no EPA-approved method for calculating upper confidence limits (see **Appendix B**), it is important to recognize that the exposure estimates used in the risk assessment are uncertain due Poisson counting error (analytical uncertainty) as well as sampling variability.

Maximum Filter Area to be Examined. The number of grid openings that must be examined during a TEM analysis of an air sample depends upon the TAS, the air sample volume, and – if an indirect preparation was necessary – the dilution needed during the indirect preparation (i.e., f-factor). Depending upon these inputs, the number of grid openings that would need to be examined to achieve the TAS may become excessive. The maximum filter area is specified to limit the analytical time and cost spent on any single analysis. For investigations conducted prior to 2010, the maximum filter area was usually about 0.5 mm^2 to 1 mm^2 (about 50-100 grid openings). For investigations conducted after 2010 (after the draft LA-specific RfC value was developed which showed that much lower analytical sensitivities were necessary to support risk estimates), the maximum filter area was usually about 10 mm^2 to 20 mm^2 (about 1,000-2,000 grid openings).

Analyses that were stopped due to the maximum filter area examined stopping rule have the largest uncertainty relative to the other stopping rules described above. As discussed in the Uncertainty Assessment (Section 10.1.2 of the main text), for most datasets, the fact that the TAS was not achieved will not alter overall risk assessment conclusions; however, supplemental TEM analysis could be performed for some of the earlier (pre-2011) datasets to reduce uncertainties.

[9] A supplemental analysis is where the TEM analyst examines additional grid openings for the same filter (and often the same grids) as the original analysis. Results of the supplemental analysis are pooled with the original analysis using the equation shown in Section 2.3.2 of the main text.

E.6.2 Evenness of Air Filter Loading

An analysis of an air filter by TEM assumes that the filter is evenly loaded (i.e., that fibers are distributed at random across the filter). The assessment of filter loading evenness is evaluated using a Chi-square (CHISQ) test, as described in ISO 10312 Annex F2. If a filter fails the CHISQ test for evenness, the reported result may not be representative of the true concentration in the sample, and the results should be given low confidence.

An evaluation of filter loading was typically performed for each investigation and summarized in the investigation-specific data summary reports. In general, the majority of ambient and ABS air samples passed the CHISQ test (i.e., p value ≥ 0.001). For example, out of 220 filters analyzed from the 2011 OU4 outdoor residential ABS investigation, 214 (97%) passed the CHISQ test. During the 2007/2008 outdoor residential investigation, 449 out of 460 filters (98%) passed the CHISQ test. Because of the low frequency of CHISQ failures, it is concluded that uneven filter loading is not of significant concern and is not likely a source of uncertainty for air samples used in the risk assessment.

E.6.3 Indirect Preparation of Air Filters

As discussed in Section 2.3.4 and 10.1.3 of the main text, if an air filter was deemed to be overloaded or if loose material was noted in the air cassette or adhering to the cowl, the filter was prepared indirectly (usually with ashing) in accordance with the indirect filter preparation procedures in Libby-specific SOP EPA-LIBBY-08. For chrysotile asbestos, indirect preparation tends to increase structure counts due to dispersion of bundles and clusters; however, the effects of indirect preparation on amphibole asbestos are generally much smaller, usually only increasing concentrations by a factor of 2-3 (Goldade and O'Brien 2014; see **Appendix D**).

As seen in **Table E-1**, the frequency of indirect preparation varies by investigation. Ambient air samples were prepared indirectly at a frequency of 2% (across all OUs and sampling programs), while ABS air filter tended to have a higher frequency of indirect preparation, depending on the ABS investigation. As expected, most of the filters that required indirect preparation were collected during source disturbance scenarios where dust generation was higher. For example, 64% of yard ABS air samples collected under the "high intensity" ABS script in 2007/2008 required indirect preparation. For OU3, more than half of the ABS air samples collected while cutting fire lines in the forested area required indirect preparation.

In order to ensure that air concentrations used in the risk assessment were not biased high due to filter preparation methods, concentrations for all air samples that were indirectly prepared were adjusted (decreased) by a factor of 2.5. This factor was based on Libby-specific studies of the potential effect of indirect preparation on air samples (see **Appendix D**). However, the actual effect of indirect preparation likely depends upon the nature of the LA structures present on the filter, which could differ depending upon the source material (e.g., soil, tree bark, VI), the sampling location (e.g., at the mine site in OU3, inside an attic at an OU4 residence), and the type of disturbance activity. Hence, an estimated concentration calculated using an adjustment factor of 2.5 may be higher or lower than the true concentration.

E.7 Data Quality Assessment Summary and Conclusions

Investigations at the Site have generated a large amount of data on the LA concentration in air and soil, which were used in the risk assessment to quantify potential human exposures and risks. EPA developed and implemented an extensive a QA/QC program for the Site to ensure that the quality of the data collected could be evaluated to ensure they were adequate to support management decisions on potential risks to human health from exposures to LA.

Key elements of the Site QA program include:

- The use of detailed SAP/QAPPs to guide all sample collection, preparation, and analysis efforts
- The use of detailed Site-specific SOPs for sample collection, preparation, and analysis
- Extensive training of all field, sample processing, and laboratory staff
- Extensive review and checking by senior staff of the work performed by field, sample preparation, and laboratory staff
- Periodic internal and external audits of field, sample preparation, and laboratory operations
- Iterative modifications to improve methods and document procedures used to address any issues or problems identified by field staff, sample processing staff, laboratory staff, or data users
- The use of approved QA plans at project laboratories
- The use of electronic data management tools for recording and transferring data that include a variety of error checks
- The collection and analysis of a variety of field, preparation facility, and laboratory QC samples
- Validation and verification of electronic data in the project databases

Based on the QC data that have been collected at the Site, it is concluded that:

- Blank samples (e.g., lot blanks, field blanks, preparation blanks, laboratory blanks) show that inadvertent contamination of field samples with LA or other forms of asbestos is not of significant concern, in the field, at the soil preparation facility, or at the analytical laboratory.

- Field duplicate samples show that variability due to small-scale heterogeneity and sample analysis is likely to be small and results tend to be reproducible.

- Soil preparation duplicates show that results are not greatly influenced by differences in soil preparation techniques.

- For both TEM (air) and PLM (soil), there is generally high agreement (good concordance) for intra-laboratory analyses. Inter-laboratory analyses suggest that, while results are generally acceptable, there are some differences in methods or procedures between analytical laboratories.

  - For TEM, between-laboratory differences in structure counting and recording methods are not expected to be a large source of uncertainty in reported air concentrations.

  - For PLM, prior to 2014, there were differences between the analytical laboratories in reported LA PLM-VE bin results, mainly in the distinction between non-detect (Bin A) and trace (Bin B1) LA soil concentrations. However, there is less uncertainty in the PLM-VE results used in the risk assessment because the majority of soil samples used to group the outdoor ABS air data were analyzed by the ESATR8 laboratory (a laboratory with demonstrated proficiency in detecting the presence of trace levels of LA in soil).

Taken together, these results indicate the QA/QC procedures used at the Site have been effective in ensuring that the data collected are of high quality. As such, these data are of acceptable quality and are reliable and appropriate to support risk management decision-making.

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TABLE E-1
Summary of Indirect Preparation Frequency by Investigation
Libby Asbestos Superfund Site

Panel A: Outdoor ABS Studies During Soil/Duff Disturbances

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU1	Summer 2013	Post-Construction ABS	Collection of personal ABS air samples during mowing and weed-trimming activities at the park	9	0	0%
OU2	Summer 2012	Post-Construction ABS	Collection of personal ABS air samples during mowing along the Flyway right-of-way and while hiking along the Kootenai River	9	0	0%
OU3	Summer 2009	Phase III	Collection of personal ABS air samples during recreational activities in the forest (ATV-riding, hiking, campfire building/burning)	227	0	0%
	Summer 2010 - 2011	Phase IV-A	Collection of personal ABS air samples while hiking along Rainy Creek	10	7	70%
			Collection of personal ABS air samples during USFS firefighter activities in the forest (cutting firelines manually and with heavy equipment)	60	36	60%
	Summer 2012	Phase V-A	Collection of personal ABS air samples during recreational activities in the Kootenai River	2	0	0%
	Summer 2014	Pulaski Nature and Extent	Collection of personal ABS air samples during USFS firefighter activities in the forest (cutting firelines manually)	60	0	0%
	Fall 2015	Trespasser ABS	Collection of personal ABS air samples during trespasser activities (ATV-riding, rock hounding) in and around the mined area.	60	0	0%
OU4	Summer 2001	Phase 2, Scenario 4	Collection of personal ABS air samples during garden rototilling	2	0	0%
	Summer 2007, Spring 2008	2007-2008 OU4 Residential Outdoor ABS	Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	450	287	64%
	Summer 2009	Libby Schools Outdoor ABS	Collection of personal ABS air samples while playing outside at schools	30	12	40%
			Collection of personal ABS air samples while mowing lawns at schools	15	5	33%
			Collection of personal ABS air samples while performing maintenance activities at schools (power-sweeping, digging, raking, and sweeping)	18	7	39%
	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	120	3	3%
			Scenario 2: Collection of personal ABS air samples during digging activities in residential gardens	60	5	8%
			Scenario 3: Collection of personal ABS air samples during playing, digging activities on residential driveways	62	2	3%
			Scenario 5: Collection of personal ABS air samples while bicycling on paths/trails in Libby	90	0	0%
	Summer 2011	2011 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards (using 2 different ABS scripts)	80	31	39%
			Scenario 2: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards previously evaluated in 2010	31	0	0%
			Scenario 3: Collection of personal ABS air samples during mowing in residential yards pre- and post-irrigation	18	2	11%
			Scenario 4: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards where curb-to-curb removal has been completed	31	5	16%
			LUA: Collection of personal ABS air samples during ATV riding in limited-use areas at residential properties	60	31	52%

TABLE E-1
Summary of Indirect Preparation Frequency by Investigation
Libby Asbestos Superfund Site

Panel A: Outdoor ABS Studies During Soil/Duff Disturbances (cont.)

