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LIBBY ASBESTOS SUPERFUND SITE
OPERABLE UNIT 3

INITIAL SCREENING LEVEL
HUMAN HEALTH RISK ASSESSMENT
FOR EXPOSURE TO ASBESTOS

Prepared by
U.S. Environmental Protection Agency
Region 8
Denver, CO

With Technical Assistance from:

SRC, Inc.
Denver, CO

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APPROVAL PAGE

This Initial Screening Level Human Health Risk Assessment for Exposure to Asbestos for Operable Unit 3 of the Libby Asbestos Superfund Site has been prepared by the U.S. Environmental Protection Agency, Region 8, with technical support from SRC, Inc., and is approved without conditions.

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1/24/2011
Date

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LIST OF ACRONYMS

95UCL	95% upper confidence limit
a	Age at first exposure
ABS	Activity-based sampling
ATSDR	Agency for Toxic Substances Disease Registry
ATV	All-terrain vehicle
cc	cubic centimeter (cm^3)
CE	Cumulative exposure
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CSM	Conceptual site model
d	Duration of exposure
DQO	Data quality objective
EF	Exposure frequency
EPA	United States Environmental Protection Agency
EPC	Exposure point concentration
ET	Exposure time
FS	Feasibility study
HQ	Hazard quotient
IUR	Inhalation unit risk
KDC	Kootenai Development Corporation
LA	Libby amphibole asbestos
OU	Operable Unit
PCM	Phase contrast microscopy
PCME	Phase contrast microscopy equivalent
RfC	Reference concentration
RI	Remedial Investigation
SAP	Sampling and analysis plan
s/cc	Structures per cubic centimeter of air
TEM	Transmission electron microscopy
TWF	Time weighting factor
um	Micrometer (10^{-6} meters)
USFS	U.S. Forest Service

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1.0 INTRODUCTION

This document is an initial screening-level human health risk assessment for exposure to Libby Amphibole asbestos (LA) at Operable Unit 3 (OU3) of the Libby Asbestos Superfund Site.

This risk assessment is based on data collected from OU3 through August 2010. Not all of these data have undergone full validation, analysis of all required laboratory-based quality control samples is not yet complete, and additional data may become available in the future. Therefore, the risk calculations presented here should be considered preliminary, and may be revised in the future. Additionally, this risk assessment uses toxicity factors for asbestos that are available as of January 2011. United States Environmental Protection Agency (EPA) is currently working to develop LA-specific cancer and non-cancer toxicity factors, but neither of these values are available yet. The purpose of these calculations is to provide an initial screening-level estimate of the levels of risk that may be associated with asbestos exposure during a range of different types of human activities in OU3 to assist in determining whether additional data are needed to fully characterize risk and/or to reduce uncertainties.

2.0 SITE DESCRIPTION

Libby is a community in northwestern Montana that is located near a large open-pit vermiculite mine. The site was actively mined for vermiculite from about 1920 to 1990. The mine is currently owned by W.R. Grace & Co.-Conn and the Kootenai Development Corporation (KDC), and is presently inactive.

Vermiculite from the mine near Libby is known to be contaminated with amphibole asbestos that includes several different mineralogical classifications. The most common forms are richterite and winchite, with lower frequencies of tremolite, edenite, magnesioriebikite, and magnesioarfendsonite (Meeker et al. 2003). Depending on the valence state of iron, some particles may also be classified as actinolite. For the purposes of EPA investigations at the Libby Asbestos Superfund Site, this mixture is referred to as Libby Amphibole (LA).

Historic mining, milling, and processing of vermiculite at the site are known to have caused releases of vermiculite and LA to the environment. Inhalation of LA associated with the vermiculite is known to have caused a range of adverse health effects in exposed humans, including workers at the mine and processing facilities (Amandus and Wheeler 1987, McDonald et al. 1986, McDonald et al. 2004, Sullivan 2007, Rohs et al. 2007), as well as residents of Libby (Peipins et al. 2003). Based on these adverse effects, EPA listed the Libby Asbestos Site on the National Priorities List in October 2002.

Using authority under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or Superfund, EPA began taking a range of cleanup actions at the site beginning in the year 2000 to eliminate sources of LA exposure to area residents and workers. Given the size and complexity of the Libby Asbestos Site, EPA designated a number of Operable Units (OUs).

This document focuses on risk associated with human exposure to LA in Operable Unit 3 (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 hazardous substances and/or pollutants or contaminants from the mine, including ponds, Rainy Creek, Carney Creek, Fleetwood Creek, and the Kootenai River. Rainy Creek Road is also included in OU3.

Figure 2-1 shows the location of the mine and a preliminary study area boundary for OU3. EPA established this preliminary study area boundary for the purpose of planning and developing the scope of the remedial investigation/feasibility study (RI/FS) for OU3. The bounds of this study area may be revised as data on the occurrence of LA in the environment are obtained and evaluated. The final boundary of OU3 will be defined by the final EPA-approved RI/FS.

3.0 EXPOSURE ASSESSMENT

3.1 Conceptual Site Model

The Kootenai Development Corporation (KDC), a subsidiary of W.R. Grace & Co., owns the mine area. Most of the land surrounding the mine is owned by the United States government and is managed by the U.S. Forest Service (USFS), although some parcels are owned by the State of Montana and are managed by the Department of Natural Resources and Conservation. Plum Creek Timberlands LP, a commercial logging company, also owns land parcels. Figure 3-1 illustrates land ownership within the OU3 study area. Most of the land in OU3 is forested, and is characterized by steep and rugged terrain. These lands are used mainly for recreational activities, and for private and commercial wood harvesting.

Figure 3-2 presents a conceptual site model (CSM) for human exposure to asbestos that summarizes EPA's current understanding of the pathways by which humans might be exposed to LA in OU3. The CSM for LA focuses on pathways of inhalation exposures, because for LA, the inhalation pathway is generally considered to be of much greater risk than oral or dermal pathways for human exposure. Additionally, although ingestion of asbestos may contribute to an increased cancer risk, EPA has not established dose-response relationship for this endpoint.

Exposed Populations

A range of different human receptors may be exposed to LA in OU3, including:

- Trespassers or "rockhounds" in the mined area – This population includes older children and adults who trespass on KDC property in the area that has been disturbed by past mining activities. In this document, this is referred to as the "mined area". Exposures of potential concern for asbestos include inhalation of ambient air and inhalation of air in the vicinity of soil, duff, and solid waste (e.g., tailings, ore) disturbances.

- Recreational visitors in the forested area – This receptor population includes older children (assumed to be age 7 or older) and adults who engage in activities such as camping, hiking, dirt bike riding, all terrain vehicle (ATV) riding, hunting, etc. Exposures of primary concern for asbestos include inhalation of ambient air, inhalation of air in the vicinity of contaminated soil, duff, or roadways/trails disturbed by recreational activity, and inhalation of LA released from contaminated tree bark while gathering wood for a campfire and while burning the wood in a campfire.

- Recreational visitors along streams and ponds – This receptor population includes adults and older children 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 as reaches of the Kootenai River that may be impacted by site releases. Exposures of potential concern for asbestos include inhalation of ambient air and inhalation of air in the vicinity of duff, dried soils or sediments that are disturbed by walking or exploring drainages. As noted above, exposure from ingestion of LA in fish is judged to be of minor concern compared to inhalation exposures that would occur during visits to OU3.

- Residential wood harvester in the forested area – This receptor population includes adult area residents who engage in sawing, hauling, and stacking wood for personal use. Exposures of potential concern for asbestos in OU3 include inhalation of ambient air, inhalation of airborne emissions of LA from roadways and inhalation of air that contains LA released from soil or duff as well as LA fibers released to air by cutting and hauling timber that has LA in the tree bark.

- Commercial loggers in the forested area – This receptor population includes adult workers who are employed in commercial logging operations in OU3. Exposures of potential concern for asbestos include inhalation of ambient air, inhalation of airborne emissions of LA from roadways and inhalation of air that contains LA released from soil or duff as well as LA fibers released to air by cutting and stacking timber that has LA in the tree bark.

- Forest service workers in the forested area – This population includes employees of the USFS who may engage in a range of forest management activities, including maintenance of roads and trails, cutting fire breaks, thinning and trimming trees, measuring trees, etc. Exposures of potential concern for asbestos include inhalation of ambient air, inhalation of airborne emissions of LA from roadways and inhalation of LA released to air from management activities that disturb soil, tree bark or duff.

- Forest service fire fighters in the forested area – This population includes employees of the USFS who respond to forest fires that occur within OU3. For ground-based fire fighters, exposures of potential concern include inhalation of ambient air, inhalation of LA released to air from disturbance of soil, duff, and tree bark while performing activities such as cutting fire lines, as well as inhalation of LA released to smoke by the fire. For pilots of aircraft that respond to fires in OU3, the exposure of concern is inhalation of LA that is released to smoke and that enters the aircraft as it passes through the smoke column.

- Area residents – Area residents who do not enter OU3 are not likely to be exposed to LA from OU3 except via inhalation exposure to LA released into air during a forest fire.

Note that other residential exposure scenarios are not included in the CSM for OU3 because any properties geographically within OU3 that are currently residential will be evaluated for routine residential scenarios as part of OU4. Based on information currently available to EPA, future residential development is not reasonably anticipated in other areas of OU3.

3.2 Exposure Scenarios of Chief Concern

Not all of the exposure scenarios to asbestos identified in Figure 3-2 are of equal concern or require equal levels of investigation. The following sections identify the pathways of chief concern to EPA and which are considered to warrant quantitative evaluation in the human health risk assessment for OU3.

Exposure to Ambient Air

All people who are present in OU3 may be exposed to LA in ambient air during passive behaviors that do not disturb any sources of LA. Therefore, this pathway has been selected for quantitative evaluation.

Exposures of Trespassers/Rockhounds within the Mined Area

The mined area is characterized by the occurrence of vermiculite interspersed with veins of LA exposed by mining, as well as large piles of mine waste, waste rock, and a coarse tailings pile. Sampling results from the Phase I remedial investigation at OU3 indicate that levels of LA greater than 1% occur at multiple locations in the mined area. The Phase I sampling results, along with observations of veins of LA exposed by mining, provide sufficient information to conclude that sources present are very likely to be of concern to human health. EPA guidance contained in OSWER Directive 9200.0-68 ("Framework for Investigating Asbestos-Contaminated Superfund Sites", EPA 2008d), provides that "if data indicate high levels of asbestos are present in soil (e.g., >1%), a risk manager may determine that a response action should be undertaken and that further efforts to characterize the source or potential airborne exposures before action is taken are not needed." Therefore, EPA has concluded that response action is necessary to prevent human exposure to LA within the mined area of OU3. EPA anticipates that access restrictions to the mined area and adjacent lands surrounding the mined area that are owned by KDC (including the unpaved portion of Rainy Creek Road) will be part of an OU3 response action and that quantification of hypothetical future exposures of trespassers within this mined area and surrounding W.R. Grace-owned property is not needed to support risk management decision-making. EPA expects that alternatives to prevent human access to the mined area will be evaluated in the feasibility study for OU3.

Exposures of Recreational Visitors in the Forest Area

Recreational visitors who enter the forested area around the mine site may be exposed to asbestos during a wide variety of activities that disturb contaminated source media, including soil, duff, and tree bark. The reasonable maximum exposure includes:

- Inhalation exposure while walking or hiking
- Inhalation exposure while riding an ATV
- Inhalation exposure while actively disturbing soil or duff when clearing a campsite or building a fire
- Inhalation exposure when gathering wood with LA contamination in bark for a campfire
- Inhalation exposure to smoke from burning wood with contaminated bark in a campfire

All of these activities are considered to be plausible and potentially important in evaluating human exposure in OU3, so all of the inhalation exposure pathways associated with these activities have been selected for quantitative evaluation. Note that due to the steep terrain, camping occurs mainly on roadways or at the sides of roadways within OU3. Similarly, because of the terrain within the forest area, ATV riding is possible only on roads in the area surrounding KDC owned property. Data to support the evaluation of risk associated with these activities were collected in the Phase III RI for OU3.