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU5	Summer/Fall 2008	Worker ABS	Collection of personal ABS air samples during outdoor worker activities (bulldozer operator, raking)	48	37	77%
		MotoX ABS	Collection of personal and stationary ABS air samples during activities at the MotoX track	34	3	9%
		Recreational ABS	Collection of personal ABS air samples while bicycling on bike path in OU5	46	17	37%
OU6	Summer 2008	BNSF ABS	Collection of personal and stationary ABS air samples during rail maintenance activities	46	4	9%
OU7	Spring/Summer 2011	OU7 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	41	1	2%
			Scenario 2: Collection of personal ABS air samples during digging activities in residential gardens	38	2	5%
			Scenario 3: Collection of personal ABS air samples during playing, digging activities on residential driveways	40	2	5%
			Scenario 4: Collection of personal ABS air samples while bicycling on paths/trails in Troy	40	0	0%
OU8	Spring 2011, Summer 2010	OU8 Outdoor Worker ABS	Collection of equipment and stationary ABS air samples during road rotomilling activities	61	5	8%
			Collection of equipment ABS air samples during mowing and brush-hogging activities	18	3	17%
	Summer 2010	2010 OU4 Residential Outdoor ABS, Scenario 5	Collection of personal ABS air while driving on roads in Libby	20	0	0%
	Summer 2011	OU7 Residential Outdoor ABS	Collection of personal ABS air while driving on roads in Troy	20	0	0%

Panel B: ABS Studies During Disturbances of Wood-Related Materials

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU3	Summer 2010	2010 OU3 Phase IVA ABS	Collection of ABS air samples while performing activities as part of the USFS land management responsibilities, including maintenance of roads and trails, thinning of trees and vegetation, and surveying trees (i.e., stand examination).	90	30	33%
			Collection of personal ABS air during residential wood harvesting at three locations in the forested area downwind (northeast) of the mine site (i.e., approximately 2 miles, 4 miles, and 8 miles from the mine site)	62	46	74%
	Summer 2012	2012 OU3 Commercial Logging ABS	Collection of personal ABS air during hand-felling of trees, "hooking and skidding" felled trees to a central landing area, mechanical de-limbing and cutting of timber, and site restoration of the landing area using a bulldozer	13	6	46%
	Summer 2014	2014 OU3 Commercial Logging ABS	Collection of personal ABS air during hand-felling of trees, "hooking and skidding" felled trees to a central landing area, mechanical processing, milling, cutting slabs pre-milling, and site restoration of the landing area using a bulldozer	29	2	7%
OU4	Summer 2011	2011 OU4 Miscellaneous ABS	Collection of ABS air samples from each of the two piles in OU5	15	0	0%
	Summer 2012	2012 OU4 ABS Woodstove Ash	Collection of air samples to measure LA concentrations in air during woodstove ash-removal activities	9	9	100%
OU5	Fall 2007	Former Stimson Lumber Mill Site-Wood Chip Pilot Study	Collection of personal ABS air samples for the excavator operator and sampling personnel during the waste bark and wood chip pile test pit excavations	16	0	0%
OU7	Spring 2013	2013 Troy Landfill Activity-Based Sampling	Collection of ABS air samples during woodchipping of a woodwaste pile at the Lincoln County Landfill in Troy	6	0	0%

TABLE E-1
Summary of Indirect Preparation Frequency by Investigation
Libby Asbestos Superfund Site

Panel C: Indoor ABS Studies

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU1	Winter 2012	Clearance Sampling	Search and Rescue builidng clearance samples	5	5	100%
OU4	Summer 2001	Phase 2	Scenario 1 & 2: Collection of personal ABS air during active and passive residential/commercial behaviors	59	12	20%
			Scenario 3: Collection of personal ABS air during simulated tradesperson activities	17	3	18%
	Summer 2005	SQAPP, Task 2	Collection of personal ABS air samples during passive (no active) residential behaviors	29	8	28%
	Summer 2007 - Spring 2008	2007-2008 OU4 Residential Indoor ABS	Collection of personal ABS air samples during active and passive residential behaviors	641	212	33%
	Summer 2009	Libby Schools Indoor ABS	Collection of stationary ABS air samples inside schools	50	2	4%
	Various	Tradesperson Re-Analysis	Re-analysis of collected personal H&S samples of workers during interior removal activities (bulk removal, demolition, detailing attic, and wet wipe/HEPA vacuum)	17	3	18%
	Winter 2013, Summer 2013	2013 OU4 Residential Indoor ABS	Scenario 1: Collection of personal ABS air samples during active and passive residential behaviors at properties where a curb-to-curb soil removal has been completed	40	1	3%
	Summer 2013		Scenario 2: Collection of personal ABS air samples during active and passive residential behaviors at properties evaluated in 2007/08	20	1	5%
OU5	Winter 2007	Indoor Worker ABS	Collection of personal ABS air samples during active and passive worker behaviors inside occupied OU5 buildings	37	23	62%
			Collection of stationary ABS air samples inside vacant OU5 buildings	50	47	94%
OU7	Spring, Summer 2011	OU7 Residential/Commercial Indoor ABS	Collection of personal ABS air samples during active and passive residential and commercial behaviors	80	6	8%

Panel D: Ambient Air Studies

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU2	2007-2008	Ambient Air	Collection of ambient air samples throughout OU2	34	0	0%
OU3	2007-2008	Ambient Air	Collection of ambient air samples throughout OU3	96	0	0%
OU4	2006-2013	Ambient Air	Collection of ambient air samples throughout OU4	803	21	3%
OU6	2007-2008	Ambient Air	Collection of ambient air samples throughout OU6	35	0	0%
OU7	2009-2013	Ambient Air	Collection of ambient air samples throughout OU7	612	10	2%

Panel E: Fire-Related Air Studies

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU3	Summer 2013	Souse Gulch Wildfire Contingency Monitoring Plan Air	Collection of air samples to provide measured data on LA exposures of responding firefighters (both to the ground crews and the aircraft support pilot) and downwind LA concentrations in air during the fire.	18	0	0%
	Spring 2015	Slash Pile Burn ABS	Collection of air samples to provide measured data on potential LA exposures to USFS forest workers and fire fighters as part of forest maintenance activities during the burning of slash piles.	26	0	0%
	Summer 2015	Understory Burn ABS	Collection of air samples to provide measured data on potential LA exposures to USUS forest workers and fire fighters as part of forest maintenance activities during an understory burn.	19	9	47%

Notes:

ABS - activity-based sampling
BNSF - Burlington Northern and Santa Fe
H&S - health and safety
HEPA - high efficiency particulate air
LA - Libby amphibole asbestos
OU - operable unit
SQAPP - Supplemental Remedial Investigative Quality Assessment and Project Plan
USFS - United States Forest Service

APPENDIX F

DETAILED DATA SUMMARY FOR ALL SAMPLES USED IN THE HUMAN HEALTH RISK ASSESSMENT

[provided electronically in attached Excel file to this PDF]

APPENDIX G

DETAILED RISK ESTIMATES FROM EXPOSURES TO LA DURING DISTURBANCES IN OU3

G.1 – SOILS, STRATIFIED BY ABS AREA
G.2 – SOILS, SPATIALLY-WEIGHTED BY EXPOSURE LOCATION
G.3 – WOOD-RELATED, SPATIALLY-WEIGHTED BY EXPOSURE LOCATION

APPENDIX G.1
Estimated Risks from Exposures to LA During Disturbances of Soils in OU3 - Stratified by ABS Area
Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	EPC Grouping Location*	ABS Area	EPC Mean Air Conc. (PCME LA s/cc)+	RME Exposure Parameters ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Cancer Risk	Non-cancer HQ
Recreational Visitor	Hiking	Along Rainy Creek	RAINY	0.0093	3.6	20	52	0.0061	**1E-05**	**0.6**
		Forest, near	ABS-10	0	8	50	52	0.034	**0E+00**	**0**
			ABS-14	0.0010	8	50	52	0.034	**6E-06**	**0.4**
		Forest, intermed.	ABS-03	0.00086	8	50	52	0.034	**5E-06**	**0.3**
			ABS-05	0.00075	8	50	52	0.034	**4E-06**	**0.3**
			ABS-06	0	8	50	52	0.034	**0E+00**	**0**
			ABS-07	0.0015	8	50	52	0.034	**9E-06**	**0.6**
			ABS-13	0	8	50	52	0.034	**0E+00**	**0**
		Forest, far	ABS-01	0	8	50	52	0.034	**0E+00**	**0**
			ABS-02	0	8	50	52	0.034	**0E+00**	**0**
			ABS-08	0	8	50	52	0.034	**0E+00**	**0**
			ABS-11	0.0010	8	50	52	0.034	**6E-06**	**0.4**
	ATV riding	Forest, near[a]	ABS-10'	0.0030	4	50	52	0.017	**9E-06**	**0.6**
			ABS-14	0	4	50	52	0.017	**0E+00**	**0**
		Forest, intermed.	ABS-03	0.0017	4	50	52	0.017	**5E-06**	**0.3**
			ABS-05	0	4	50	52	0.017	**0E+00**	**0**
			ABS-06	0	4	50	52	0.017	**0E+00**	**0**
			ABS-07	0.00075	4	50	52	0.017	**2E-06**	**0.1**
			ABS-13	0	4	50	52	0.017	**0E+00**	**0**
		Forest, far	ABS-01	0	4	50	52	0.017	**0E+00**	**0**
			ABS-02	0	4	50	52	0.017	**0E+00**	**0**
			ABS-08	0	4	50	52	0.017	**0E+00**	**0**
			ABS-11	0.0010	4	50	52	0.017	**3E-06**	**0.2**
	Campfire building/ burning	Forest, near[a]	ABS-10'	0.0080	2	50	52	0.0085	**1E-05**	**0.8**
			ABS-14	0	2	50	52	0.0085	**0E+00**	**0**
		Forest, intermed.	ABS-03	0.0026	2	50	52	0.0085	**4E-06**	**0.2**
			ABS-05	0.0030	2	50	52	0.0085	**4E-06**	**0.3**
			ABS-06	0.0024	2	50	52	0.0085	**3E-06**	**0.2**
			ABS-07	0.00075	2	50	52	0.0085	**1E-06**	**0.07**
			ABS-13	0.0026	2	50	52	0.0085	**4E-06**	**0.2**
		Forest, far	ABS-01	0.00085	2	50	52	0.0085	**1E-06**	**0.08**
			ABS-02	0.00085	2	50	52	0.0085	**1E-06**	**0.08**
			ABS-08	0	2	50	52	0.0085	**0E+00**	**0**
			ABS-11	0	2	50	52	0.0085	**0E+00**	**0**
	Driving	Forest, intermed.[b]	ABS-06	0.00027	3	50	52	0.013	**6E-07**	**0.04**
		Forest, intermed.	ABS-07	0	3	50	52	0.013	**0E+00**	**0**
		Forest, far	ABS-02	0	3	50	52	0.013	**0E+00**	**0**
	Fishing/ boating	Kootenai River	ISLAND	0	8	60	52	0.041	**0E+00**	**0**
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, intermed.[b]	ABS-06	0	10	14	10	0.0023	**0E+00**	**0**
		Forest, intermed.	ABS-07	0.014	10	14	10	0.0023	**5E-06**	**0.3**
		Forest, far	ABS-02	0.0045	10	14	10	0.0023	**2E-06**	**0.1**
	Cutting firelines with heavy machinery	Forest, intermed.[b]	ABS-06	0.0021	10	14	10	0.0023	**8E-07**	**0.05**
		Forest, intermed.	ABS-07	0.0029	10	14	10	0.0023	**1E-06**	**0.07**
		Forest, far	ABS-02	0.0016	10	14	10	0.0023	**6E-07**	**0.04**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

*Distances from the mine are defined as follows:
- Forest, near: within two miles from the mine
- Forest, intermed.: between two and six miles from the mine.
- Forest, far: greater than or equal to six miles from the mine

[a] During the ABS, activities for ABS-10 were performed in an area located immediately west of ABS-10 (north of the mine, but still within 2 miles); this area is referred to as ABS-10'.

[b] During the ABS, this area was moved approximately 1 mile further downwind of the mine than ABS-10 in close proximity to ABS-06.

Notes:

ABS - activity-based sampling
ATV - all terrain vehicle
Conc. - concentration
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RC - Rainy Creek
KR - Kootenai River
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX G.2

Estimated Risks from Exposures to LA During Disturbances of Soils in OU3 - Spatially-Weighted by Exposure Location

Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Exposure Location[a]	EPC	RME Exposure Parameters						Cancer Risk	Non-cancer HQ	% contrib. to total
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	Total EF (days/ year)	% of total EF in location[b]	Location-specific EF (days/year)	ED (years)	TWF			
Recreational Visitor	Hiking	Forest, near	0.00050	8	50	40%	20.0	52	0.0136	**1E-06**	**0.08**	40%
		Forest, intermed.	0.00065	8	50	40%	20.0	52	0.014	**2E-06**	**0.1**	50%
		Forest, far	0.00023	8	50	20%	10.0	52	0.007	**3E-07**	**0.02**	10%
		All locations								**3E-06**	**0.2**	
	ATV Riding[c]	Forest, near	0.0014	4	50	40%	20.0	52	0.0068	**2E-06**	**0.1**	68%
		Forest, intermed.	0.00050	4	50	40%	20.0	52	0.0068	**6E-07**	**0.04**	27%
		Forest, far	0.00022	4	50	20%	10.0	52	0.0034	**1E-07**	**0.008**	5%
		All locations							0.017	**2E-06**	**0.1**	
	Campfire building/ burning	Forest, near	0.0024	2	50	40%	20.0	52	0.00339	**1E-06**	**0.09**	50%
		Forest, intermed.	0.0022	2	50	40%	20.0	52	0.0034	**1E-06**	**0.08**	45%
		Forest, far	0.00046	2	50	20%	10.0	52	0.0017	**1E-07**	**0.009**	5%
		All locations							0.0085	**3E-06**	**0.2**	
	Driving	Forest, near[d]	0.001	3	50	40%	20.0	52	0.00509	**1E-06**	**0.08**	91%
		Forest, intermed.	0.00013	3	50	40%	20.0	52	0.0051	**1E-07**	**0.008**	9%
		Forest, far	0	3	50	20%	10.0	52	0.0025	**0E+00**	**0**	0%
		All locations							0.013	**1E-06**	**0.09**	
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near[d]	0.069	10	14	40%	5.6	10	0.00091	**1E-05**	**0.7**	89%
		Forest, intermed.	0.0069	10	14	40%	5.6	10	0.0009	**1E-06**	**0.07**	9%
		Forest, far	0.0045	10	14	20%	2.8	10	0.00046	**3E-07**	**0.02**	3%
		All locations							0.0023	**1E-05**	**0.8**	
	Cutting firelines with heavy machinery	Forest, near[d]	0.025	10	14	40%	5.6	10	0.00091	**4E-06**	**0.3**	89%
		Forest, intermed.	0.0025	10	14	40%	5.6	10	0.0009	**4E-07**	**0.03**	9%
		Forest, far	0.0016	10	14	20%	2.8	10	0.00046	**1E-07**	**0.008**	2%
		All locations							0.0023	**4E-06**	**0.3**	
Mine Trespasser	ATV Riding[c]	On-road, Route A	0.0030	4	10	25%	2.5	52	0.00085	**4E-07**	**0.03**	7%
		On-road, Route B	0.0024	4	10	25%	2.5	52	0.0008	**3E-07**	**0.02**	4%
		On-road, Route C	0.022	4	10	25%	2.5	52	0.00085	**3E-06**	**0.2**	44%
		Off-road, disturbed area	0.022	4	10	25%	2.5	52	0.00085	**3E-06**	**0.2**	44%
		All locations							0.0034	**7E-06**	**0.4**	

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Distances from the mine are defined as follows:

Forest, near: within 2 miles from the mine

Forest, intermed.: between 2 and 6 miles from the mine.

Forest, far: greater than or equal to 6 miles from the mine

[b] Fraction of exposure frequency spent in each area is based on areal extent (i.e., 0-2 mile, 2-6 mile, and 6-10 mile concentric areas to a total 10-mile area) and in consideration of area accessibility (i.e., proximity to USFS service roads). Assumes 40% of days/year are spent in near area, 40% of days/year are spent in intermediate area, and 20% of days/year are spent in far area.

[c] Assumes ATV riding exposure frequency is split equally across all four riding locations (i.e., all hree on-road routes and the off-road disturbed area)

[d] No ABS results for near location; assumes near concentrations are equal to 10x intermediate location.

Notes:

ABS - activity-based sampling
ATV - all terrain vehicle
Conc. - concentration
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX G.3
Estimated Risks from Exposure to LA During Disturbances of Wood-Related Materials - Spatially-Weighted by Exposure Location
Libby Asbestos Superfund Site