Exposures of Recreational Visitors Along Ponds and Creeks

Sediments in ponds and creeks that drain OU3 are known to be contaminated with LA, and recreational visitors who disturb the sediments while walking or fishing along the ponds or creeks might be exposed to LA released to air. In this regard, release of LA from sediments that are submerged is not of concern, and release from sediments that are exposed but still wet is likely to be relatively low. However, releases from contaminated sediments that become exposed and dry out during periods of low water could be of concern. The inhalation exposure pathway associated with these activities has been selected for quantitative evaluation.

Since EPA anticipates that access restrictions to the mined area and adjacent lands owned by KDC will be part of an OU3 response action, EPA's chief concern is for recreational visitors along the lower portion of Rainy Creek which is outside the boundary of KDC-owned property.

Exposures of USFS Workers

USFS workers have the potential to be exposed to LA released from disturbed soil, duff and tree bark during a range of different forest management activities such as trail maintenance, tree thinning, and stand examination. The inhalation exposure pathways associated with these activities have been selected for quantitative evaluation.

Exposures of USFS Firefighters

USFS firefighters have the potential to be exposed to LA released from disturbed soil, duff and tree bark when responding to wildfires in OU3. For ground-based firefighters, exposures of chief concern include inhalation of LA released from soil, duff, and tree bark while cutting firelines by hand and with heavy equipment. For pilots who respond by air, the exposure of chief concern is inhalation of LA in smoke that enters the aircraft cockpit. The inhalation exposure pathways associated with these activities have been selected for quantitative evaluation.

Exposure of Commercial Loggers

Commercial loggers harvesting wood in OU3 may be exposed as a result of release of fibers from soil, duff or tree bark into breathing zone air. At present, EPA has not collected any data that are specifically intended to allow an evaluation of risks to commercial loggers. EPA will consider the need to collect such data in the future, depending on the existing results and discussions with representatives of commercial logging companies regarding how well existing data characterize exposures to commercial loggers.

Exposure While Driving on Roads in OU3

With the exception of recreational visitors who hike along Lower Rainy Creek, it is expected that people who visit or work in OU3 are likely to travel in a vehicle (car, truck) on roads in OU3 to get to their destination. The movement of the vehicle along the road may disturb contaminated soil in or along the roadway, potentially leading to inhalation exposure of the vehicle occupants. Therefore, the inhalation exposure pathway associated with driving on roads in OU3 has been selected for quantitative evaluation

Exposures of Area Residents

Area residents who drive to the OU3 study area to harvest wood for use as a heating source have the potential to be exposed to LA released from disturbed soil, duff, and tree bark. The inhalation exposure pathways associated with this activity have been selected for quantitative evaluation. Data to support the evaluation of risk associated with residential wood harvesting were collected in the Phase IV RI for OU3.

In addition to the exposures associated with harvesting wood, during a forest fire within OU3, area residents also have the potential to be exposed to LA released in smoke from burning trees if the smoke travels to areas where people reside. EPA has established a set of monitoring stations that are activated when fires occur in OU3, but at present there are no data to support a quantitative risk characterization.

3.3 Approach for Characterizing Exposure

The amount of LA fibers released to air by humans visiting or working in OU3 will vary depending upon a number of factors, including:

- the level of LA in the source material (e.g., outdoor soil, duff, tree bark, roadways)
- the nature, intensity, and duration of the disturbance activity
- meteorological conditions (e.g., relative humidity, wind direction and speed)
- conditions of the source material (e.g., soil moisture, vegetative cover)

Because of this, predicting the LA levels in air associated with disturbance activities based only on measured LA levels in the source material is extremely difficult. For this reason, EPA recommends an empiric approach for investigating asbestos-contaminated Superfund sites in which concentrations of asbestos in air at the location of a source disturbance are measured rather than predicted (EPA 2008d). The use of personal air monitors to measure an individual's exposure to asbestos fiber concentrations in air are generally preferred over stationary air monitors, since personal monitors more accurately reflect the concentration of asbestos in the breathing zone of the exposed person. Activity-based sampling (ABS), a standard method used by industrial hygienists to evaluate workplace exposures, is a personal monitoring approach that is emphasized in EPA guidance to generate data for risk assessment (EPA 2008d).

3.4 Analytical Methods and Units of Concentration

The concentration of asbestos in air is traditionally expressed in units of structures per cubic centimeter of air (s/cc). Concentration values are estimated by drawing a known volume of air through a filter, and then examining a portion of the filter using an appropriate microscopic technique, and recording the number of asbestos structures that are observed. The concentration is then estimated as:

$$C = N / V$$

where:

C = concentration (s/cc)
N = Number of asbestos structures observed
V = Volume of air that passed through the area of filter examined (cc)

Historically, the method used to analyze air filters for asbestos was Phase Contrast Microscopy (PCM). This method uses relatively low magnification (up to 400x). Using the PCM method, a structure observed on the filter is counted if it has a fibrous morphology (generally parallel sides), has a length ≥ 5 um, and has an aspect ratio (length divided by width) of at least 3:1. Typically, fibers thinner than about 0.25 um in diameter are too small to be detected by PCM.

An important limitation of PCM analysis is that the method can not reliably distinguish between different types of asbestos, or even between asbestos and non-asbestos fibers. Therefore, at OU3, EPA has required that analyses of filters collected during ABS events be performed using Transmission Electron Microscopy (TEM) in accordance with the International Organization for Standardization (ISO) method 10312:1995(E) ISO 1995). This method allows reliable differentiation between asbestos and non-asbestos particles, and allows identification of asbestos fiber types. For OU3, EPA has specified that all amphibole structures that have appropriate Selective Area Electron Diffraction patterns and Energy Dispersive X-Ray Analysis spectra, and having length greater than or equal to 0.5 um and an aspect ratio greater than or equal to 3:1 will be recorded.

TEM can detect fibers much thinner than those that can be detected using PCM. Structures that are observed under TEM examination that satisfy the rules of PCM analysis (length ≥ 5 um, aspect ratio ≥ 3:1, thickness > 0.25 um) are referred to as PCM-equivalent (PCME) fibers. Thus, the concentration of PCME fibers is an estimate of what would have been observed had the sample been analyzed by PCM rather than TEM.

3.5 Summary of Available Data on LA in Air

EPA has performed a Remedial Investigation (RI) at OU3 to collect data on the concentration of LA that occurs in air under conditions when no disturbances are occurring (ambient air), and also under a range of human disturbances that are considered to be realistic and representative of activities that are performed in OU3 (activity based sampling, or ABS). The RI has been performed in a phased approach. For each phase of the RI, a detailed Sampling and Analysis Plan (SAP), including quantitative Data Quality Objectives (DQOs) was prepared to help ensure that all data collection efforts were well planned and that the resulting data would be appropriate for use in risk assessment (EPA 2007a, 2008, 2009, 2010). Table 3-1 summarizes the design of each of the air data collection efforts, and lists the number of samples that have been collected and analyzed to date.

Raw data for all ABS air samples, expressed both as total LA s/cc and as PCME LA s/cc, are provided in Appendix A.

4.0 TOXICITY ASSESSMENT

The adverse effects of asbestos exposure in humans have been the subject of a large number of studies and publications. The following section provides a brief overview of the primary types of adverse health effects that have been observed in humans. More detailed reviews of the literature are provided in IARC (1977), WHO (2000), and ATSDR (2001, 2004).

4.1 Non-Cancer Effects

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 1986).

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 (American Thoracic Society 2004).

Pleural Abnormalities

Exposure to asbestos may induce several types of abnormality in the pleura (the membrane surrounding the lungs).

- *Pleural effusions* are areas where excess fluid accumulates in the pleural space. Most pleural effusions last several months, although they may be recurrent.

- *Pleural plaques* are acellular collagenous deposits, often with calcification. Pleural plaques are the most common manifestations of asbestos exposure (ATSDR 2001, American Thoracic Society 2004).

- *Diffuse pleural thickening* is a non-circumscribed fibrous thickening of the visceral pleura with areas of adherence to the parietal pleura. Diffuse thickening may be extensive and cover a whole lobe or even an entire lung. Infolding of thickened visceral pleura may result in collapse of the intervening lung parenchyma (rounded atelectasis). Gevenois et al. (1998) and Schwartz et al. (1991) report that diffuse pleural thickening may occur as a result of pleural effusions.

Pleural effusions and plaques are generally asymptomatic, although rarely they may be associated with decreased ventilatory capacity, fever, and pain (e.g., Bourbeau et al. 1990). Diffuse pleural thickening can cause decreased ventilatory capacity (Baker et al. 1985; Churg 1986; Jarvholm and Larsson 1988). Severe effects are rare, although Miller et al. (1983) reported on severe cases of pleural thickening that lead to death.

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

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).

4.2 Cancer Effects

Many epidemiological studies have reported increased mortality from cancer in asbestos workers, 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 1993).

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; NTP 2005).

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 20-40 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).

Other Cancers

A number of studies suggest asbestos exposure may increase risk of cancer at various gastrointestinal sites (EPA 1986). NAS (2006) 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 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 (e.g., 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. However, 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.

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 (e.g., Selikoff et al. 1979; Enterline et al. 1987; Puntoni et al. 1979). 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.

5.0 QUANTIFICATION OF EXPOSURE AND RISK

5.1 Non-Cancer Risk

The basic equation for characterizing risk of non-cancer effects from inhalation exposure to asbestos is as follows:

$$HQ = C / RfC_{a,d}$$

where:

HQ	=	Hazard Quotient
C	=	Exposure concentration (PCM or PCME s/cc)
$RfC_{a,d}$	=	Reference concentration (PCM s/cc) for an exposure that begins at age "a" and lasts for duration "d" years

At present, there is no inhalation RfC available on EPA's Integrated Risk Information System for the assessment of non-cancer risks from airborne asbestos exposure. EPA is currently working to derive $RfC_{a,d}$ values for evaluating inhalation exposures to LA, but the approach is still under development and is not yet available for use in estimation of HQ values. Therefore, no quantitative evaluation of non-cancer risk is included in this risk assessment.

5.2 Cancer Risk

Excess lifetime risk of cancer (lung cancer plus mesothelioma) from exposure to asbestos in air is related to the amount of asbestos inhaled and the age when exposure occurs. The basic equation is (EPA 2008d):

$$Risk = EPC \cdot TWF \cdot IUR_{a,d}$$

where:

Risk = Lifetime excess risk of developing cancer (lung cancer or mesothelioma) as a consequence of the site-related asbestos exposure.

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

TWF = Time weighting factor. The value of the TWF term ranges from zero to one, and describes the average fraction of full time that exposure occurs in the time interval being evaluated. The general equation is (EPA 2008d):

$$TWF = ET/24 \cdot EF/365$$

where:

ET = Average exposure time (hrs/day) on days when exposure is occurring

EF = Average exposure frequency (days/year) in years when exposure is occurring

$IUR_{a,d}$ = Inhalation unit risk (PCM s/cc)$^{-1}$ for an exposure that begins at age "a" and lasts for duration "d" years

Note that in the application of the general equation for estimating cancer risk from inhalation of asbestos, the EPC must be expressed in the same units as the IUR. The units of concentration employed in the current EPA approach for estimating cancer risks are fibers per cubic centimeter (f/cc) as measured by PCM or PCME concentrations measured by TEM.

The level of cancer risk that is of concern is a matter of personal, community, and regulatory judgment. Under the Superfund program, the human health baseline risk assessment provides a basis for EPA, in consultation with the State, to determine whether response action is needed to protect human health. EPA guidance contained in OSWER Directive 9355.0-30, "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (EPA 1991) indicates that where the cumulative carcinogenic risk to an individual based on reasonable maximum exposure for both current and future land use is less than 1E-04 (one in ten thousand), and the non-cancer hazard quotient is less than 1, remedial action is generally not warranted unless there are adverse environmental impacts. The guidance also states that a risk manager may decide that a risk level lower than 1E-04 is unacceptable and that remedial action is warranted where there are uncertainties in the risk assessment results.

5.3 Exposure Point Concentrations

The value of the EPC term is based on TEM measurements of asbestos concentration levels in air (expressed as PCME LA s/cc) at the location of concern and for the exposure scenario of concern. Ideally, the EPC would be the true average concentration of LA in breathing zone air, averaged across the exposure duration "d". However, the true average exposure concentration can only be approximated from a finite set of measurements, and the sample mean might be either higher or lower than the true mean.