Receptor Population	Exposure/Disturbance Description	Wood Source*	EPC	Exposure Parameters						Cancer Risk	Non-cancer HQ	% contrib. to total
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)**	% of total EF in location	Location-specific EF (days/year)	ED (years)	TWF			
Resident	Wood harvesting (Felling trees, de-limbing, cutting, stacking firewood) [a]	Forest, near[d]	0.011	10	15	40%	6.0	40	0.00391	**7E-06**	**0.5**	90%
		Forest, intermed.	0.0011	10	15	40%	6.0	40	0.0039	**7E-07**	**0.05**	9%
		Forest, far	0.00014	10	15	20%	3.0	40	0.0020	**5E-08**	**0.003**	1%
		All locations							0.0098	**8E-06**	**0.6**	
	Emptying woodstove ash after burning firewood [b]	~1 mile from mine	0.14	0.25	48	40%	19.2	45	0.00035	**8E-06**	**0.5**	93%
		Flower Creek	0.0074	0.25	48	40%	19.2	45	0.00035	**4E-07**	**0.03**	6%
		Bear Breek	0.0029	0.25	48	20%	9.6	45	0.00018	**9E-08**	**0.006**	1%
		All locations							0.00088	**9E-06**	**0.5**	
Outdoor Worker (USFS worker)	Forest management (Road maintenance, tree thinning, forest surveying) [a]	Forest, near[d]	0.0032	8	30	40%	12.0	10	0.00157	**9E-07**	**0.06**	88%
		Forest, intermed.	0.00032	8	30	40%	12.0	10	0.0016	**9E-08**	**0.006**	9%
		Forest, far	0.00020	8	30	20%	6.0	10	0.0008	**3E-08**	**0.002**	3%
		All locations							0.0039	**1E-06**	**0.07**	
Outdoor Worker (Commercial logger)	Logging: Hand-felling trees [c]	~1 mile from mine	0.0034	8	24	40%	9.6	6	0.00075	**4E-07**	**0.03**	50%
		~4 miles from mine	0.0022	8	24	60%	14.4	6	0.0011	**4E-07**	**0.03**	50%
		All locations							0.0019	**9E-07**	**0.06**	
	Logging: Hooking/skidding, processing timber [c]	~1 mile from mine	0.10	10	24	40%	9.6	12	0.0019	**3E-05**	**2**	99%
		~4 miles from mine	0.00065	10	24	60%	14.4	12	0.0028	**3E-07**	**0.02**	1%
		All locations							0.0047	**3E-05**	**2**	
	Logging: Site restoration [c]	~1 mile from mine	0.032	10	24	40%	9.6	12	0.0019	**1E-05**	**0.7**	88%
		~4 miles from mine	0.0040	10	24	60%	14.4	12	0.0028	**2E-06**	**0.1**	13%
		All locations							0.0047	**1E-05**	**0.8**	
	Logging: Simulated milling (chipping) [c]	~1 mile from mine	0.0068	10	24	40%	9.6	12	0.0019	**2E-06**	**0.1**	100%
		~4 miles from mine	0	10	24	60%	14.4	12	0.0028	**0E+00**	**0**	0%
		All locations							0.0047	**2E-06**	**0.1**	

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

*Distances from the mine are defined as follows:
Forest, near: within 2 miles from the mine
Forest, intermed.: between 2 and 6 miles from the mine
Forest, far: greater than or equal to 6 miles from the mine
Flower Creek: approximately 6 miles from the mine
Bear Breek: approximately 10 miles from the mine

[a] Fraction of exposure frequency spent in each area is based on areal extent (i.e., 0-2 mile, 2-6 mile, and 6-10 mile concentric areas to a total 10-mile area) and in consideration of area accessibility (i.e., proximity to USFS service roads). Assumes 40% of days/year are spent in near area, 40% of days/year are spent in intermediate area, and 20% of days/year are spent in far area.
[b] Assumes "near mine" is representative of 0-4 mile area, Flower Creek is representative of 4-6 mile area, and Bear Creek is representative of 6-10 mile area. Assumes 40% of days/year are spent in 0-4 mile area, 40% of days/year are spent in 4-6 mile area, and 20% of days/year are spent in 6-10 mile area.
[c] Assumes "~1 mile from mine" is representative of 0-4 mile area and "~4 miles from mine" is representative of 4-10 mile area. Assumes 40% of days/year are spent in 0-4 mile area and 60% of days/year are spent in 4-10 mile area.
[d] No ABS results for near location; assumes near concentrations are equal to 10x intermediate location

Notes:

Conc. - concentration	LA - Libby amphibole asbestos
CTE - central tendency exposure	OU - operable unit
ED - exposure duration	PCME - phase contrast microscopy - equivalent
EF - exposure frequency	RME - reasonable maximum exposure
EPC - exposure point concentration	s/cc - structures per cubic centimeter
ET - exposure time	TWF - time-weighting factor
HQ - hazard quotient	USFS - United States Forest Service

APPENDIX H
SITE-SPECIFIC EXPOSURE INFORMATION

H.1 – OU1 Search & Rescue Building
H.2 – OU5 Motocross Track
H.3 – OU5 Occupied Buildings

Appendix H.1
Exposure Questionnaire - OU1 Former Export Plant, Search and Rescue Volunteers
Libby Asbestos Superfund Site

Individual #	EF at OU1 (days/yr)	Total ET at OU1 (hours/day)	As Reported: Time Indoors (%)	As Reported: Time Outdoors (%)	Adjusted (a): Time Indoors (%)	Adjusted (a): Time Outdoors (%)	As Reported: % Indoor Time in Garage	As Reported: % Indoor Time in Meeting Room	Adjusted (a): % Indoor Time in Garage	Adjusted (a): % Indoor Time in Meeting Room	Calculated ET (hours/day): ET (outdoor)	Calculated ET (hours/day): ET (indoor)
1	**45**	2	75%	25%	75%	25%	25%	75%	25%	75%	**0.50**	**1.50**
2	**60**	2	25%	60%	29%	71%	10%	20%	33%	67%	**1.41**	**0.59**
3	**35**	4	10%	90%	10%	90%	10%	90%	10%	90%	**3.60**	**0.40**
4	**104**	2	75%	25%	75%	25%	25%	75%	25%	75%	**0.50**	**1.50**
5	**50**	2	85%	15%	85%	15%	25%	75%	25%	75%	**0.30**	**1.70**
6	**100**	2	80%	20%	80%	20%	40%	60%	40%	60%	**0.40**	**1.60**
7	**25**	3	80%	20%	80%	20%	25%	70%	26%	74%	**0.60**	**2.40**
8	**35**	4	80%	20%	80%	20%	20%	80%	20%	80%	**0.80**	**3.20**
9	**20**	2	90%	10%	90%	10%	50%	50%	50%	50%	**0.20**	**1.80**
10	**42**	4	80%	20%	80%	20%	10%	90%	10%	90%	**0.80**	**3.20**
11	**30**	2	90%	10%	90%	10%	10%	80%	11%	89%	**0.20**	**1.80**
12	**120**	2	95%	5%	95%	5%	25%	75%	25%	75%	**0.10**	**1.90**
13	**104**	4	70%	30%	70%	30%	90%	10%	90%	10%	**1.20**	**2.80**
14	**60**	2	60%	40%	60%	40%	40%	60%	40%	60%	**0.80**	**1.20**
15	**100**	1	80%	20%	80%	20%	30%	70%	30%	70%	**0.20**	**0.80**
16	**30**	2	70%	30%	70%	30%	20%	80%	20%	80%	**0.60**	**1.40**
17	**300**	2	99%	1%	99%	1%	1%	99%	1%	99%	**0.02**	**1.98**
18	**36**	4	30%	70%	30%	70%	18%	65%	22%	78%	**2.80**	**1.20**

Summary Statistics

Statistic	**EF (days/year)**	**ET, indoor (hours/day)**
Mean	**72**	**1.7**
Stdev	65	0.8
Min	20	0.4
Max	300	3.2
95th %tile	**147**	**3.2**

Selected for use in the risk characterization

Notes:
NA = not available
a) Cells highlighted in blue are cases where the values on proportion of time spent in two location categories do not sum to 100% as expected. In these cases, the reported values were re-scaled to sum to 100% while maintaining the ratio of the values reported.
b) Three respondents did not indicate an expected age at stop. An age of 70 years was assumed in these cases. Stop ages reported as 90-100 years were assumed to be 80 years.
c) 5th percentile value rather than 95th percentile

APPENDIX H.2
OU5 MOTO-X PARK ACTIVITY SURVEY RESULTS
Libby Asbestos Superfund Site

Participant	Reported Survey Results			Estimated Exposure Parameter Values†	
	d/yr @ track	hr/d @ track	hr/d riding	EF (d/yr)	ET* (hr/d)
1	21-30	3-4	1-2	**25**	**1.5**
2	31-50	1-2	1-2	**40**	**1.5**
3	21-30	3-4	1-2	**25**	**1.5**
4	31-50	3-4	1-2	**40**	**1.5**
5	21-30	1-2	0.5-0.9	**25**	**0.75**
6	21-30	3-4	3-4	**25**	**3.5**
			CTE (mean):	**30**	**2**
			RME (max):	**40**	**4**

† Based on midpoint of reported range
* Based on reported time spent riding

APPENDIX H.3
RESULTS OF ACTIVITY SURVEY FOR WORKERS IN CURRENTLY-OCCUPIED BUILDINGS IN OU5
Libby Asbestos Superfund Site

Survey ID	Code	Building	ET (hr/d)	EF (d/yr)	% Active	Notes
22	CMB-B&C	CMB-B&C Packaging	6.00	180	100	
23	CMB-B&C	CMB-B&C Packaging	6.00	180	100	
24	CMB-B&C	CMB-B&C Packaging	7.00	180	100	
25	CMB-B&C	CMB-B&C Packaging	6.00	180	100	
26	CMB-B&C	CMB-B&C Packaging	6.00	180	100	
1	CMB	CMB-A1	1.00	365	95	
15	CMB	CMB-Columbia Mechanical	3.00	240	90	
16	CMB	CMB-Columbia Mechanical	3.00	240	90	
18	CMB	CMB-Kootenai Insulation	1.00	96	100	
19	CMB	CMB-Kootenai Insulation	4.00	300	90	
17	CMB	CMB-RPO Stone	8.00	240	100	
20	CMB	CMB-RPO Stone	7.00	140	100	
5	CMB	CMB-TBC	1.00	100	100	
21	CMB	CMB-Thompson Contracting	5.00	15	100	
27	CMB	CMB-Thompson Contracting	1.00	60	100	
28	CMB	CMB-Thompson Contracting	0.50	60	100	
29	CMB	CMB-Thompson Contracting	1.00	150	40	
30	CMB	CMB-Thompson Contracting	1.00	60	50	
31	CMB	CMB-Thompson Contracting	10.00	30	50	
32	CMB	CMB-Thompson Contracting	2.00	4	90	
33	CMB	CMB-Thompson Contracting	1.00	320	50	
34	CMB	CMB-Thompson Contracting	1.00	60	100	
2	LEG	Luck EG Electrical Shed	0.17	300	100	
3	LEG	Luck EG Electrical Shed	0.17	240	100	
4	LEG	Luck EG Electrical Shed	0.33	300	100	
6		Luck EG Electrical Shed	0.08	2	100	Excluded
6	LEGO	Luck EG Office	6.00	220	50	
7	SH	Scale House	0.07	9	100	
8	SH	Scale House	0.07	10	100	
9	SH	Scale House	0.07	9	100	
10	SH	Scale House	0.07	8	100	
11	SH	Scale House	0.08	10	100	
12	SH	Scale House	0.08	9	100	
13	SH	Scale House	0.07	8	100	
14	SH	Scale House	0.05	10	100	
(a)	CDM Smith	Office - Type 1 worker	8.00	250	5	
(a)	CDM Smith	Office - Type 2 worker	4.00	280	5	
(a)	CDM Smith	Office - Type 3 worker	1.00	250	5	

(a) Based on info from CDM Smith on 9/17/08

OU5 INDOOR WORKER ACTIVITY SURVEY SUMMARY

Panel A: CTE (Based on mean values)

OU5 Building Location	N surveyed	% of Time Active	ET (hr/d)	EF (d/yr)
CMB - B&C Pkg	5	100	6.2	180
CMB - other	17	85	3.0	146
Luck EG Shed	3	100	0.22	280
Luck EG Office	1	50	6.0	220
Scale House	8	100	0.07	9
CDM Smith Office Type 1 (a)	10	5	8.0	250
CDM Smith Office Type 2 (a)	20	5	4.0	280
CDM Smith Office Type 3 (a)	30	5	1.0	250

Panel B: RME (Based on high-end values)

OU5 Building Location	N surveyed	% of Time Active	ET (hr/d)	EF (d/yr)
CMB - B&C Pkg	5	100	7.0	180
CMB - other	17	100	8.4	329
Luck EG Shed	3	100	0.33	300
Luck EG Office	1	--	--	--
Scale House	8	100	0.08	10
CDM Smith Office Type 1		80 (b)	8.0	250

(a) Mean statistics provided by CDM Smith; risk calculations are based on Type 1
(b) Assumed

CMB = Central Maintenance Building
ET = exposure time
EF = exposure frequency

APPENDIX I
UPPER-BOUND RISK CALCULATIONS

APPENDIX I.1
Estimated Risks from Exposure to LA in Ambient Air Based on Upper-Bound Concentrations
Libby Asbestos Superfund Site

Exposure Media	Receptor Population	Exposure Location	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor air, under ambient conditions	Resident	OU4, Libby	0.0000062	0.000040	6.9	350	52	0.20	2E-07	1E-06	0.01	0.09
		Within community	0.0000048	0.000039	6.9	350	52	0.20	2E-07	1E-06	0.01	0.09
		Along transportation corridors	0.0000098	0.000043	6.9	350	52	0.20	3E-07	2E-06	0.02	0.1
		OU7, Troy	0.0000015	0.00067	6.9	350	52	0.20	5E-08	2E-05	0.003	2
	Recreational visitor	OU3, mine site	0.00020	0.000040	8	50	52	0.034	1E-06	2E-07	0.07	0.02

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[a] Non-detect samples are evaluated at zero.
[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.2

Estimated Risks from Exposure to LA During Disturbances of Residential Soils Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Panel A: Residential Exposures

Operable Unit	Exposure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	**Yards (Mowing, Raking, Digging)**											
	Bin A	**high intensity**	0.0040	0.0062	0.3	60	52	0.0015	1E-06	2E-06	0.07	0.1
		typical intensity	0.00011	0.0014	6.3	60	52	0.032	6E-07	8E-06	0.04	0.5
								TOTAL	2E-06	9E-06	0.1	0.6
	Bin B1	**high intensity**	0.061	0.064	0.3	60	52	0.0015	2E-05	2E-05	1	1
		typical intensity	0.0024	0.0036	6.3	60	52	0.032	1E-05	2E-05	0.9	1
								TOTAL	3E-05	4E-05	2	2
	Bin B2/C	**high intensity**	0.21	0.21	0.3	60	52	0.0015	5E-05	5E-05	4	4
		typical intensity	0.0080	0.0082	6.3	60	52	0.032	4E-05	4E-05	3	3
								TOTAL	1E-04	1E-04	7	7
	Gardens (Rototilling)											
	Bin B1	---	0.039	0.039	2	2	52	0.00034	2E-06	2E-06	0.1	0.1
	Gardens (Digging)											
	Bin A	---	0.00020	0.0016	3.3	40	52	0.011	4E-07	3E-06	0.03	0.2
	Bin B1	---	0.00066	0.0059	3.3	40	52	0.011	1E-06	1E-05	0.08	0.7
	Bin B2/C	---	0	0.0030	3.3	40	52	0.011	0E+00	6E-06	0	0.4
	Driveway (Playing & Digging)											
	Bin A	---	0	0.0039	2	225	15	0.011	0E+00	7E-06	0	0.5
	Bin B1	---	0.0057	0.0094	2	225	15	0.011	1E-05	2E-05	0.7	1
	Bin B2/C	---	0.0050	0.0036	2	225	15	0.011	9E-06	7E-06	0.6	0.4
	LUAs (ATV-riding)											
	Bin A	---	0.0012	0.0026	2	20	52	0.0034	7E-07	2E-06	0.05	0.1
	Bin B1	---	0.0014	0.0024	2	20	52	0.0034	8E-07	1E-06	0.05	0.09
OU7	**Yards (Mowing, Raking, Digging)**											
	Bin A	**typical intensity**	0.000062	0.00025	6.6	60	52	0.034	4E-07	1E-06	0.02	0.09
	Bin B1	**typical intensity**	0	0.00022	6.6	60	52	0.034	0E+00	1E-06	0	0.08
	Residential, Outdoor Gardens (Digging & Rototilling) [++]											
	Bin A	---	0.000023	0.00023	5.3	42	52	0.019	7E-08	7E-07	0.005	0.05
	Bin B1	---	0	0.00022	5.3	42	52	0.019	0E+00	7E-07	0	0.05
	Residential, Outdoor Driveway (Playing & Digging)											
	Bin A	---	0.000079	0.00028	2	225	15	0.011	1E-07	5E-07	0.01	0.03
	Bin B1	---	0.000085	0.00021	2	225	15	0.011	2E-07	4E-07	0.01	0.03

Panel B: Outdoor Worker Exposures

Operable Unit	Exposure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	**Yards (Mowing, Raking, Digging)**											
	Bin A	**high intensity**	0.0040	0.0062	0.4	100	25	0.0016	1E-06	2E-06	0.07	0.1
		typical intensity	0.00011	0.0014	7.6	100	25	0.031	6E-07	7E-06	0.04	0.5
								TOTAL	2E-06	9E-06	0.1	0.6
	Bin B1	**high intensity**	0.061	0.064	0.4	100	25	0.0016	2E-05	2E-05	1	1
		typical intensity	0.0024	0.0036	7.6	100	25	0.031	1E-05	2E-05	0.8	1
								TOTAL	3E-05	4E-05	2	2
	Bin B2/C	**high intensity**	0.21	0.21	0.4	100	25	0.0016	6E-05	6E-05	4	4
		typical intensity	0.0080	0.0082	7.6	100	25	0.031	4E-05	4E-05	3	3
								TOTAL	1E-04	1E-04	7	7
	Gardens (Rototilling)											
	Bin B1	---	0.039	0.039	2	100	25	0.008	5E-05	5E-05	4	4
	Gardens (Digging)											
	Bin A	---	0.00020	0.0016	2	100	25	0.008	3E-07	2E-06	0.02	0.1
	Bin B1	---	0.00066	0.0059	2	100	25	0.008	9E-07	8E-06	0.06	0.5
	Bin B2/C	---	0	0.0030	2	100	25	0.008	0E+00	4E-06	0	0.3
OU7	**Yards (Mowing, Raking, Digging)**											
	Bin A	**typical intensity**	0.000062	0.00025	8	100	25	0.033	3E-07	1E-06	0.02	0.09
	Bin B1	**typical intensity**	0	0.00022	8	100	25	0.033	0E+00	1E-06	0	0.08
	Residential, Outdoor Gardens (Digging & Rototilling) [+++]											
	Bin A	---	0.000023	0.00023	4	100	25	0.016	6E-08	6E-07	0.004	0.04
	Bin B1	---	0	0.00022	4	100	25	0.016	0E+00	6E-07	0	0.04

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[++] Exposure time and frequency have been summed because the EPC is based on a combination of the activities.

[+++] Exposure time has been summed because the EPC is based on a combination of the activities.