To minimize the chances of underestimating the true amount 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), and has developed a software application (ProUCL) to assist with the calculation of 95UCL values (EPA 2007b). 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 2008d). EPA is presently working to develop a new software application that will be appropriate for use with asbestos data sets, but the application is not yet available for use. Because the 95UCL cannot presently be calculated with confidence, risk calculations presented in this report utilize the sample mean only (EPA 2008d). Because the sample mean may be either higher or lower than the true mean, the risk estimates presented here may be either higher or lower than the true risks.

When computing the mean of set of air measurements, the best estimate of the mean is obtained simply by averaging the concentrations across all samples, treating "non-detects" (samples with a count of zero) as having a concentration of zero (EPA 2008d). However, as the number of non-detects in a data set becomes large, the uncertainty around the best estimate of the mean tends to increase. Therefore, for the purposes of this evaluation, the mean of each data set was calculated in two ways:

- Best estimate = sample mean treating all "non-detects" (zero count samples) as zero.
- Conservative Bound = sample mean assuming the concentration of each non-detect was less than one PCME structure times the analytical sensitivity of that sample. This approach is considered to be conservative, especially when many or all of the samples in a data set have a count of zero.

Appendix B provides summary statistics and EPC values (expressed as PCME LA s/cc), calculated as described above, for each of the exposure scenarios of potential concern.

5.4 Exposure Parameters

No data are presently available on the frequency or duration of human exposures that occur in OU3, and EPA has not established default parameters that are applicable for any of the exposure scenarios of potential concern. Therefore, for the purposes of this screening level risk assessment, exposure parameters for each exposure scenario were selected based on professional judgment. These values are shown in Table 5-1. These values are intended to be conservative. That is, it is considered likely that actual exposures in OU3 do not occur as often or as long as assumed, and that risk estimates based on the conservative assumptions are likely to be higher than actual.

5.5 Inhalation Unit Risk Values

Values of $IUR_{a,d}$ for a wide range of values for "a" (age at first exposure) and "d" (exposure duration) are provided in EPA (2008d). Table 5-2 provides the assumed age at first exposure and assumed exposure duration along with the corresponding value of $IUR_{a,d}$ for each of the exposure scenarios that are evaluated in this screening-level risk assessment.

5.6 Results

5.6.1 Risks from Breathing Ambient Air

As discussed previously, EPA collected multiple ambient air samples at multiple sampling stations near the mine area during both the Phase I and the Phase II RI. Sampling locations are shown in Figure 5-1. For Phase I, a total of eight stations were monitored for four successive 5-day periods between 10/2/2007 and 10/22/2007. For Phase II, a total of eight stations were monitored for a period of eight successive 5-day sampling periods between 7/7/2008 and 10/17/2008.

The results are summarized in Table 5-3, along with the estimated level of risk to people who are engaged in passive activities that do not cause a release of LA from a source. As shown, based on the best estimate EPC values, cancer risks are all at or below 6.4E-06, with an average across all stations and all sampling periods of 1.1E-06. Based on the conservative bound EPC values, risks are all less than 8.9E-06, with an average value of less than 4.4E-06.

5.6.2 Risks to a Recreational Visitor in the Forested Area

In Phase III of the RI, samples of personal air were collected from individuals engaged in a variety of activities that are considered representative of a recreational visitor in OU3. This included ATV riding, hiking, and building and burning a campfire. Each of these three scenarios was performed up to eight times by two individuals at each of 11 different areas in OU3. These ABS areas are shown in Figure 5-2.

The measured average exposure concentrations and the corresponding risk estimates are summarized in Table 5-4. In accord with the Phase III SAP (EPA 2009), because of the large number of samples, only the samples for one of the two individuals have been analyzed, and the remainder are being held for later analysis, if needed.

As shown, based on the best estimate EPC values, cancer risks are all at or below 3.3E-05, with an average across all stations and activities of 6.0E-06. Based on the conservative bound EPC values, risks are all less than 4.6E-05, with an average value of less than 4.1E-05.

5.6.3 Risks to a Recreational Visitor Along Lower Rainy Creek

In Phase IV of the RI, personal air samples were collected from two individuals hiking along lower Rainy Creek. This activity was performed five times, for a total of 10 samples. The measured average exposure concentrations and the corresponding risk estimates are summarized in Table 5-5. As shown, based on the best estimate EPC values, cancer risk is 3.1E-05. Based on the conservative bound EPC values, risk is less than 3.3E-05.

5.6.4 Risks to a Residential Wood Harvester

In Phase IV of the RI, samples of personal air were collected from two individuals engaged in wood harvesting activities at three different areas of OU3. These study areas are shown in Figure 5-3. During the first round, air samples were collected on one filter for the combined activity of cutting and hauling firewood. In later sampling rounds, the activity was split into two activities, including felling/limbing a tree and cutting/stacking firewood in a truck. Each of these activities was performed five times at each area.

The measured average exposure concentrations and the corresponding risk estimates are summarized in Table 5-6. As shown, based on the best estimate EPC values, cancer risks are all at or below 8.3E-06, with an average across all stations and activities of 2.4E-06. Based on the conservative bound EPC values, risks are all less than 1.3E-05, with an average value of less than 8.6E-06.

5.6.5 Risks to a USFS Worker

In Phase IV of the RI, samples of personal air were collected from two individuals engaged in several different activities that simulate actions that are performed by USFS workers as part of their forest management duties. This included trail maintenance, thinning trees, and stand examination (measuring the diameter and height of trees). Each of these activities was performed five times by two individuals at each of three areas.

The measured average exposure concentrations and the corresponding risk estimates are summarized in Table 5-7. As shown, based on the best estimate EPC values, cancer risks are all at or below 4.0E-06, with an average across all stations and activities of 1.5E-06. Based on the conservative bound EPC values, risks are all less than 4.1E-05, with an average value of less than 3.2E-05.

5.6.6 Risks to a USFS Fire Fighter

In Phase IV of the RI, samples of personal air were collected from individuals engaged in activities that simulate actions that are performed by USFS workers as part of their fire fighting activities. This included cutting fire lines by hand and with heavy equipment (a bulldozer).

Each of these activities was performed five times by two individuals at each of three areas. These activities were performed to capture exposures resulting from disturbance of soil, duff and tree bark, and do not include any exposures associated with inhalation of LA released in smoke from actual forest fires.

The measured average exposure concentrations and the corresponding risk estimates are summarized in Table 5-8. As shown, based on the best estimate EPC values, cancer risks are all at or below 6.6E-05, with an average across all stations and activities of 2.2E-05. Based on the conservative bound EPC values, risks are all less than 7.9E-05, with an average value of less than 3.8E-05.

5.6.7 Risks from Driving on Roads in OU3

In the Phase IV investigation, samples of personal air were collected from two individuals riding to and from three different areas in OU3. Samples were collected for each of five different events, yielding a total of 10 samples per area (30 total). Although these samples were collected as part of the wood harvesting scenario, the results are applicable to any people who travel in cars or trucks on roadways in OU3.

The exposure concentrations and risk estimates are summarized in Table 5-9. As shown, no PCME LA fibers were detected in any of the driving air samples, so best estimate EPC values and cancer risks are all zero. Based on the conservative bound EPC values, risks are all less than 2.8E-05, depending on the exposure frequency, exposure duration, and the age at first exposure for the population of concern.

5.6.8 Combined Risks

As noted above, it is considered likely that most visitors or workers in OU3 will be exposed during the drive to and from the exposure area as well as while engaged in outdoor activities. Therefore, the total risk to each population is the sum of the risks from driving and outdoor activities. These combined risks are presented in Table 5-10. As shown, the best estimates of risk range from 1.1E-06 to 3.1E-05, while conservative bound values range from 1.2E-05 to 6.9E-05. Because both the exposure parameters and the methods used to estimate exposure concentrations are likely to be conservative, it is considered probably that actual levels of exposure and risk to humans in OU3 are somewhat lower than estimated.

6.0 UNCERTAINTIES

There are a number of uncertainties that arise during the process of estimating human risk from exposure to asbestos, and these uncertainties affect the confidence in the estimated risks to people who may visit or work in OU3. Uncertainties act to both under-estimate and over-estimate the true risk. The principal sources of this uncertainty are discussed below.

Uncertainty in LA Concentrations in Inhaled Air

Concentrations of LA in air are inherently variable, so estimates of mean exposure concentrations (EPCs) are subject to uncertainty arising from random variation between individual samples. This uncertainty is further compounded by the effect of analytical measurement error. That is, for each air sample collected, the measured concentration value is a random variable that is characterized by the Poisson distribution:

$$C_{observed} \sim \text{POISSON} (C_{true} \cdot \text{Volume Analyzed}) / \text{Volume Analyzed}$$

As a consequence, the total variability (and hence uncertainty) in the measured concentration values is greater than the variability due to sampling variation alone. Consequently, risks calculated based on the mean may be either higher or lower than the true risk, but the magnitude of the potential error cannot be estimated because appropriate statistical methods are not yet available to calculate the 95UCL.

Uncertainty Arising from Use of an Indirect Preparation Technique

TEM analysis of air samples can not be reliably performed if dust covers more than about 25% of the filter. In the event that a sample is overloaded with dust, it is necessary to perform an indirect preparation, in which the material on the filter is suspended in water and sonicated, and a fraction of the water is applied to a secondary filter. For chrysotile asbestos, indirect preparation may sometimes cause a substantial increase in the number of asbestos particles counted during the analysis. The magnitude of the increase in estimated concentration due to indirect preparation is usually in the range of 2-100-fold (Hwang and Wang 1983, Sahle and Laszlo 1996), but may sometimes be as large as 1000-2000-fold (Kauffer at al. 1996, Chesson and Hatfield 1990). For amphibole asbestos, several reports indicate that the magnitude of the effect of indirect preparation is somewhat smaller (less than 10-fold) than for chrysotile (Bishop et al. 1978, Sahle and Laszlo 1996).

As shown in Table 6-1, a number of ABS samples collected during Phase IV were overloaded with dust and hence required indirect preparation. Consequently, EPCs from some Phase IV activities may be higher than the true average. This is especially true for hiking along lower Rainy Creek, cutting and hauling firewood, and cutting firelines, where the fraction of samples requiring indirect preparation was 50% or more. However, because the estimated risks are generally lower than the decision threshold for requiring response action under the Superfund program, even without any adjustment to account for this potential overestimation, this is not considered to be a major source of uncertainty in this particular case.

Uncertainty from Exposure Scenarios Not Evaluated

At present, no data have been collected for several scenarios of potential concern in OU3. Chief among these are the following:

- Inhalation exposure of USFS fire fighters (both ground-based and pilots of firefighting aircraft) to LA in smoke from burning trees and duff during forest fires in OU3
- Inhalation exposure of commercial loggers to LA released by disturbance of contaminated soil, duff and tree bark when harvesting wood in OU3

Lack of data for these scenarios results in uncertainty in the overall risks from exposures in OU3.

Lack of an Approved Non-Cancer Inhalation RfC

As noted above, EPA has not yet developed national guidance for evaluating the risk of non-cancer effects from inhalation exposure to asbestos. For most chemicals that cause both cancer and non-cancer effects, it is usually true that unacceptable risks from cancer occur at lower environmental exposure levels than unacceptable risks of non-cancer effects. In this case, if action is taken to protect humans from unacceptable cancer risk, concern over non-cancer risk is generally low. However, this may not be the case for LA. Studies of former workers and area residents (Armstrong et al. 1988; McDonald et al. 1986a, 1986b; Amandus et al. 1987; Peipins et al. 2003; Muravov et al. 2005; Whitehouse 2004) provide strong evidence that exposure to LA results in an increased incidence of non-cancer adverse effects, and that these effects occur in some individuals who appear to have had only low exposure. Thus, it should not necessarily be presumed that cancer risk is the "risk driver" at Libby OU3 or other parts of the Libby Site.

Uncertainty in Human Exposure Parameters

Risk from asbestos is strongly dependent not only on the level of exposure, but also on the time and frequency of exposure and on the age when exposure begins and ends. For OU3, all exposure parameters were assumed based on professional judgment, and hence all values are uncertain. As noted above, the values selected for use in this screening-level assessment are intended to be "high end", and hence actual exposures and risks are likely to be lower than estimated for a large majority of people.

Uncertainty in the Cancer Exposure-Response Relationship

Although the approach currently recommended by EPA for evaluation of cancer risk from asbestos (EPA 2008d) is based on extensive studies in humans, there are some uncertainties and potential limitations to the use of this method, as follows:

- The method is based on studies of workers exposed to a range of different types of asbestos (including chrysotile, various forms of amphibole, or to mixtures of chrysotile and amphibole asbestos), but the method does not distinguish between the potency of different mineral types of asbestos. However, there are a number of studies which suggest that mineral type may be an important determinant of potency, at least for mesothelioma, with amphibole asbestos being more potent than chrysotile asbestos. To the extent that amphibole is more potent that chrysotile, use of the current EPA method may tend to underestimate risks in Libby, where the mineral form of concern is amphibole.

- To the extent that the particle size distributions vary between workplaces (i.e., the ratio is not constant between the concentration of PCM fibers and the concentrations of other size ranges with differing potencies), the current method cannot account for these differences, and may either underestimate or overestimate risk.

- The current method is based on observations in male workers, and does not address any potential differences in susceptibility that might exist between different types of populations (e.g., children, women).

- The current method is based on the central tendency estimates of the potency factors, not an upper bound on the values. Thus, the true potency factors might be either higher or lower than the values selected.

- The current method is based on mortality statistics from the 1970's. As life expectancy in the United States has increased, risks from asbestos exposure also tends to increase. Thus, risk estimates based on the current method may be somewhat low.

Uncertainty Associated with Cumulative Exposures

Many people who visit or work in OU3 may also live or work in or about Libby, and hence may have exposure to LA from locations and activities outside of OU3. Because this risk assessment evaluates only risks associated with activities in OU3, the risk estimates should not be interpreted as total risk.

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TABLE 3-1
SUMMARY OF EPA STUDIES OF LA IN OU3 AIR

RI Phase	Exposed Population	Exposure Scenario	Number of Locations	Events per Location	Samples per Event	Target Samples	Number of Samples			SAP
							Collected	Analyzed		
								Direct	Indirect	
I	All	Ambient air	8	4	1	32	32	32	--	EPA 2007
II	All	Ambient air	8	8	1	64	64	64	--	EPA 2008
III	Recreational visitor	ATV Riding in forested area	11	8	2	176	152	76 (a)	--	EPA 2009
		Hiking in forested area	11	8	2	176	148	74 (a)	--	
		Fire building/burning	11	8	2	176	152	76 (a)	--	
IV	Recreational visitor	Hiking along Rainy Creek	1	5	2	10	10	3	7	EPA 2010
	Residential wood harvester	Driving to and from harvest area	3	5	2	30	30	27	3	
		Cutting and hauling firewood	3	1	2	6	6	2	4	
		Felling and limbing	3	4	2	24	32	4	28	
		Cutting and stacking	3	4	2	24	24	10	14	
	USFS Worker (forest management activities)	Trail maintenance	3	5	2	30	30	21	9	
		Thinning trees	3	5	2	30	30	15	15	
		Stand exam	3	5	2	30	30	24	6	
	USFS Firefighter (ground-based)	Cutting firelines by hand	3	5	2	30	30	16	14	
		Cutting firelines with heavy equipment	3	5	2	30	30	8	22	

(a) Only samples from one individual were planned for analysis. The remaining samples are held in achive, if needed.

TABLE 5-1
SCREENING LEVEL EXPOSURE PARAMETERS

Panel A: Outdoor Activities

Exposed Population	Exposure Scenario	ET (hrs/day)	EF (days/yr)	TWF --
Recreational visitor	Passive activities (ambient air)	8	50	0.0457
	Hiking/camping in forested area	8	50	0.0457
	Hiking along Rainy Creek	4	20	0.0091
Residential wood harvester	Cutting and hauling firewood	8	10	0.0091
USFS Worker	Forest management	8	30	0.0274
USFS Firefighter	Cutting firelines	8	30	0.0274

Panel B: Driving Scenario

Exposed Population	Exposure Scenario	ET (hrs/day)	EF (days/yr)	TWF --
Recreational visitor	Passive activities (ambient air)	1	50	0.0057
	Hiking/camping in forested area	1	50	0.0057
	Hiking along Rainy Creek	0	20	0.0000
Residential wood harvester	Cutting and hauling firewood	1	10	0.0011
USFS Worker	Forest management	1	30	0.0034
USFS Firefighter	Cutting firelines	1	30	0.0034

TABLE 5-2
SCREENING LEVEL UNIT RISK VALUES

Exposed Population	Exposure Scenario	Age at first exposure (yrs)	Exposure Duration (yrs)	IURa,d $(PCM\ f\text{-}yrs/cc)^{-1}$
Recreational visitor	Passive activities (ambient air)	7	40	0.1448
	Hiking/camping in forested area	7	40	0.1448
	Hiking along Rainy Creek	7	40	0.1448
Residential wood harvester	Cutting and hauling firewood	18	40	0.0902
USFS Worker	Forest management	18	40	0.0902
	Cutting firelines	18	40	0.0902

TABLE 5-3
SCREENING LEVEL RISKS FOR PASSIVE EXPOSURES (AMBIENT AIR)

Panel A: Best Estimate

Station	EPC (PCME s/cc)			Screening Level Cancer Risk		
ID	Phase I	Phase II	Combined	Phase I	Phase II	Combined
A-1	0.00000		0.00000	0.0E+00		0.0E+00
A-2	0.00000		0.00000	0.0E+00		0.0E+00
A-3	0.00000		0.00000	0.0E+00		0.0E+00
A-4	0.00000	0.00000	0.00000	0.0E+00	0.0E+00	0.0E+00
A-5	0.00000	0.00060	0.00040	0.0E+00	4.0E-06	2.6E-06
A-6	0.00000	0.00006	0.00004	0.0E+00	4.2E-07	2.8E-07
A-7	0.00000		0.00000	0.0E+00		0.0E+00
A-8	0.00000	0.00000	0.00000	0.0E+00	0.0E+00	0.0E+00
A-9		0.00096	0.00096		6.4E-06	6.4E-06
A-10		0.00000	0.00000		0.0E+00	0.0E+00
A-11		0.00045	0.00045		3.0E-06	3.0E-06
A-12		0.00000	0.00000		0.0E+00	0.0E+00
All	0.00000	0.00026	0.00017	0.0E+00	1.7E-06	1.1E-06

Panel B: Conservative Bound

Station	EPC (PCME s/cc)			Screening Level Cancer Risk		
ID	Phase I	Phase II	Combined	Phase I	Phase II	Combined
A-1	< 0.00053		< 0.00053	< 3.5E-06		< 3.5E-06
A-2	< 0.00053		< 0.00053	< 3.5E-06		< 3.5E-06
A-3	< 0.00053		< 0.00053	< 3.5E-06		< 3.5E-06
A-4	< 0.00055	< 0.00052	< 0.00053	< 3.6E-06	< 3.4E-06	< 3.5E-06
A-5	< 0.00055	< 0.00091	< 0.00079	< 3.6E-06	< 6.0E-06	< 5.2E-06
A-6	< 0.00053	< 0.00053	< 0.00053	< 3.5E-06	< 3.5E-06	< 3.5E-06
A-7	< 0.00053		< 0.00053	< 3.5E-06		< 3.5E-06
A-8	< 0.00061	< 0.00054	< 0.00056	< 4.0E-06	< 3.6E-06	< 3.7E-06
A-9		< 0.00134	< 0.00134		< 8.9E-06	< 8.9E-06
A-10		< 0.00056	< 0.00056		< 3.7E-06	< 3.7E-06
A-11		< 0.00084	< 0.00084		< 5.6E-06	< 5.6E-06
A-12		< 0.00053	< 0.00053		< 3.5E-06	< 3.5E-06
All	< 0.00055	< 0.00072	< 0.00066	< 3.6E-06	< 4.8E-06	< 4.4E-06

TWF 0.0457

IURa,d 0.1448 (PCM f-yrs/cc)$^{-1}$

TABLE 5-4
SCREENING LEVEL RISKS TO RECREATIONAL FOREST VISITORS

Scenario	ABS Area	Best Estimate		Conservative Bound	
		EPC (PCME s/cc)	Screening Level Cancer Risk	EPC (PCME s/cc)	Screening Level Cancer Risk
ATV Riding	ABS-01	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-02	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-03	0.0017	1.1E-05	< 0.0069	< 4.5E-05
	ABS-05	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-06	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-07	0.0008	5.0E-06	< 0.0060	< 4.0E-05
	ABS-08	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-10	0.0030	2.0E-05	< 0.0070	< 4.6E-05
	ABS-11	0.0010	6.6E-06	< 0.0060	< 4.0E-05
	ABS-13	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-14	0.0000	0.0E+00	< 0.0060	< 4.0E-05
Hiking	ABS-01	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-02	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-03	0.0009	5.7E-06	< 0.0069	< 4.5E-05
	ABS-05	0.0009	5.7E-06	< 0.0060	< 4.0E-05
	ABS-06	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-07	0.0015	9.9E-06	< 0.0060	< 4.0E-05
	ABS-08	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-10	0.0000	0.0E+00	< 0.0070	< 4.6E-05
	ABS-11	0.0010	6.6E-06	< 0.0060	< 4.0E-05
	ABS-13	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-14	0.0010	6.6E-06	< 0.0060	< 4.0E-05
Fire Building/Burning	ABS-01	0.0009	5.6E-06	< 0.0060	< 4.0E-05
	ABS-02	0.0009	5.6E-06	< 0.0060	< 4.0E-05
	ABS-03	0.0026	1.7E-05	< 0.0069	< 4.5E-05
	ABS-05	0.0030	2.0E-05	< 0.0060	< 4.0E-05
	ABS-06	0.0025	1.7E-05	< 0.0060	< 4.0E-05
	ABS-07	0.0007	4.9E-06	< 0.0060	< 4.0E-05
	ABS-08	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-10	0.0050	3.3E-05	< 0.0070	< 4.6E-05
	ABS-11	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-13	0.0026	1.7E-05	< 0.0060	< 4.0E-05
	ABS-14	0.0000	0.0E+00	< 0.0060	< 4.0E-05
All Activities Combined	ABS-01	0.0003	1.9E-06	< 0.0060	< 4.0E-05
	ABS-02	0.0003	1.9E-06	< 0.0060	< 4.0E-05
	ABS-03	0.0017	1.1E-05	< 0.0069	< 4.5E-05
	ABS-05	0.0013	8.5E-06	< 0.0060	< 4.0E-05
	ABS-06	0.0008	5.6E-06	< 0.0060	< 4.0E-05
	ABS-07	0.0010	6.6E-06	< 0.0060	< 4.0E-05
	ABS-08	0.0000	0.0E+00	< 0.0060	< 4.0E-05
	ABS-10	0.0027	1.8E-05	< 0.0070	< 4.6E-05
	ABS-11	0.0007	4.4E-06	< 0.0060	< 4.0E-05
	ABS-13	0.0009	5.6E-06	< 0.0060	< 4.0E-05
	ABS-14	0.0003	2.2E-06	< 0.0060	< 4.0E-05
All Areas, All Activities		0.0009	6.0E-06	< 0.0062	< 4.1E-05

TWF 0.0457

IURa,d 0.1448 $(\text{PCM f-yrs/cc})^{-1}$

TABLE 5-5
SCREENING LEVEL RISKS TO HIKERS ON
LOWER RAINY CREEK

Scenario	ABS Area	Best Estimate		Conservative Bound	
		EPC (PCME s/cc)	Screening Level Cancer Risk	EPC (PCME s/cc)	Screening Level
Hiking	Lower Rainy	0.0234	3.1E-05	< 0.0253	< 3.3E-05

TWF	0.0091	
IURa,d	0.1448	$(\text{PCM f-yrs/cc})^{-1}$

TABLE 5-6
SCREENING LEVEL RISKS TO RESIDENTIAL WOOD HARVESTER

Scenario	Location	Best Estimate		Conservative Bound	
		EPC (PCME s/cc)	Screening Level Cancer	EPC (PCME s/cc)	Screening Level Cancer Risk
Cutting and hauling firewood	ABS-10	0.0047	3.9E-06	0.0047	3.9E-06
	ABS-07	0.0101	8.3E-06	< 0.0124	< 1.0E-05
	ABS-02	0.0000	0.0E+00	< 0.0077	< 6.3E-06
Felling and limbing	ABS-10	0.0000	0.0E+00	< 0.0096	< 7.9E-06
	ABS-07	0.0074	6.1E-06	< 0.0118	< 9.7E-06
	ABS-02	0.0006	5.1E-07	< 0.0132	< 1.1E-05
Cutting and stacking	ABS-10	0.0000	0.0E+00	< 0.0114	< 9.4E-06
	ABS-07	0.0035	2.9E-06	< 0.0084	< 6.9E-06
	ABS-02	0.0000	0.0E+00	< 0.0153	< 1.3E-05
Combined	ABS-10	0.0016	1.3E-06	< 0.0086	< 7.0E-06
	ABS-07	0.0070	5.8E-06	< 0.0109	< 9.0E-06
	ABS-02	0.0002	1.7E-07	< 0.0121	< 9.9E-06
All Areas, All Activities		0.0029	2.4E-06	< 0.0105	< 8.6E-06

TWF 0.0091

IURa,d 0.0902 $(\text{PCM f-yrs/cc})^{-1}$

TABLE 5-7
SCREENING LEVEL RISKS TO USFS WORKERS

Scenario	Location	Best Estimate EPC (PCME s/cc)	Best Estimate Screening Level Cancer Risk	Conservative Bound EPC (PCME s/cc)	Conservative Bound Screening Level Cancer Risk
Trail maintenance	ABS-10	0.0000	0.0E+00	< 0.0166	< 4.1E-05
	ABS-07	0.0015	3.7E-06	< 0.0152	< 3.8E-05
	ABS-02	0.0008	1.9E-06	< 0.0164	< 4.0E-05
Thinning trees	ABS-10	0.0000	0.0E+00	< 0.0144	< 3.6E-05
	ABS-07	0.0008	1.9E-06	< 0.0113	< 2.8E-05
	ABS-02	0.0008	1.9E-06	< 0.0152	< 3.8E-05
Stand exam	ABS-10	0.0000	0.0E+00	< 0.0082	< 2.0E-05
	ABS-07	0.0016	4.0E-06	< 0.0095	< 2.3E-05
	ABS-02	0.0000	0.0E+00	< 0.0088	< 2.2E-05
Combined	ABS-10	0.0000	0.0E+00	< 0.0131	< 3.2E-05
	ABS-07	0.0013	3.2E-06	< 0.0120	< 3.0E-05
	ABS-02	0.0005	1.2E-06	< 0.0134	< 3.3E-05
All Areas, All Activities		0.0006	1.5E-06	< 0.0128	< 3.2E-05

TWF 0.0274

IURa,d 0.0902 (PCM f-yrs/cc)$^{-1}$

TABLE 5-8
SCREENING LEVEL RISKS TO USFS FIREFIGHTERS

Scenario	Location	Best Estimate		Conservative Bound	
		EPC (PCME s/cc)	Screening Level Cancer Risk	EPC (PCME s/cc)	Screening Level Cancer Risk
Cutting firelines by hand	ABS-10	0.0000	0.0E+00	< 0.0116	< 2.9E-05
	ABS-07	0.0267	6.6E-05	< 0.0318	< 7.9E-05
	ABS-02	0.0106	2.6E-05	< 0.0155	< 3.8E-05
Cutting firelines with heavy equipment	ABS-10	0.0052	1.3E-05	< 0.0105	< 2.6E-05
	ABS-07	0.0072	1.8E-05	< 0.0107	< 2.7E-05
	ABS-02	0.0039	9.7E-06	< 0.0132	< 3.3E-05
Combined	ABS-10	0.0026	6.4E-06	< 0.0110	< 2.7E-05
	ABS-07	0.0170	4.2E-05	< 0.0213	< 5.3E-05
	ABS-02	0.0073	1.8E-05	< 0.0144	< 3.5E-05
All Areas, All Activities		0.0089	2.2E-05	< 0.0156	< 3.8E-05

TWF 0.0274

IURa,d 0.0902 $(\text{PCM f-yrs/cc})^{-1}$

TABLE 5-9
SCREENING LEVEL RISKS FROM DRIVING ON ROADS

Exposed Population	Exposure Scenario	Best Estimate		Conservative Bound	
		EPC (a) (PCME s/cc)	Screening Level Cancer	EPC (b) (PCME s/cc)	Screening Level Cancer Risk
Recreational visitor	Passive activities (ambient air)	0	0.0E+00	< 0.0338	< 2.8E-05
Recreational visitor	Hiking/camping in forested area	0	0.0E+00	< 0.0338	< 2.8E-05
Recreational visitor	Hiking along Rainy Creek	NA		NA	
Residential wood harvester	Cutting and hauling firewood	0	0.0E+00	< 0.0338	< 3.5E-06
USFS Worker	Forest management	0	0.0E+00	< 0.0338	< 1.0E-05
USFS Firefighter	Cutting firelines	0	0.0E+00	< 0.0338	< 1.0E-05

NA = not applicable

(a) EPC is based on the average of 30 samples collected while driving to and from three different locations in OU3

(b) EPC is based on the average of the analytical sensitivity for 30 samples collected while driving to and from three different locations in OU3

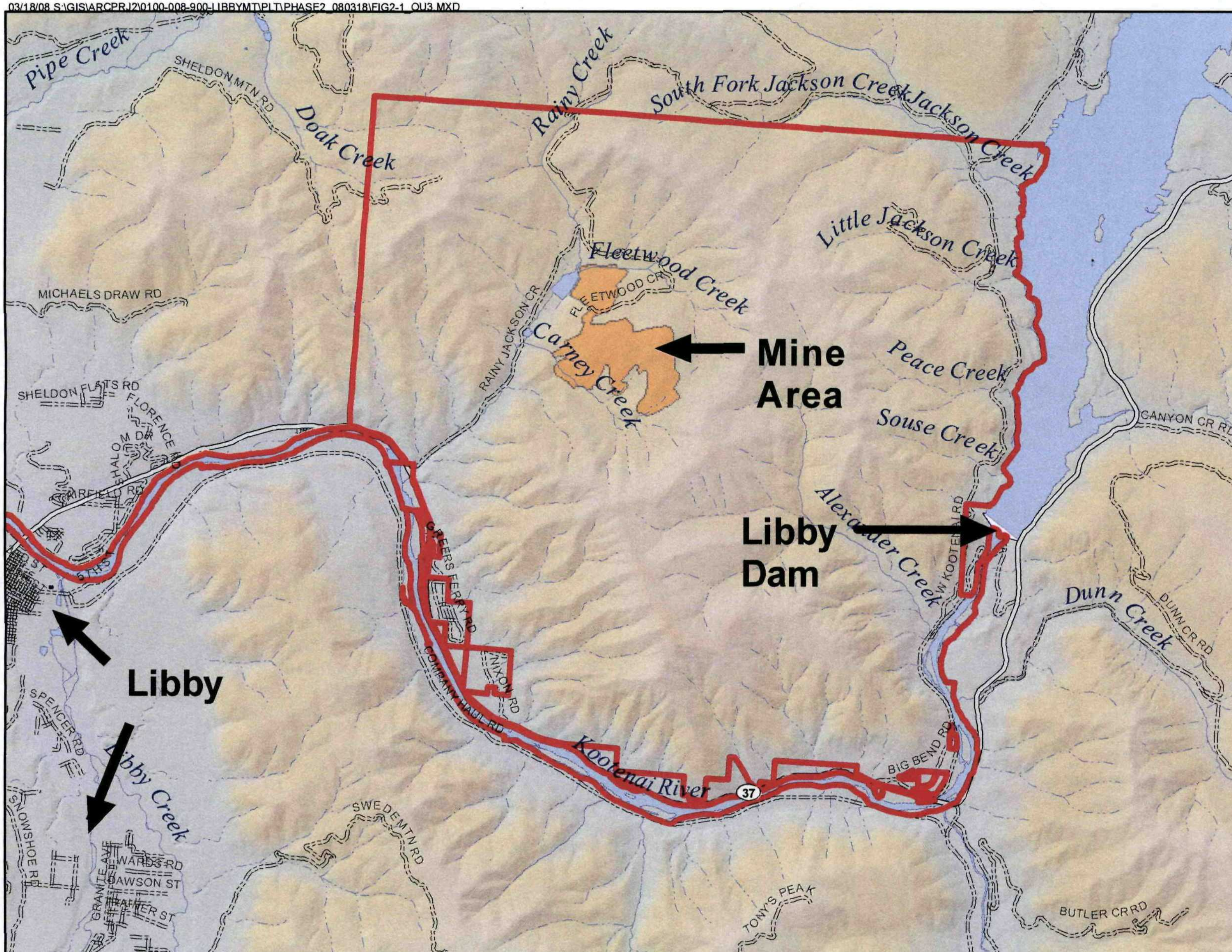
TABLE 5-10
COMBINED SCREENING LEVEL RISKS FROM DRIVING AND OUTDOOR

Exposed Population	Exposure Scenario	Screening Level Cancer Risk	
		Best Est.	Conserv. Bound
Recreational visitor	Passive activities (ambient air)	1.1E-06	< 3.2E-05
	Hiking/camping in forested area	6.0E-06	< 6.9E-05
	Hiking along Rainy Creek	3.1E-05	< 3.3E-05
Residential wood	Cutting and hauling firewood	2.4E-06	< 1.2E-05
USFS Worker	Forest management	1.5E-06	< 4.2E-05
	Cutting firelines	2.2E-05	< 4.9E-05

TABLE 6-1
SUMMARY OF INDIRECT PREPARATIONS

RI Phase	Exposed Population	Exposure Scenario	Number of Samples			% Indirect
			Collected	Analyzed		
				Direct	Indirect	
I	All	Ambient air	32	32	0	0%
II	All	Ambient air	64	64	0	0%
III	Recreational visitor	ATV Riding in forested area	152	76	0	0%
		Hiking in forested area	148	74	0	0%
		Fire building/burning	152	76	0	0%
IV	Recreational visitor	Hiking along Rainy Creek	10	3	7	70%
	Residential wood harvester	Driving to and from harvest area	30	27	3	10%
		Cutting and hauling firewood	6	2	4	67%
		Felling and limbing	32	4	28	88%
		Cutting and stacking	24	10	14	58%
	USFS Worker (forest management activities)	Trail maintenance	30	21	9	30%
		Thinning trees	30	15	15	50%
		Stand exam	30	24	6	20%
	USFS Firefighter (ground-based)	Cutting firelines by hand	30	16	14	47%
		Cutting firelines with heavy equipment	30	8	22	73%

03/18/08 S:\GIS\ARCPRJ2\0100-008-900-LIBBYMT\PLT\PHASE2_080318\FIG2-1_OU3.MXD



Libby Montana Superfund Site
Operable Unit 3

FIGURE 2-1

Operable Unit 3

PROJECT: 0100-008-900	MAR 18, 2008	
REV: 0	BY: VFS	CHECKED: ACK

20-SEP-2007 S:\GIS\ARCPRJ2\0100-008-900-LIBBYMT\PLT\PHASE1_070920\FIG5-6_OWNERSHIP.MXD

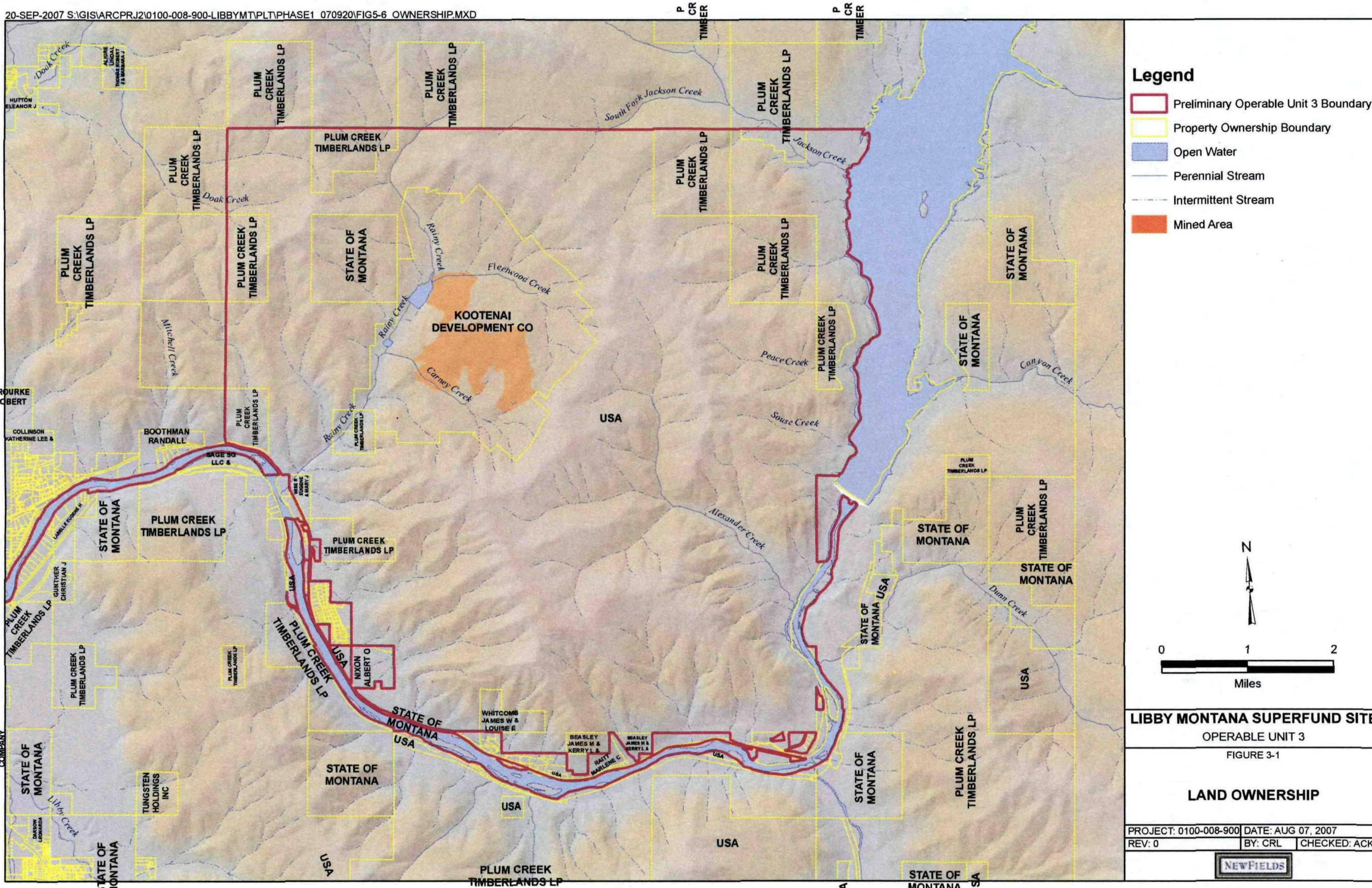
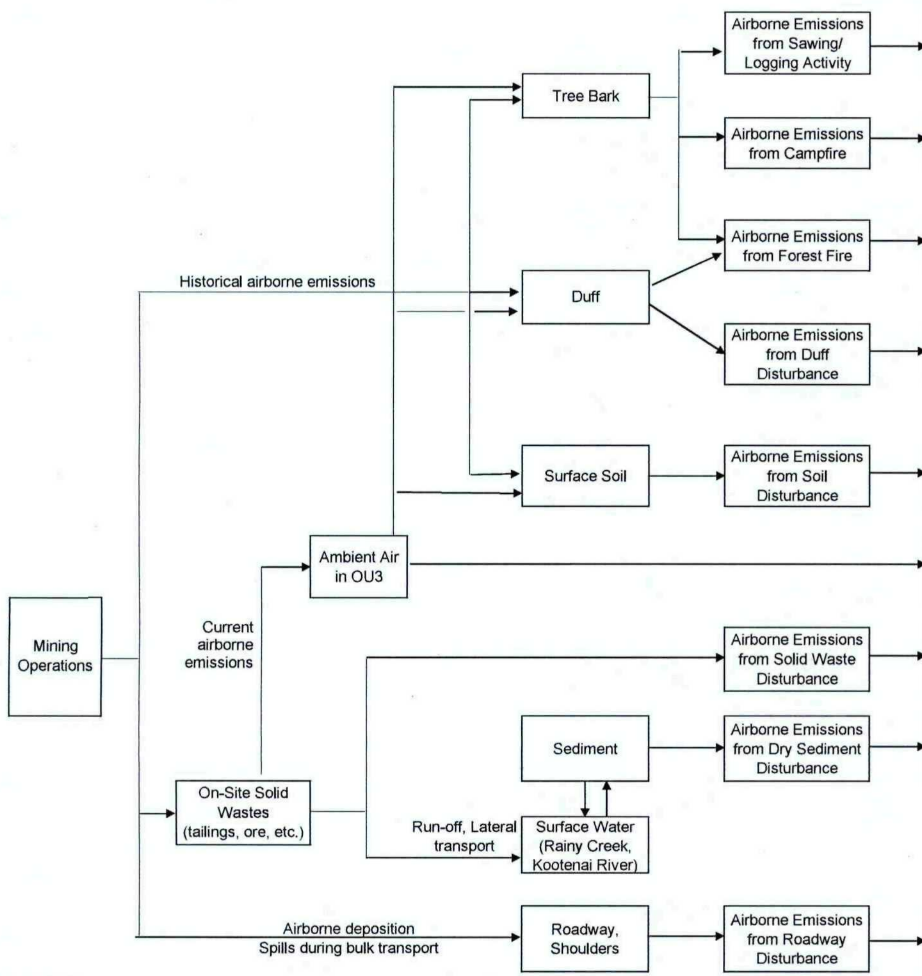


Figure 3-2. Conceptual Site Model for Human Exposure to Asbestos



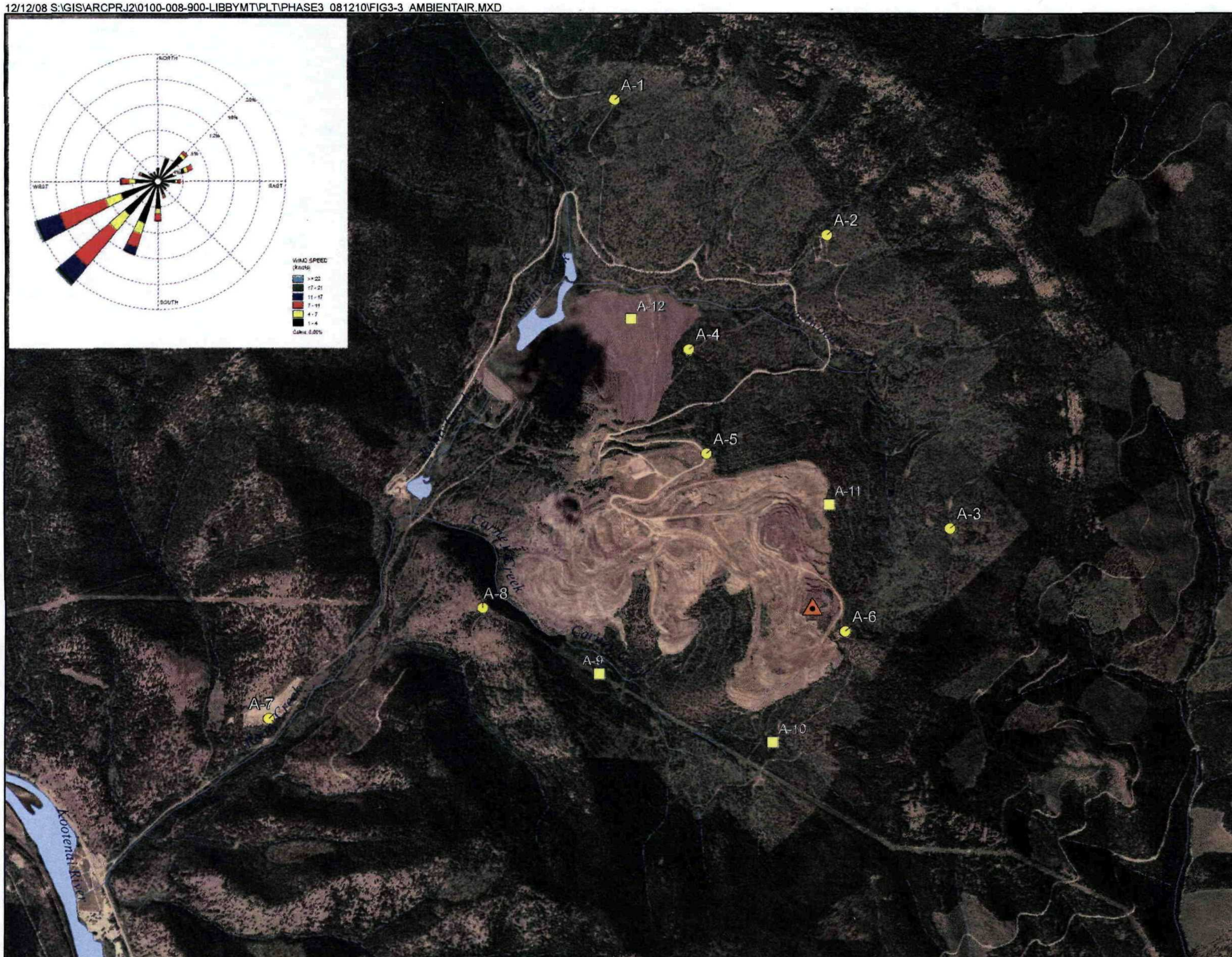
Source	Route	Trespasser/ Rockhound (mined area)	Recreational visitor in forest	Recreational visitior along LRC	Residential wood harvester	Commercial logger	USFS Worker	USFS Fire fighter	Area Resident
Airborne Emissions from Sawing/ Logging Activity	Inhalation				●	●	●	●	
Airborne Emissions from Campfire	Inhalation		●						
Airborne Emissions from Forest Fire	Inhalation							●	●
Airborne Emissions from Duff Disturbance	Inhalation	●	●	●	●	●	●	●	
Airborne Emissions from Soil Disturbance	Inhalation	●	●	●	●	●	●	●	
Ambient Air in OU3	Inhalation	●	●	●	●	●	●	●	
Airborne Emissions from Solid Waste Disturbance	Inhalation	●							
Airborne Emissions from Dry Sediment Disturbance	Inhalation			●					
Airborne Emissions from Roadway Disturbance	Inhalation	●	●		●	●	●	●	

LEGEND

● Pathway is complete and exposure may be significant

(blank) Pathway is incomplete or believed to be negligible

12/12/08 S:\GIS\ARCPRJ2\0100-008-900-LIBBYMT\PLT\PHASE3_081210\FIG3-3_AMBIENTAIR.MXD



Legend

- Phase I Air Monitoring Location
- Phase II Air Monitoring Location
- Meterological Station
- Open Water
- Perennial Stream
- Intermittent Stream

N

0 2,000 4,000

Feet

LIBBY MONTANA SUPERFUND SITE

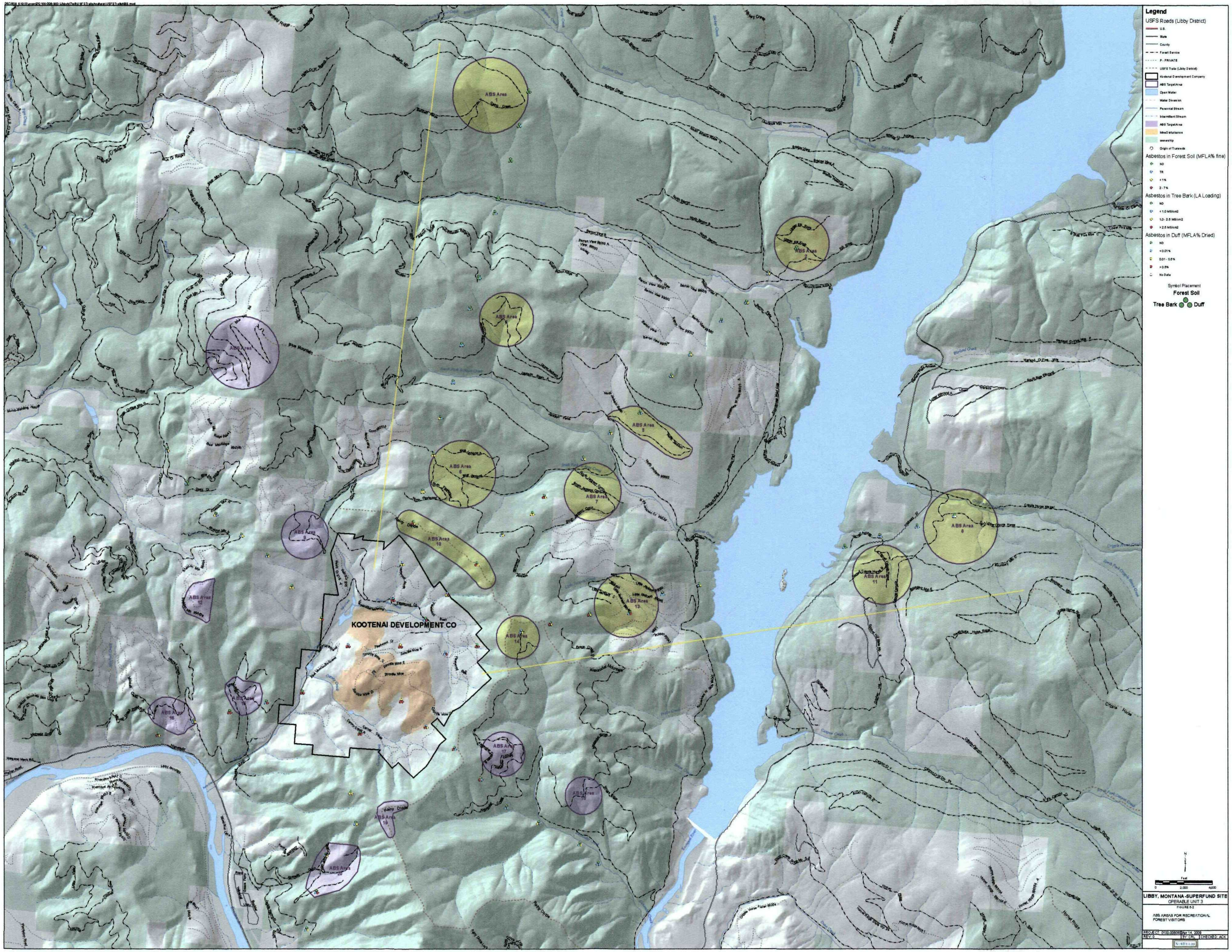
OPERABLE UNIT 3

FIGURE 5-1

AIR MONITORING LOCATIONS

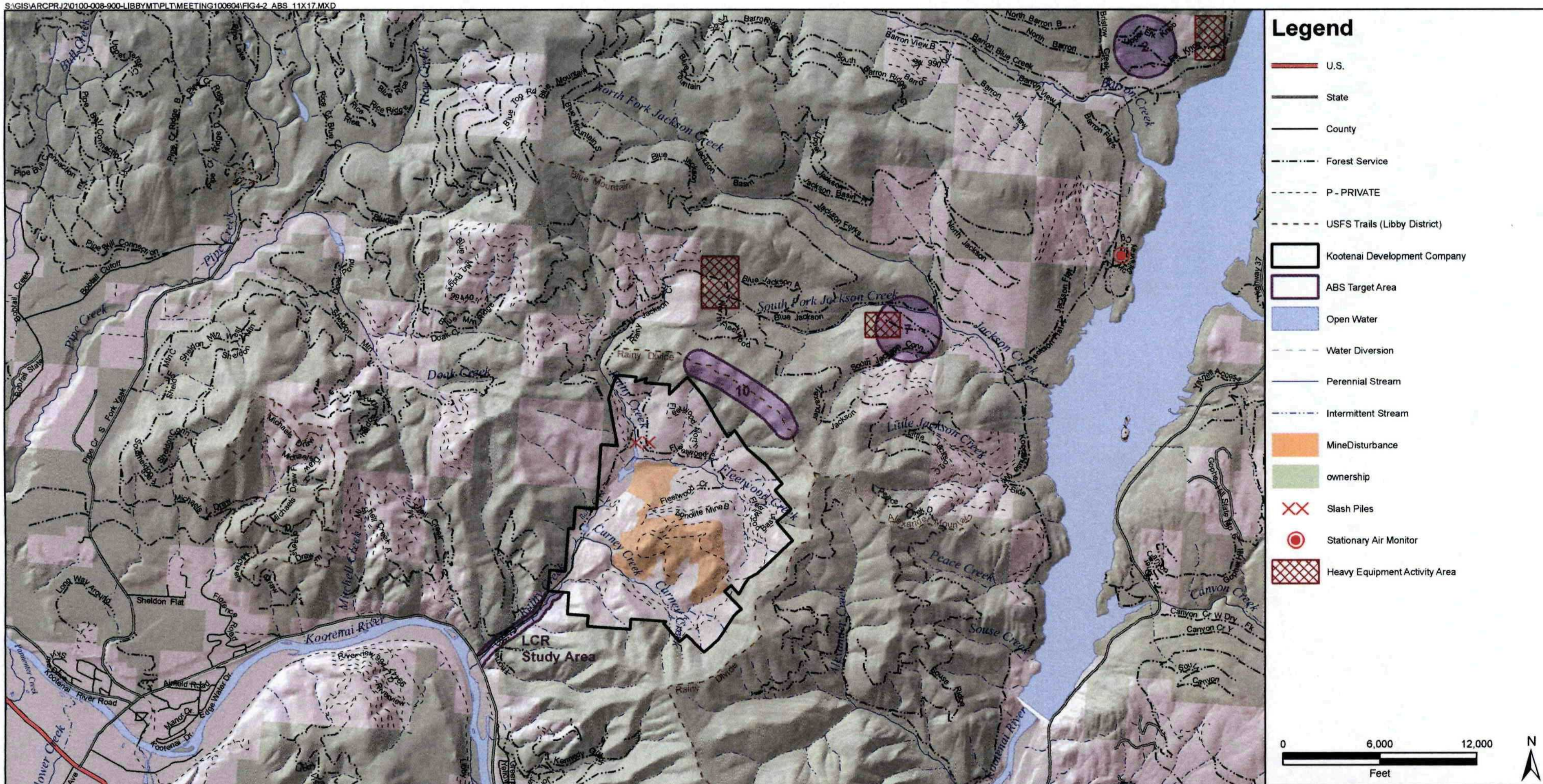
PROJECT: 0100-008-900	DEC 12, 2008	
REV: 1	BY: CRL	CHECKED: ACK

NEWFIELDS



Legend
USFS Roads (Libby District)
U.S.
State
County
Forest Service
P - PRIVATE
USFS Trails (Libby District)
Kootenai Development Company
ABS Target Area
Open Water
Water Diversion
Perennial Stream
Intermittent Stream
ABS Target Area
Mine Disturbance
ownership
Origin of Transects
Asbestos in Forest Soil (MFLA% fine)
ND
TR
< 1%
2 - 7%
Asbestos in Tree Bark (LA Loading)
ND
< 1.0 MS/cm2
1.0 - 2.5 MS/cm2
> 2.5 MS/cm2
Asbestos in Duff (MFLA% Dried)
ND
< 0.01%
0.01 - 0.5%
> 0.5%
No Data
Symbol Placement
Forest Soil
Tree Bark
Duff
KOOTENAI DEVELOPMENT CO
Feet
0
2,000
4,000
LIBBY, MONTANA - SUPERFUND SITE
OPERABLE UNIT 3
FIGURE 5-2
ABS AREAS FOR RECREATIONAL FOREST VISITORS
PROJECT: 0100-008090
Apr 14, 2009
REV: 0
BY: CRL
CHECKED: ACK

S:\GIS\ARCPRJ2\0100-008-900-LIBBYMT\PLT\MEETING100604\FIG4-2_ABS_11X17.MXD



LIBBY, MONTANA-SUPERFUND SITE

OPERABLE UNIT 3

FIGURE 5-3

ABS AREAS FOR PHASE IV STUDIES

PRJ: 0100-0080900	DATE: JUL 15, 2010
REV: 0	BY: CRL FOR: ACK

FORMATION ENVIRONMENTAL

APPENDIX A

RAW DATA *(provided electronically on the attached CD)*

TARGET SHEET

EPA REGION VIII

SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOCUMENT NUMBER: 1185563

SITE NAME: LIBBY ASBESTOS SITE

DOCUMENT DATE: 01/23/2011

DOCUMENT NOT SCANNED

Due to one of the following reasons:

- ☐ PHOTOGRAPHS
- ☐ 3-DIMENSIONAL
- ☐ OVERSIZED
- ☐ AUDIO/VISUAL
- ☐ PERMANENTLY BOUND DOCUMENTS
- ☐ POOR LEGIBILITY
- ☐ OTHER
- ☐ NOT AVAILABLE
- ☐ TYPES OF DOCUMENTS NOT TO BE SCANNED
  (Data Packages, Data Validation, Sampling Data, CBI, Chain of Custody)

DOCUMENT DESCRIPTION:

CD - APPENDIX A RAW DATA (SEE SDMS #1185564)

APPENDIX B

EXPOSURE POINT CONCENTRATIONS

APPENDIX B

TABLE B1. EPC FOR AMBIENT AIR

Phase	Station	N Samples	N Detects	Mean S (1/cc)	EPC (PCME s/cc)	
					Best Est.	Conserv. Bound
1	A-1	4	0	0.00053	0.00000	< 0.00053
	A-2	4	0	0.00053	0.00000	< 0.00053
	A-3	4	0	0.00053	0.00000	< 0.00053
	A-4	4	0	0.00055	0.00000	< 0.00055
	A-5	4	0	0.00055	0.00000	< 0.00055
	A-6	4	0	0.00053	0.00000	< 0.00053
	A-7	4	0	0.00053	0.00000	< 0.00053
	A-8	4	0	0.00061	0.00000	< 0.00061
2	A-4	8	0	0.00052	0.00000	< 0.00052
	A-5	8	4	0.00058	0.00060	< 0.00091
	A-6	8	1	0.00053	0.00006	< 0.00053
	A-8	8	0	0.00054	0.00000	< 0.00054
	A-9	8	3	0.00057	0.00096	< 0.00134
	A-10	8	0	0.00056	0.00000	< 0.00056
	A-11	8	2	0.00052	0.00045	< 0.00084
	A-12	8	0	0.00053	0.00000	< 0.00053

APPENDIX B
PHASE I

Station ID	Round	Index ID	Sensitivity 1/cc	LA Count		LA Conc. (s/cc)		EPC (s/cc)			
								Best Estimate		Conserv. Bound	
				Total	PCME	Total	PCME	Total	PCME	Total	PCME
A-1	1	P1-00005	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0005	< 0.0005
	2	P1-00017	0.0006	0	0	< 0.0006	< 0.0006				
	3	P1-00243	0.0005	0	0	< 0.0005	< 0.0005				
	4	P1-00277	0.0006	0	0	< 0.0006	< 0.0006				
A-2	1	P1-00006	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0005	< 0.0005
	2	P1-00018	0.0006	0	0	< 0.0006	< 0.0006				
	3	P1-00244	0.0005	0	0	< 0.0005	< 0.0005				
	4	P1-00278	0.0006	0	0	< 0.0006	< 0.0006				
A-3	1	P1-00010	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0005	< 0.0005
	2	P1-00024	0.0006	0	0	< 0.0006	< 0.0006				
	3	P1-00250	0.0005	0	0	< 0.0005	< 0.0005				
	4	P1-00284	0.0006	0	0	< 0.0006	< 0.0006				
A-4	1	P1-00007	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0006	< 0.0006
	2	P1-00020	0.0006	0	0	< 0.0006	< 0.0006				
	3	P1-00245	0.0005	0	0	< 0.0005	< 0.0005				
	4	P1-00279	0.0006	0	0	< 0.0006	< 0.0006				
A-5	1	P1-00008	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0005	< 0.0005
	2	P1-00022	0.0006	0	0	< 0.0006	< 0.0006				
	3	P1-00247	0.0005	0	0	< 0.0005	< 0.0005				
	4	P1-00281	0.0006	0	0	< 0.0006	< 0.0006				
A-6	1	P1-00009	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0005	< 0.0005
	2	P1-00023	0.0006	0	0	< 0.0006	< 0.0006				
	3	P1-00249	0.0004	0	0	< 0.0004	< 0.0004				
	4	P1-00283	0.0006	0	0	< 0.0006	< 0.0006				
A-7	1	P1-00001	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0005	< 0.0005
	2	P1-00015	0.0006	0	0	< 0.0006	< 0.0006				
	3	P1-00241	0.0004	0	0	< 0.0004	< 0.0004				
	4	P1-00275	0.0006	0	0	< 0.0006	< 0.0006				
A-8	1	P1-00003	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0006	< 0.0006
	2	P1-00016	0.0008	0	0	< 0.0008	< 0.0008				
	3	P1-00242	0.0004	0	0	< 0.0004	< 0.0004				
	4	P1-00276	0.0006	0	0	< 0.0006	< 0.0006				

Round 1: 10/2/2007 - 10/7/2007
Round 2: 10/7/2007 - 10/12/2007
Round 3: 10/12/2007 - 10/17/2007
Round 4: 10/17/2007 - 10/22/2007

APPENDIX B
PHASE II

Station ID	Round	Index ID	Sensitivity 1/cc	LA Count		LA Conc. (s/cc)		EPC (s/cc)			
								Best Estimate		Conserv. Bound	
				Total	PCME	Total	PCME	Total	PCME	Total	PCME
A-4	1	P2-00608	0.0005	0	0	< 0.0005	< 0.0005	0.0000	0.0000	< 0.0005	< 0.0005
	2	P2-00621	0.0005	0	0	< 0.0005	< 0.0005				
	3	P2-00632	0.0005	0	0	< 0.0005	< 0.0005				
	4	P2-00643	0.0005	0	0	< 0.0005	< 0.0005				
	5	P2-00653	0.0005	0	0	< 0.0005	< 0.0005				
	6	P2-00664	0.0005	0	0	< 0.0005	< 0.0005				
	7	P2-00674	0.0005	0	0	< 0.0005	< 0.0005				
	8	P2-00686	0.0005	0	0	< 0.0005	< 0.0005				
A-5	1	P2-00607	0.0005	0	0	< 0.0005	< 0.0005	0.0009	0.0006	< 0.0012	< 0.0009
	2	P2-00620	0.0005	2	2	0.0010	0.0010				
	3	P2-00634	0.0006	1	1	0.0006	0.0006				
	4	P2-00642	0.0005	9	5	0.0047	0.0026				
	5	P2-00652	0.0009	0	0	< 0.0009	< 0.0009				
	6	P2-00662	0.0005	1	1	0.0005	0.0005				
	7	P2-00673	0.0005	0	0	< 0.0005	< 0.0005				
	8	P2-00685	0.0005	0	0	< 0.0005	< 0.0005				
A-6	1	P2-00605	0.0005	0	0	< 0.0005	< 0.0005	0.0001	0.0001	< 0.0005	< 0.0005
	2	P2-00618	0.0005	0	0	< 0.0005	< 0.0005				
	3	P2-00629	0.0005	1	1	0.0005	0.0005				
	4	P2-00639	0.0006	0	0	< 0.0006	< 0.0006				
	5	P2-00649	0.0005	0	0	< 0.0005	< 0.0005				
	6	P2-00660	0.0006	0	0	< 0.0006	< 0.0006				
	7	P2-00671	0.0005	0	0	< 0.0005	< 0.0005				
	8	P2-00683	0.0005	0	0	< 0.0005	< 0.0005				
A-8	1	P2-00610	0.0006	0	0	< 0.0006	< 0.0006	0.0000	0.0000	< 0.0005	< 0.0005
	2	P2-00614	0.0005	0	0	< 0.0005	< 0.0005				
	3	P2-00625	0.0006	0	0	< 0.0006	< 0.0006				
	4	P2-00636	0.0005	0	0	< 0.0005	< 0.0005				
	5	P2-00646	0.0005	0	0	< 0.0005	< 0.0005				
	6	P2-00657	0.0005	0	0	< 0.0005	< 0.0005				
	7	P2-00668	0.0005	0	0	< 0.0005	< 0.0005				
	8	P2-00680	0.0005	0	0	< 0.0005	< 0.0005				
A-9	1	P2-00602	0.0005	0	0	< 0.0005	< 0.0005	0.0013	0.0010	< 0.0016	< 0.0013
	2	P2-00615	0.0009	1	0	0.0009	< 0.0009				
	3	P2-00626	0.0005	14	11	0.0072	0.0056				
	4	P2-00637	0.0005	1	1	0.0005	0.0005				
	5	P2-00647	0.0005	0	0	< 0.0005	< 0.0005				
	6	P2-00658	0.0005	4	3	0.0020	0.0015				
	7	P2-00669	0.0006	0	0	< 0.0006	< 0.0006				
	8	P2-00681	0.0005	0	0	< 0.0005	< 0.0005				
A-10	1	P2-00604	0.0005	0	0	< 0.0005	< 0.0005	0.0000	0.0000	< 0.0006	< 0.0006
	2	P2-00617	0.0007	0	0	< 0.0007	< 0.0007				
	3	P2-00627	0.0005	0	0	< 0.0005	< 0.0005				
	4	P2-00638	0.0005	0	0	< 0.0005	< 0.0005				
	5	P2-00648	0.0005	0	0	< 0.0005	< 0.0005				
	6	P2-00659	0.0006	0	0	< 0.0006	< 0.0006				
	7	P2-00670	0.0005	0	0	< 0.0005	< 0.0005				
	8	P2-00682	0.0005	0	0	< 0.0005	< 0.0005				
A-11	1	P2-00606	0.0005	0	0	< 0.0005	< 0.0005	0.0006	0.0004	< 0.0010	< 0.0008
	2	P2-00619	0.0006	0	0	< 0.0006	< 0.0006				
	3	P2-00630	0.0005	8	5	0.0041	0.0026				
	4	P2-00641	0.0005	0	0	< 0.0005	< 0.0005				
	5	P2-00650	0.0005	0	0	< 0.0005	< 0.0005				
	6	P2-00661	0.0005	2	2	0.0010	0.0010				
	7	P2-00672	0.0005	0	0	< 0.0005	< 0.0005				
	8	P2-00684	0.0005	0	0	< 0.0005	< 0.0005				
A-12	1	P2-00609	0.0005	0	0	< 0.0005	< 0.0005	0.0000	0.0000	< 0.0005	< 0.0005
	2	P2-00622	0.0005	0	0	< 0.0005	< 0.0005				
	3	P2-00633	0.0005	0	0	< 0.0005	< 0.0005				
	4	P2-00644	0.0005	0	0	< 0.0005	< 0.0005				
	5	P2-00654	0.0005	0	0	< 0.0005	< 0.0005				
	6	P2-00665	0.0005	0	0	< 0.0005	< 0.0005				
	7	P2-00676	0.0005	0	0	< 0.0005	< 0.0005				
	8	P2-00687	0.0006	0	0	< 0.0006	< 0.0006				

Round 1: 7/7/2008 - 7/12/2008
Round 2: 7/20/2008 - 7/25/2008
Round 3: 8/5/2008 - 8/10/2008
Round 4: 8/17/2008 - 8/22/2008
Round 5: 8/31/2008 - 9/5/2008
Round 6: 9/14/2008 - 9/19/2008
Round 7: 9/28/2008 - 10/3/2008
Round 8: 10/12/2008 - 10/17/2008

APPENDIX B

TABLE B2. EPC FOR RECREATIONAL FOREST VISITOR

Scenario	ABS Area	N Samples	N Detects	Mean S (1/cc)	EPC (PCME s/cc)	
					Best Est.	Conserv. Bound
ATV Riding	ABS-01	7	0	0.0060	0.0000	< 0.0060
	ABS-02	8	0	0.0060	0.0000	< 0.0060
	ABS-03	7	1	0.0060	0.0017	< 0.0069
	ABS-05	7	0	0.0060	0.0000	< 0.0060
	ABS-06	7	0	0.0060	0.0000	< 0.0060
	ABS-07	8	1	0.0060	0.0008	< 0.0060
	ABS-08	6	0	0.0060	0.0000	< 0.0060
	ABS-10	6	2	0.0060	0.0030	< 0.0070
	ABS-11	6	1	0.0060	0.0010	< 0.0060
	ABS-13	7	0	0.0060	0.0000	< 0.0060
	ABS-14	7	0	0.0060	0.0000	< 0.0060
Hiking	ABS-01	6	0	0.0060	0.0000	< 0.0060
	ABS-02	8	0	0.0060	0.0000	< 0.0060
	ABS-03	7	1	0.0060	0.0009	< 0.0069
	ABS-05	7	1	0.0060	0.0009	< 0.0060
	ABS-06	7	0	0.0060	0.0000	< 0.0060
	ABS-07	8	1	0.0060	0.0015	< 0.0060
	ABS-08	6	0	0.0060	0.0000	< 0.0060
	ABS-10	6	0	0.0060	0.0000	< 0.0070
	ABS-11	6	1	0.0060	0.0010	< 0.0060
	ABS-13	7	0	0.0060	0.0000	< 0.0060
	ABS-14	6	1	0.0060	0.0010	< 0.0060
Fire Building/Burning	ABS-01	7	1	0.0060	0.0009	< 0.0060
	ABS-02	7	1	0.0060	0.0009	< 0.0060
	ABS-03	7	3	0.0060	0.0026	< 0.0069
	ABS-05	8	3	0.0060	0.0030	< 0.0060
	ABS-06	7	2	0.0060	0.0025	< 0.0060
	ABS-07	8	1	0.0060	0.0007	< 0.0060
	ABS-08	6	0	0.0060	0.0000	< 0.0060
	ABS-10	6	3	0.0060	0.0050	< 0.0070
	ABS-11	6	0	0.0060	0.0000	< 0.0060
	ABS-13	7	2	0.0060	0.0026	< 0.0060
	ABS-14	7	0	0.0060	0.0000	< 0.0060

APPENDIX B
TABLE B3. EPC FOR PHASE IV SCENARIOS

Population	Scenario	ABS Script	Area	N Samples	N Detects	Mean S (1/cc)	EPC (PCME s/cc)	
							Best Est.	Conserv. Bound
Recreational visitor	Hiking along Rainy Creek	1	RAINY	10	7	0.0039	0.0234	< 0.0253
Residential wood harvester	Driving to and from harvest area	2A	ABS-10	10	0	0.0336	0.0000	< 0.0336
		2A	ABS-07	10	0	0.0354	0.0000	< 0.0354
		2A	ABS-02	10	0	0.0325	0.0000	< 0.0325
	Cutting and hauling firewood	2B	ABS-10	2	2	0.0047	0.0047	0.0047
		2B	ABS-07	2	1	0.0057	0.0101	< 0.0124
		2B	ABS-02	2	0	0.0077	0.0000	< 0.0077
	Felling and limbing	2B.1	ABS-10	10	0	0.0096	0.0000	< 0.0096
		2B.1	ABS-07	10	7	0.0092	0.0074	< 0.0118
		2B.1	ABS-02	12	1	0.0132	0.0006	< 0.0132
	Cutting and stacking	2B.2	ABS-10	8	0	0.0114	0.0000	< 0.0114
		2B.2	ABS-07	8	3	0.0066	0.0035	< 0.0084
		2B.2	ABS-02	8	0	0.0153	0.0000	< 0.0153
USFS Worker (forest management activities)	Trail maintenance	3A	ABS-10	10	0	0.0166	0.0000	< 0.0166
		3A	ABS-07	10	2	0.0152	0.0015	< 0.0152
		3A	ABS-02	10	1	0.0164	0.0008	< 0.0164
	Thinning trees	3B	ABS-10	10	0	0.0144	0.0000	< 0.0144
		3B	ABS-07	10	1	0.0113	0.0008	< 0.0113
		3B	ABS-02	10	1	0.0152	0.0008	< 0.0152
	Stand exam	3C	ABS-10	10	0	0.0082	0.0000	< 0.0082
		3C	ABS-07	10	2	0.0090	0.0016	< 0.0095
		3C	ABS-02	10	0	0.0088	0.0000	< 0.0088
USFS Firefighter (ground-based)	Cutting firelines by hand	3D	ABS-10	10	0	0.0116	0.0000	< 0.0116
		3D	ABS-07	10	8	0.0117	0.0267	< 0.0318
		3D	ABS-02	10	6	0.0097	0.0106	< 0.0155
	Cutting firelines with heavy equipment	3E	ABS-10	10	4	0.0072	0.0052	< 0.0105
		3E	ABS-07	10	6	0.0088	0.0072	< 0.0107
		3E	ABS-02	10	2	0.0109	0.0039	< 0.0132