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

[1] PLM-VE Bin:

A - ND

B1 - Tr

B2 - <1%

C - ≥ 1%

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
PLM-VE - polarized light microscopy - visual area estimation
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.3

Estimated Risks from Exposure to LA During Disturbances of Residential Soils Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Operable Unit	Receptor Type	Exposure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
				Mean [a]	Estimated Upper-Bound [b]	ET (hours/day)	EF (days/year)[++]	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4/OU7	Outdoor Worker	Bin A	digging, high intensity	0.0053	0.0094	2	32.5	25	0.0027	2E-06	4E-06	0.2	0.3
		Bin B1	digging, high intensity	0.16	0.16	2	7.5	25	0.00061	2E-05	2E-05	1	1
		Bin B2/C	digging, high intensity	0.52	0.52	2	10	25	0.00082	7E-05	7E-05	5	5
									TOTAL	**9E-05**	**9E-05**	6	6
	Resident	Bin A	digging, high intensity	0.0053	0.0094	2	1	52	0.00017	2E-07	3E-07	0.01	0.02
		Bin B1	digging, high intensity	0.16	0.16	2	1	52	0.00017	4E-06	4E-06	0.3	0.3
		Bin B2/C	digging, high intensity	0.52	0.52	2	1	52	0.00017	2E-05	2E-05	1	1

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[++] The total exposure frequency for the worker has been allocated to the various soil conditions according to the assumed frequency each condition is expected to be encountered.

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

[1] PLM-VE Bin:

A - ND

B1 - Tr

B2 - <1%

C - ≥ 1%

Notes:

ABS - activity-based sampling

ED - exposure duration

EF - exposure frequency

EPC - exposure point concentration

ET - exposure time

HQ - hazard quotient

LA - Libby amphibole asbestos

OU - operable unit

PCME - phase contrast microscopy - equivalent

PLM-VE - polarized light microscopy - visual area estimation

RME - reasonable maximum exposure

s/cc - structures per cubic centimeter

TWF - time-weighting factor

APPENDIX I.4
Estimated Risks from Exposure to LA During Disturbances of Soils at Schools and Parks Based on Upper-Bound Concentrations
Libby Asbestos Superfund Site

Operable Unit	Exposure Location	Receptor Type	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	Kootenai Valley Head Start	Student	0	0.0018	0.5	128	2	0.00021	0E+00	6E-08	0	0.004
		Maintenance Worker	0	0.0025	1.0	128	25	0.0052	0E+00	2E-06	0	0.1
		Lawn Mower	0.00074	0.0039	10	22	25	0.0090	1E-06	6E-06	0.07	0.4
	Libby Elementary School	Student	0.0019	0.0031	2.0	180	6	0.0035	1E-06	2E-06	0.07	0.1
		Maintenance Worker	0	0.0020	1.5	260	25	0.016	0E+00	5E-06	0	0.3
		Lawn Mower	0	0.0028	10	22	25	0.0090	0E+00	4E-06	0	0.3
	Libby Middle School	Student	0.0020	0.0027	1.6	90	3	0.00070	2E-07	3E-07	0.02	0.02
		Maintenance Worker	0	0.0019	0.5	260	25	0.0053	0E+00	2E-06	0	0.1
		Lawn Mower	0	0.0061	10	22	25	0.0090	0E+00	9E-06	0	0.6
	Libby High School	Student	0.00017	0.0054	0.67	45	4	0.00020	6E-09	2E-07	0.0004	0.01
		Maintenance Worker	0	0.0026	1.0	260	25	0.011	0E+00	5E-06	0	0.3
		Lawn Mower	0	0.0023	10	22	25	0.0090	0E+00	3E-06	0	0.2
	Libby Admin. Building	Student	0	0.00022	0.75	180	6	0.0013	0E+00	5E-08	0	0.003
		Maintenance Worker	0	0.00027	1.5	260	25	0.016	0E+00	7E-07	0	0.05
		Lawn Mower	0.000019	0.00022	10	22	25	0.0090	3E-08	3E-07	0.002	0.02
	Libby High School and Libby Admin Building	Power Sweeper	0	0.0021	2.0	22	25	0.0018	0E+00	7E-07	0	0.04
	Cabinet View Country Club	Maintenance Worker	0.00056	0.00096	8.0	100	15	0.020	2E-06	3E-06	0.1	0.2
OU7	Morrison Elementary School	Student	0	0.00022	2.0	180	6	0.0035	0E+00	1E-07	0	0.009
	Timberbeast Golf Course	Recreational Visitor, adult	0	0.00022	5.0	48	52	0.020	0E+00	7E-07	0	0.05
	Roosevelt Park, ball fields	Recreational Visitor, adult	0.00011	0.00022	5.0	48	52	0.020	4E-07	7E-07	0.02	0.05
	Roosevelt Park, playground	Recreational Visitor, child	0	0.00022	10.7	48	10	0.0084	0E+00	3E-07	0	0.02

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[a] Non-detect samples are evaluated at zero.
[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.5

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils on Bike Paths and Trails Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Operable Unit	Sector	Receptor Type	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	Sector A-C	Adult Rider	0	0.0034	2	90	52	0.015	0E+00	9E-06	0	0.6
		Inside Trailer	0	0.0086	2	90	5	0.0015	0E+00	2E-06	0	0.1
OU7	---	Adult Rider	0	0.00022	0.75	90	52	0.0057	0E+00	2E-07	0	0.01
		Inside Trailer	0.000011	0.00022	0.75	90	5	0.00055	1E-09	2E-08	0.00007	0.001

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.6

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU1 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor	Exposure Scenario	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
	Mowing	0.00044	0.0028	6	13	25	0.0032	2E-07	1E-06	0.02	0.1
	Weed-trimming	0	0.011	1	13	25	0.00053	0E+00	1E-06	0	0.07
Recreational Visitor	Recreating in park [c]	0.00044	0.0028	2	48	52	0.00814	6E-07	4E-06	0.04	0.3

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

[c] ABS was not performed for recreational activities; results from the mowing scenario are used to evaluate recreational exposures.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter
RME - reasonable maximum exposure
TWF - time-weighting factor

APPENDIX I.7

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU2 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor Worker	Mowing Hwy 37 ROW	0	0.018	1	5	15	0.00012	0E+00	4E-07	0	0.02
Recreational Visitor	Hiking along Kootenai River	0	0.0048	2	10	52	0.0017	0E+00	1E-06	0	0.09

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
ROW - right-of-way
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.8

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU3 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Exposure Area*	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Recreational Visitor	Hiking	Rainy Creek	0.0093	0.011	3.6	20	52	0.006	1E-05	1E-05	0.6	0.8
		Forest, near	0.00050	0.0042	8	50	52	0.034	3E-06	2E-05	0.2	2
		Forest, intermed.	0.00065	0.0056	8	50	52	0.034	4E-06	3E-05	0.2	2
		Forest, far	0.00023	0.0052	8	50	52	0.034	1E-06	3E-05	0.09	2
	ATV-riding	Forest, near	0.0014	0.0065	4	50	52	0.017	4E-06	2E-05	0.3	1
		Forest, intermed.	0.00050	0.0062	4	50	52	0.017	1E-06	2E-05	0.09	1
		Forest, far	0.00022	0.0060	4	50	52	0.017	6E-07	2E-05	0.04	1
	Campfire building/burning	Forest, near	0.0024	0.0072	2	50	52	0.0085	3E-06	1E-05	0.2	0.7
		Forest, intermed.	0.0022	0.0064	2	50	52	0.0085	3E-06	9E-06	0.2	0.6
		Forest, far	0.00046	0.0060	2	50	52	0.0085	7E-07	9E-06	0.04	0.6
	Driving	Forest, near	---	---	---	---	---	---	---	---	---	---
		Forest, intermed.	0	0.025	3	50	52	0.013	3E-07	5E-05	0.02	4
		Forest, far	0	0.024	3	50	52	0.013	0E+00	5E-05	0	3
	Fishing/boating	Kootenai River	0	0.00031	8	60	52	0.041	0E+00	2E-06	0	0.1
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	---	---	---	---	---	---	---	---	---	---
		Forest, intermed.	0.007	0.013	10	14	10	0.0023	3E-06	5E-06	0.2	0.3
		Forest, far	0.0045	0.0092	10	14	10	0.0023	2E-06	4E-06	0.1	0.2
		Forest, NPL boundary	0.00017	0.0011	10	14	10	0.0023	7E-08	4E-07	0.004	0.03
	Cutting firelines with heavy machinery	Forest, near	---	---	---	---	---	---	---	---	---	---
		Forest, intermed.	0.0025	0.0069	10	14	10	0.0023	1E-06	3E-06	0.06	0.2
		Forest, far	0.0016	0.011	10	14	10	0.0023	6E-07	4E-06	0.04	0.3
Mine Trespasser	ATV-riding	Mine (on/off-road)	0.014	0.017	4	10	52	0.0034	8E-06	1E-05	0.5	0.6
	Rockhound	Disturbed area	0.14	0.14	6	3	52	0.0015	4E-05	4E-05	2	2

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

--- = No ABS air samples have been collected within two miles from the mine for this scenario

*Distances from the mine are defined as follows:
- Forest, near: within two miles from the mine
- Forest, intermed.: between two and six miles from the mine
- Forest, far: greater than or equal to six miles from the mine
- Forest, NPL boundary: locations along the NPL boundary evaluated in the nature & extent forest study (see Section 6.6.2.4)

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
NPL - National Priorities List
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.9

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU5 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor Type	Exposure Location	Exposure Type	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Recreational Visitor	MotoX Track	Participant	0	0.0098	4	40	55	0.014	0E+00	2E-05	0	2
		Spectator	0	0.0011	4	60	45	0.018	0E+00	3E-06	0	0.2
	Bike Path	Rider, adult	0.000038	0.00091	2	48	52	0.0081	5E-08	1E-06	0.003	0.08
		Trailer, child	0.000053	0.00098	2	48	5	0.00078	7E-09	1E-07	0.0005	0.009
Outdoor Worker	Area 1	Worker	0.00080	0.011	4	135	25	0.022	3E-06	4E-05	0.2	3
	Area 2	Worker	0.00091	0.0040	4	135	25	0.022	3E-06	2E-05	0.2	1
	Area 3	Worker	0.0025	0.0036	4	135	25	0.022	9E-06	1E-05	0.6	0.9
	Area 4	Worker	0	0.0043	4	135	25	0.022	0E+00	2E-05	0	1
	Area 5	Worker	0.0057	0.017	4	135	25	0.022	2E-05	7E-05	1	4
	Area 6	Worker	0.0010	0.0035	4	135	25	0.022	4E-06	1E-05	0.2	0.9
	Area 7	Worker	0.00071	0.0027	4	135	25	0.022	3E-06	1E-05	0.2	0.7
	Area 8	Worker	0.0013	0.0025	4	135	25	0.022	5E-06	9E-06	0.3	0.6

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.10

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU6 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Operable Unit	Exposure Scenario	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU6	Pedestrian tresspasser	0	0.00065	4	60	52	0.020	0E+00	2E-06	0	0.1
	On-looker	0	0.0010	2	60	15	0.0029	0E+00	5E-07	0	0.03
	BNSF worker	0	0.00034	8	60	50	0.039	0E+00	2E-06	0	0.1

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

__Notes:__

ABS - activity-based sampling
BNSF - Burlington Northern Santa Fe
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.11

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU8 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-Cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Recreational Visitor	ATV riding ROW	0.00018	0.0029	4	184	52	0.062	2E-06	3E-05	0.1	2
Outdoor Worker	Brush-hogging ROW	0.0036	0.0055	8	60	30	0.023	1E-05	2E-05	0.9	1
	Mowing	0	0.0041	8	60	30	0.023	0E+00	2E-05	0	1
	Rotomilling	0.000049	0.0036	8	60	30	0.023	2E-07	1E-05	0.01	0.9
Various	Driving on Libby roads	0	0.00065	2	225	52	0.038	0E+00	4E-06	0	0.3
	Driving on Troy roads	0.00033	0.00047	0.75	225	52	0.014	8E-07	1E-06	0.05	0.08

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

* Original number of samples was 62 but sample number HW-00890 was overloaded

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ATV - all-terrain vehicle
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
ROW - right-of-way
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.12

Estimated Risks from Exposure to LA from Indoor Air in OU4 and OU7 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor Type	Building Description	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/day)	EF (days/year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Resident	OU4 Residential Properties - "Pre-Removal"	Active Behaviors	0.00099	0.016	5.8	350	52	0.17	3E-05	5E-04	2	30
		Passive Behaviors	0.000068	0.00024	16.9	350	52	0.50	6E-06	2E-05	0.4	1
								Total:	3E-05	5E-04	2	30
	OU4 Residential Properties - "Post-Removal"	Active Behaviors	0.00018	0.00038	5.8	350	52	0.17	5E-06	1E-05	0.3	0.7
		Passive Behaviors	0.000032	0.00020	16.9	350	52	0.50	3E-06	2E-05	0.2	1
								Total:	8E-06	3E-05	0.5	2
	OU4 Residential Properties - "No Removal"	Active Behaviors	0.000095	0.00049	5.8	350	52	0.17	3E-06	1E-05	0.2	0.9
		Passive Behaviors	0.000038	0.00021	16.9	350	52	0.50	3E-06	2E-05	0.2	1
								Total:	6E-06	3E-05	0.4	2
Indoor Worker	OU4 Commercial Properties - "Pre-Removal"	Active Behaviors	0.0033	0.0076	4	250	25	0.041	2E-05	5E-05	2	3
		Passive Behaviors	0.00027	0.00040	4	250	25	0.041	2E-06	3E-06	0.1	0.2
								Total:	2E-05	6E-05	2	3
	OU4 Commercial Properties - "Post-Removal"	Active Behaviors	0.00013	0.00015	4	250	25	0.041	9E-07	1E-06	0.06	0.07
		Passive Behaviors	0.0000096	0.000060	4	250	25	0.041	7E-08	4E-07	0.004	0.03
								Total:	1E-06	1E-06	0.06	0.1
	OU4 Commercial Properties - "No Removal"	Active Behaviors	0.00021	0.00059	4	250	25	0.041	1E-06	4E-06	0.09	0.3
		Passive Behaviors	0.000039	0.00028	4	250	25	0.041	3E-07	2E-06	0.02	0.1
								Total:	2E-06	6E-06	0.1	0.4
Resident	OU7 Residential Properties - "Post-Removal"	Active Behaviors	0.000056	0.000079	5.8	350	52	0.17	2E-06	2E-06	0.1	0.2
		Passive Behaviors	0.000016	0.000026	16.9	350	52	0.50	1E-06	2E-06	0.09	0.1
								Total:	3E-06	5E-06	0.2	0.3
	OU7 Residential Properties - "No Removal"	Active Behaviors	0.000027	0.000058	5.8	350	52	0.17	8E-07	2E-06	0.05	0.1
		Passive Behaviors	0.000013	0.000027	16.9	350	52	0.50	1E-06	2E-06	0.07	0.1
								Total:	2E-06	4E-06	0.1	0.2
Indoor Worker	OU7 Residential Properties - "No Removal"	Active Behaviors	0.000046	0.000068	4	250	25	0.041	3E-07	5E-07	0.02	0.03
		Passive Behaviors	0.0000048	0.000019	4	250	25	0.041	3E-08	1E-07	0.002	0.009
								Total:	4E-07	6E-07	0.02	0.04
Tradesperson, worker	OU4 Residential/Commerical - "Pre-Removal"	Bulk VI Removal	0.044	0.044	4	250	25	0.041	3E-04	3E-04	20	20
		Demolition	0.0078	0.0078	4	250	25	0.041	5E-05	5E-05	4	4
		Detailing attic	0.025	0.025	4	250	25	0.041	2E-04	2E-04	20	20
		Wet wipe/HEPA vac	0.015	0.015	4	250	25	0.041	1E-04	1E-04	7	7
Student	Kootenai Valley Head Start	Typical behaviors	0	0.00057	7	200	2	0.0046	0E+00	4E-07	0	0.03
	Libby Elementary School	Typical behaviors	0.000059	0.00056	7	200	6	0.014	1E-07	1E-06	0.009	0.08
	Libby Middle School	Typical behaviors	0.000051	0.00056	7	200	3	0.0068	6E-08	6E-07	0.004	0.04
	Libby High School	Typical behaviors	0	0.00054	7	200	4	0.0091	0E+00	8E-07	0	0.05
	Libby Admin. Building	Typical behaviors	0	0.00058	7	200	6	0.014	0E+00	1E-06	0	0.09
Teacher	Kootenai Valley Head Start	Typical behaviors	0	0.00057	8	210	25	0.068	0E+00	7E-06	0	0.4
	Libby Elementary School	Typical behaviors	0.000059	0.00056	8	210	25	0.068	7E-07	6E-06	0.05	0.4
	Libby Middle School	Typical behaviors	0.000051	0.00056	8	210	25	0.068	6E-07	6E-06	0.04	0.4
	Libby High School	Typical behaviors	0	0.00054	8	210	25	0.068	0E+00	6E-06	0	0.4
	Libby Admin. Building	Typical behaviors	0	0.00058	8	210	25	0.068	0E+00	7E-06	0	0.4

\+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.13

Estimated Risks from Exposure to LA from Indoor Air in OU1 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Building Description	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Office	Active (high-end)	0.00033	0.00033	3.2	147	52	0.040	2E-06	2E-06	0.1	0.1
Garage	Active (high-end)	0.00022	0.00022	3.2	147	52	0.040	1E-06	1E-06	0.1	0.1

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.14

Estimated Risks from Exposure to LA from Indoor Air in OU5 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Building Description	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Occupied Buildings											
B+C Packaging	Active Behaviors	0.000094	0.0058	1	300	5	0.0024	4E-08	2E-06	0.003	0.2
	Passive Behaviors	0	0.00049	*100% of time assumed to be active for RME*							
Bioreactor Building	Active Behaviors	0.00023	0.00061	6.4	250	25	0.065	3E-06	7E-06	0.2	0.4
	Passive Behaviors	0	0.00049	1.6	250	25	0.016	0E+00	1E-06	0	0.09
CDM Smith Main Office	Active Behaviors	0.0013	0.0032	6.4	250	25	0.065	1E-05	4E-05	1	2
	Passive Behaviors	0	0.00049	1.6	250	25	0.016	0E+00	1E-06	0	0.09
Central Maintenance Building	Active Behaviors	0.0010	0.013	8	319	27	0.11	2E-05	2E-04	1	20
	Passive Behaviors	0.00021	0.00021	*100% of time assumed to be active for RME*							
Fire Hall	Active Behaviors	0	0.0059	6.4	250	25	0.065	0E+00	7E-05	0	4
	Passive Behaviors	0	0.00049	1.6	250	25	0.016	0E+00	1E-06	0	0.09
Log Yard Truck Scale House	Active Behaviors	0.0065	0.050	0.083	10	25	0.000034	4E-08	3E-07	0.002	0.02
	Passive Behaviors	0	0.00050	*100% of time assumed to be active for RME*							
Luck EG Electric Motor Shed	Active Behaviors	0.0025	0.0025	0.33	300	15	0.0024	1E-06	1E-06	0.07	0.07
	Passive Behaviors	0	0.00045	*100% of time assumed to be active for RME*							
Office/Laboratory	Active Behaviors	0.00025	0.00084	6.4	250	25	0.065	3E-06	9E-06	0.2	0.6
	Passive Behaviors	0	0.00049	1.6	250	25	0.016	0E+00	1E-06	0	0.09
Vacant Buildings											
Chemical Storage Building	Active (high-end)	0	0.00049	8	250	25	0.082	0E+00	7E-06	0	0.4
Diesel Fire Pump House	Active (high-end)	0.00011	0.00066	8	250	25	0.082	2E-06	9E-06	0.1	0.6
Electric Pump House	Active (high-end)	0.00034	0.0016	8	250	25	0.082	5E-06	2E-05	0.3	1
Intermediate Injection Building	Active (high-end)	0	0.00048	8	250	25	0.082	0E+00	7E-06	0	0.4
LTU Leachate Building #1	Active (high-end)	0.000039	0.00043	8	250	25	0.082	5E-07	6E-06	0.04	0.4
LTU Leachate Building #2	Active (high-end)	0	0.00049	8	250	25	0.082	0E+00	7E-06	0	0.4
Pipe Shop	Active (high-end)	0	0.0022	8	250	25	0.082	0E+00	3E-05	0	2
Power house/office	Active (high-end)	0	0.00091	8	250	25	0.082	0E+00	1E-05	0	0.8
Shed 12	Active (high-end)	0	0.00039	8	250	25	0.082	0E+00	5E-06	0	0.4
Tank Farm Building	Active (high-end)	0	0.00049	8	250	25	0.082	0E+00	7E-06	0	0.4

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
OU - operable unit
LA - Libby amphibole asbestos
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX I.15

Estimated Risks from Exposure to LA During Disturbances of Wood-Related Materials Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Exposure Media	Receptor Population	Exposure/Disturbance Description	Wood Source*	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
				Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor air, during bark disturbances	Resident	Wood harvesting (Felling trees, de-limbing, cutting, stacking firewood)	Forest, near	---	---	---	---	---	---	---	---	---	---
			Forest, intermed.	0.0011	0.0069	10	15	40	0.0098	2E-06	1E-05	0.1	0.7
			Forest, far	0.00014	0.011	10	15	40	0.0098	2E-07	2E-05	0.01	1
	Outdoor Worker (commercial logger)	Hand-felling trees	~1 mile from mine	0.0034	0.0034	8	24	6	0.0019	1E-06	1E-06	0.07	0.07
		Hooking/skidding, processing timber	~1 mile from mine	0.10	0.105	10	24	12	0.0047	8E-05	8E-05	5	5
		Mechanical Processing	~1 mile from mine	0.0015	0.0015	10	24	12	0.0047	1E-06	1E-06	0.08	0.08
		Site restoration	~1 mile from mine	0.032	0.032	10	24	12	0.0047	3E-05	3E-05	2	2
		Simulated milling (chipping)	~1 mile from mine	0.0068	0.0068	10	24	12	0.0047	5E-06	5E-06	0.4	0.4
		Hand Felling	~4 miles from mine	0.0022	0.0065	8	24	6	0.0019	7E-07	2E-06	0.05	0.1
		Skidding/Hooking	~4 miles from mine	0.00065	0.0054	10	24	12	0.0047	5E-07	4E-06	0.03	0.3
		Mechanical Processing	~4 miles from mine	0	0.0064	10	24	12	0.0047	0E+00	5E-06	0	0.3
		Cutting slabs (pre-milling)	~4 miles from mine	0	0.0063	10	24	12	0.0047	0E+00	5E-06	0	0.3
		Simulated milling (chipping)	~4 miles from mine	0	0.0062	10	24	12	0.0047	0E+00	5E-06	0	0.3
		Site Restoration	~4 miles from mine	0.0040	0.0072	10	24	12	0.0047	3E-06	6E-06	0.2	0.4
	Outdoor Worker (at landfill)	Chipping wood waste piles	various	0	0.0021	4	135	25	0.022	0E+00	8E-06	0	0.5
	Outdoor Worker (USFS worker)	Forest management (Road maintenance, tree thinning, forest surveying)	Forest, near	---	---	---	---	---	---	---	---	---	---
			Forest, intermed.	0.00032	0.012	8	30	10	0.0039	2E-07	8E-06	0.01	0.5
			Forest, far	0.00020	0.013	8	30	10	0.0039	1E-07	9E-06	0.009	0.6
Outdoor air, during woodchip/ mulch disturbances	Outdoor Worker (at OU5)	Woodchip/waste bark pile disturbances	various	0	0.0012	4	135	25	0.022	0E+00	5E-06	0	0.3
	Resident	Woodchip/mulch disturbances during gardening	various	0	0.00060	2	40	52	0.0068	0E+00	7E-07	0	0.05
Indoor Air, during wood-derived ash disturbances	Resident	Emptying woodstove ash after burning firewood	~1 mile from mine	0.14	0.14	0.25	48	52	0.0010	2E-05	2E-05	2	2
			Flower Creek	0.0074	0.0074	0.25	48	52	0.0010	1E-06	1E-06	0.08	0.08
			Bear Breek	0.0029	0.014	0.25	48	52	0.0010	5E-07	2E-06	0.03	0.2

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

--- = No ABS air samples have been collected within two miles from the mine for this scenario

*Distances from the mine are defined as follows:

Forest, near: within two miles from the mine

Forest, intermed.: between two and six miles from the mine.

Forest, far: greater than or equal to six miles from the mine

Flower Creek: approximately six miles from the mine

Bear Breek: approximately 10 miles from the mine

**Monitor was placed in the cockpit of the responding helicopter

Notes:

ED - exposure duration

EF - exposure frequency

EPC - exposure point concentration

ET - exposure time

HQ - hazard quotient

LA - Libby amphibole asbestos

OU - operable unit

PCME - phase contrast microscopy - equivalent

RME - reasonable maximum exposure

s/cc - structures per cubic centimeter

TWF - time-weighting factor

USFS - United States Forest Service

APPENDIX I.16
Estimated Risks from Exposure to LA During Fire-Related Disturbances Based on Upper-Bound Concentrations
Libby Asbestos Superfund Site

Exposure Media	Receptor Population	Exposure/Disturbance Description	Wood Source*	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
				Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor air, during simulated burning activities	Outdoor Worker (firefighter during understory burn)	During burn (personal air)	~1 mile from mine	0.078	0.078	3	7	25	0.0009	1E-05	1E-05	0.7	0.7
		During dry mop-up	~1 mile from mine	0.75	0.75	2	7	25	0.0006	7E-05	7E-05	5	5
		During wet mop-up	~1 mile from mine	0.18	0.18	2	7	25	0.0006	2E-05	2E-05	1	1
	Resident (during understory burn)	During burn (200-ft monitor)	~1 mile from mine	0.00052	0.0018	24	8	52	0.0163	1E-06	5E-06	0.09	0.3
	Outdoor Worker (USFS worker during slashpile burn)	Building slashpile	~1 mile from mine	0.12	0.12	8	10	10	0.0013	3E-05	3E-05	2	2
		During burn (personal air)	~1 mile from mine	0.011	0.012	4	10	10	0.0007	1E-06	1E-06	0.08	0.09
		During dry mop-up	~1 mile from mine	0.13	0.13	2	10	10	0.0003	7E-06	7E-06	0.5	0.5
		During wet mop-up	~1 mile from mine	0.068	0.068	2	10	10	0.0003	4E-06	4E-06	0.2	0.2
	Resident (during slashpile burn)	During burn (200-ft monitor)	~1 mile from mine	0.00047	0.0038	24	8	52	0.0163	1E-06	1E-05	0.09	0.7
Outdoor air, during authetic wildfire	Resident	Downwind stations during wildfire	Souse Gulch	0	0.00070	24	8	52	0.0163	0E+00	2E-06	0	0.1
	Outdoor Worker (firefighter)	Ground-based firefighter activities	Souse Gulch	0.00031	0.0018	15	39	25	0.0239	1E-06	7E-06	0.08	0.5
		Air-based wildfire suppression**	Souse Gulch	0	0.0024	15	39	25	0.0239	0E+00	1E-05	0	0.6

[a] Non-detect samples are evaluated at zero.
[b] Non-detect samples are evaluated at the achieved sensitivity.
+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)
*Distances from the mine are defined as follows:
  Forest, near: within two miles from the mine
  Forest, intermed.: between two and six miles from the mine.
  Forest, far: greater than or equal to six miles from the mine
  Flower Creek: approximately six miles from the mine
  Bear Breek: approximately 10 miles from the mine
**Monitor was placed in the cockpit of the responding helicopter

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor
USFS - United States Forest Service

APPENDIX I.17

Estimated Risks from Exposure to LA During Background Soil Disturbances Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

ABS Script	ABS Dataset*	EPC (PCME LA s/cc)[+]		RME Exposure Parameters[++]				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
"Bucket of dirt" digging	OU4 Background Areas	0.0016	0.0019	6.6	60	52	0.034	9E-06	1E-05	0.6	0.7
	OU7 Background Areas	0.00032	0.00058	6.6	60	52	0.034	2E-06	3E-06	0.1	0.2
	OU4 Topsoil Borrow Sources	0.000046	0.00013	6.6	60	52	0.034	3E-07	7E-07	0.02	0.05
Raking, mowing, digging	OU4 "Curb-to-Curb" Yards	0.00039	0.00055	6.6	60	52	0.034	2E-06	3E-06	0.1	0.2

* See the *Background Soil Summary Report* (EPA 2014) for a detailed discussion of each type of ABS dataset.

[+] Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

[++] Exposure parameters for the RME residential yard soil disturbance scenario are used in the risk estimates.

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor