INTERNATIONAL ENVIRONMENTAL RESEARCH FOUNDATION

Preliminary Analysis of the Asbestos Exposures Associated with Motorcycle Riding and Hiking in the Clear Creek Management Area (CCMA) San Benito County, California

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Executive Summary

The International Environmental Research Foundation (IERF) conducted air sampling to characterize the asbestos exposures, particularly to typical motorcycle riders, at the Clear Creek Management Area (CCMA) in San Benito and Fresno Counties, California. Ambient air samples were collected for determining the background of airborne asbestos for comparison with those found while riding off-highway vehicles (OHV) and hiking. These cumulative asbestos exposures were used for an asbestos-related cancer risk assessment presented in this document.

The IERF study was conducted at the request of the Off-Highway Motor Vehicle Recreation Division of California State Parks. The purpose of the study was to compare airborne asbestos concentrations measured during motorcycle OHV operation with results and conclusions from previous studies, in particular the May 2008 study conducted by the United States Environmental Protection Agency, Region 9 (EPA, 2008).

The IERF air sampling during OHV activity was limited to motorcycle riding because the highest asbestos exposures reported at CCMA are associated with this activity (Cooper *et al.* 1979). In the EPA Region 9 study all terrain vehicles (ATVs) were 3% higher than motorcycles, but EPA exposures for both OHVs were almost 10-fold lower than Cooper *et al.* 1979 (EPA, 2008). The IERF study evaluates motorcycle riding at CCMA as a recreational activity that individuals do for five days or less per year—not on a daily basis. This estimate is based on consultation with OHV enthusiasts who have previously visited CCMA for purposes of motorcycle recreation.

In addition to finding airborne chrysotile asbestos, about half the airborne fibers were needle-like, or acicular, tremolite particles. The morphological characteristics of the tremolite were inconsistent with tremolite asbestos and no fiber bundles were found. Tremolite asbestos is a rare mineral while non-asbestos tremolite is a common amphibole in the crust of the earth. However, for a worst case scenario, the acicular fragments longer than five microns were assumed to be asbestos and included in the cumulative asbestos exposure for the risk assessment.

The United States Occupational Safety and Health Administration (OSHA) has established an occupational permissible exposure limit (PEL) for asbestos at a concentration of 0.1 fibers per milliliter (f/mL) of air. No individual air sample exceeded the PEL and on average the concentration of asbestos (chrysotile and acicular tremolite) in all of the air samples IERF collected at CCMA was more than 10-fold lower than the OSHA asbestos PEL.

The World Health Organization (WHO), in a 1986 report, reported the ambient, or background, concentration of airborne asbestos worldwide as ranging between < 0.001 and 0.01 f/mL. The background airborne concentration of asbestos in the CCMA was 0.00137 f/mL, the low end of the WHO range for asbestos in the ambient air. Motorcycle riding increased the airborne asbestos concentration by about a factor of 10, to about 0.013 f/mL—an asbestos exposure more than 20-fold lower the EPA Region 9 value for motorcycle riding at CCMA.

Conditions for motorcycle riding at the CCMA in the previous studies appear to have been drier, and no mention was made of efforts to ride in such a way to minimize dust exposure. The earlier reports have higher levels of airborne dust and asbestos than found in the IERF study. Moisture conditions and riding practices are probably the key factors for obtaining the low cumulative asbestos exposures reported here.

Earlier studies report trailing riders have an asbestos exposure 5 to 10-fold higher than lead riders. In the IERF study the lead rider had a 36% higher exposure than the trailing rider and we average to two exposures assuming motorcycle riders would spend a similar amount of time in both positions.

The IERF study assumes in its risk assessment that motorcycle OHV enthusiasts will visit CCMA five days for one year and ride for eight hours on each of those days. Using the pessimistic 1986 EPA Airborne Asbestos Health Assessment Update, the lifetime risk for asbestos-related cancer for an OHV motorcycle rider, five days in one year, under the conditions we observed, would be 0.18 asbestos-related cancer deaths per million motorcycle riders. The above-referenced 1986 EPA Health Assessment Update is based on the increase in asbestos-related deaths from occupational asbestos exposures, and it is also the most protective in that it assumes a no threshold, linear dose-response.

For perspective, this risk is similar to the lifetime risk of death for smoking less than one cigarette over the same one year period. Other recreational activities, such as swimming, hiking, and snow skiing are over a 100-fold more dangerous.

The percentage of mesothelioma deaths predicted among the CCMA motorcycle riders for both sexes (0.000016%) is more than 6,500-fold lower than percentage of mesothelioma deaths in the US general population (0.11%).

Based on the IERF analysis, the results of which are included herein, there is clearly an opportunity to allow OHV recreation at CCMA. Under the conditions we observed, and similar seasonal conditions, OHV enthusiasts would not be exposed to unacceptably high levels of airborne asbestos.

1. Origin of the Problem: Summary of Previous Studies

We have reviewed three studies that analyze risk of asbestos exposure from motorcycle riding in the Clear Creek Management Area (CCMA). These are Cooper *et al*. 1979; PTI, 1992; and the United States Environmental Protection Agency (EPA) Region 9, 2008 report. We summarize the first one (Cooper *et al.* 1979) and the most recent EPA Region 9 2008 report, before describing our results and conclusions.

Cooper WC, Murchio W, Popendorf W, Wenk HR (1979) Chrysotile Asbestos in California Recreational Area. *Science* 206: 685-688.

The study was carried out in the spring and summer of 1978 and published the following year.

The CCMA is in San Benito County, California. It is located in the New Idria serpentinite, which is 90% or more chrysotile asbestos. The CCMA is 60,000 acres in the southern Diablo Range, 115 miles southeast of San Francisco. In 1975, 41,150 people visited the area, and about 85% operated off-highway motor vehicles, principally motorcycles; others were campers, hunters, and mineral collectors. At that time there were three chrysotile asbestos mines (Atlas, Johns-Manville, Union Carbide) operating in the area, producing 100,000 tons of chrysotile per year. The mines have since ceased production.

Personal air samples analyzed by Cooper and colleagues found asbestos exposures ranged from 0.3 to 5.6 fibers per milliliter of air (f/mL) (Table 1, Cooper *et al.* 1979). The airborne fibers were counted using phase-contrast optical microscopy (PCOM). The counting criteria required that only particles with lengths ≥ 5 microns (µm, a length of one micron equals 0.001 millimeters (mm)) and aspect ratios of ≥ 3:1 be counted. The aspect ratio is the length divided by the width. The use of PCOM allowed the investigators to compare the asbestos exposures from motorcycle riding to worker cohorts with occupational asbestos exposure and known health risks.

Motorcycle riding was found to increase the airborne concentration of total dust to about 20 milligrams per cubic meter (mg/m^3), where about 90% of the dust was chrysotile (Table 1). Cooper *et al.* 1979 were among the first to report asbestos exposures from recreational activities in ranges where prolonged exposure is known to be pathogenic. These exposures resulted from erosion of serpentinite containing asbestos rather than mining, milling, or industrial use of the minerals.

Three runs of personal air samples were collected in the breathing zones of six motorcycle riders on June 18, 1978. During the first two runs the riders were asked to maintain their starting orders. In the third run, the riders behind the leader could change position as they desired.

Other than the motorcycle samples, two other types of air samples were collected:

1. A personal air sample was collected on a United States Bureau of Land Management (BLM) ranger during a typical patrol of 5 kilometers (km) in a pickup truck on the main dirt road.

2. An area sample to determine the background asbestos concentration was collected at a fixed location 12.9 km north of the main road.

There were no strong winds to affect these two samples.

Fibers were counted using PCOM at 450x magnification. Selected samples were also examined by analytical transmission electron microscopy (ATEM). The ATEM analysis was not used for determining airborne fiber concentration but for the mineralogical identification of the airborne particles.

Summary of Cooper *et al.* 1979 Results

The airborne asbestos concentrations associated with motorcycle riding, for fibers ≥ 5 μm in length, was 0.3 to 5.6 f/mL with a mean value 3 ±1.5 f/mL (Table 1). Exposure to the lead rider was lower, 0.6 ±0.3 f/mL, while the trailing riders had higher exposures of 3.4 ±1.2 f/mL. Fibers ≥ 5μm long and visible by PCOM are the fraction used to estimate the risk of asbestos-related cancer. Fibers that are shorter than 5 μm have never been regulated in the asbestos exposure standard nor considered in any models for risk assessment of asbestos-related cancer (Appendix 1, see National Institute of Occupation Safety and Health's NIOSH-7400 Method, Hodgson and Darnton 2000, Gamble and Gibbs 2008, Langer 2008).

The average concentration in the air breathed by a BLM ranger during a typical pickup truck patrol was 0.4f/mL, and an area sample of ambient CCMA air for background was reported as 0.2f/mL (Table 1).

The total concentration of airborne dust during motorcycle riding was 0.0 to 61 mg/m^3 with a mean value of about 20 mg/m^3.

Cooper *et al* 1979 state, "… airborne concentrations approach the maximum that might be expected from natural sources, in view of the unusually high concentrations of chrysotile in the rocks and soils, the dry terrain, and the dust-generating activities that were taking place."

Ten to 20% of the airborne fibers had widths between 3 and 4μm. These comparatively large widths indicate the airborne fibers were predominantly fiber bundles not individual fibrils. Individual chrysotile fibrils do not have widths in this size range. Fiber bundles are likely to become airborne from the motorcycle riding, but are too large to remain in the air for a long period of time.

In 1975, the United States Occupational Health and Safety Administration (OSHA) lowered the occupational permissible exposure limit (PEL) (meaning exposure to a concentration of fibers in the air that is breathed) to 2 f/mL, but allowed excursions where the exposure levels were allowed to increase to 10 f/mL for 15 minutes.

Two of the air samples from motorcycle riders were in excess of the asbestos exposure ceiling proposed in Cooper *et al*. 1979 of 5 f/mL for recreational vehicles in CCMA (Table 1).

No correlation was found between fiber count and total mass of airborne dust largely due to the chunks of chrysotile in the respirable size range (< 3-5μm). The chunks occur as mats and do not have 3 to 1 aspect ratio.

Cooper *et al.* 1979 are silent on the presence of other types of asbestos besides chrysotile or the presence of other non-asbestos fiber types.

Major Findings of Cooper *et al.* 1979

1. Due to the high concentration of chrysotile in the New Idria serpentinite, airborne fibers in CCMA have widths, lengths, and concentrations suspected to be hazardous to health if inhaled over long periods of time.

2. It is doubtful that the number of fibers that have been inhaled to date by enthusiast who have visited the CCMA intermittently will constitute a measurable increased risk of asbestos-related cancers.

3. It is likely that appreciable concentrations of airborne asbestos may occur in other areas within CCMA where serpentinite crops out.

4. Sustained or frequent repetitive exposures to concentrations such as reported at CCMA, especially by children, do not seem justifiable.

5. If the federal government's guiding principal regarding asbestos exposure is that there be a zero-threshold level for carcinogenic effect, then it probably cannot ignore the potential asbestos exposures at CCMA, and exposures should therefore be kept "as low as feasible."

6. Cooper *et al.* 1979 state: "This demonstration of the high natural exposures further emphasizes the need for better understanding of the dose-response relationships between asbestos and malignancies to guide those who must set levels of acceptable exposures."

Table 1. The results of air sampling by Cooper *et al.* 1979 to quantify asbestos exposure in the CCMA. The mean exposure for the lead riders and the trailing riders was 0.6f/mL and 3.4f/mL respectively.

Position of Rider	Run 1 5.1km (15 minutes) f/mL	Run 1 Total Dust mg/m^3	Run 2 1.2 km (5 minutes) f/mL	Run 2 Total Dust mg/m^3	Run 3 10.3km (41 minutes) f/mL	Run 3 Total Dust mg/m^3
Lead	0.9	0.97	0.6	0.0	0.3	1.0
Trailing 1	5.6	31	3.0	12	1.9	17
Trailing 2	2.3	19	3.0	37	3.2	13
Trailing 3	4.3	21	4.9	20	2.9	11
Trailing 4	2.8	59	4.4	13	1.7	9
Trailing 5	5.3	61	3.1	22	2.9	22
Mean						
Lead	**0.9**	**0.97**	**0.6**	**0.0**	**0.3**	**1.0**
Trailing	**4.1**	**38**	**3.7**	**21**	**2.5**	**14**
All	**3.5**	**32**	**3.2**	**17**	**2.2**	**12**
BLM Ranger	0.4	1.7				
Area Sample	0.2	0.4				

Environmental Protection Agency (2008) Region 9: Report on the *Clear Creek Management Area Asbestos Exposure and Human Health Risk Assessment* (EPA Region 9, 2008)

Determination of Airborne Asbestos Concentration in CCMA by EPA Region 9

In its 2008 report, EPA Region 9 used ATEM rather than PCOM to analyze air filter samples they collected for their investigation. The PCOM method is recommended by the National Institute for Occupational Safety and Health (NIOSH) in their NIOSH 7400 Method (Appendix 1) for determining the concentration of airborne asbestos in the workplace and was used by Cooper *et al.* for their 1979 CCMA study. The EPA Region 9 2008 study reports the airborne concentrations of asbestos as the phase-contrast microscope equivalent (PCME) fraction of the airborne particles so the airborne asbestos concentrations in the two studies can be compared.

Occupational exposure to asbestos is not measured by counting all the airborne asbestos fibers, but rather by counting a subpopulation of the asbestos having a specific morphology visible by PCOM (Appendix 1). Airborne asbestos fibers are entrained on a membrane filter by drawing a known volume of air through the filter. By counting the number of asbestos fibers with a specific morphology in a given area of the filter, the concentration in fibers per milliliter of air (f/mL) can then be determined.

Asbestos exposures in the occupational workplace for regulatory purposes have never been monitored by ATEM. All of the asbestos risk assessments were developed from cumulative asbestos exposures determined using PCOM, or the fiber counts were converted to units of f/mL of air from earlier airborne particle counting using midget impinger measurements, historically reported in units of millions of particles per cubic foot (Hodgson and Darnton 2000, Gamble and Gibbs 2008, Gibbs and Berry 2008, Berry and Gibbs 2008).

The advantages of ATEM is the ability to go to higher magnifications than PCOM, allowing the airborne fibers that are < 5µm in length to be identified. It can also image fibers too narrow to be seen with the light microscopy.

Summary of EPA Region 9 2008 Results

EPA Region 9 reports the mean asbestos exposure for all adult motorcycle riders was 0.3071 f/mL and for children, it was 0.3671 f/mL (Table 2 and Table 3 herein, adapted from Tables G-1 and G-2 in EPA Region 9 2008 report). Exposure to the lead adult rider was lower, 0.0329 f/mL (Table 2). Similar to Cooper *et al.* 1979, EPA Region 9 reported higher exposures for trailing riders.

EPA Region 9 used a smaller number of motorcycle riders than the six used by Cooper *at al.* 1979. They used three riders.

The mean asbestos exposures for all adult all-terrain vehicle (ATV) riders and sport utility vehicle (SUV) drivers in all positions were 0.3174 f/mL and 0.1841 f/mL, respectively (Table 3). The lead rider exposures were markedly lower than all positions; exposures for the child riders were higher than the adults for motorcycles and ATVs.

About 8% of the airborne fibers analyzed by EPA Region 9 were reported to be amphibole asbestos. Chrysotile is the predominant asbestos type in most ambient air. There are no other reports in the scientific literature that claim as high an amphibole asbestos concentration in ambient air, anywhere in the world, with the exception of air samples taken in the proximity of a mine that contains amphibole asbestos (Thompson 1978, World Health Organization, 1986).

Soil samples were collected and analyzed for fiber concentrations as part of the EPA Region 9 study. The ratio of amphiboles to chrysotile in soil samples is much less than what the EPA detected in their air samples. This suggests the soil samples are not representative of the air samples, and the amphibole fibers are not uniformly distributed in the serpentinite.

Based on 29 ambient air samples analyzed for the EPA Region 9 2008 study, there was a mean asbestos fiber concentration of 0.00278 f/mL in the ambient air (Table 3 from Table G-200 in the EPA Region 9 2008 report).

Based on Table G-1 in the EPA Region 9 2008 study, a total of 33 personal air samples were collected from the adult motorcycle riders, not including the second air samples collected on the adult riders to model the exposures of child motorcycle riders (Table 2).

The EPA Region 9 2008 study references an "other amphibole" type detected in 25% of the air samples (Appendix H in EPA Region 9, 2008). The type of the "other amphibole" was not specified in further detail and was always found alone, not associated with any other detected amphibole fiber type.

In the 2008 study, EPA Region 9 reports, "When the sampling results were evaluated by the general meteorological conditions of the dates sampling was conducted, 'dry', 'moist', and 'wet', it was observed that asbestos air concentrations were only reduced when it was actively raining" (see EPA Region 9 2008 report, Executive Summary, page 2).

In a May 2008 "fact sheet" produced by EPA as a summary of the EPA Region 9 2008 study, it states, "based on the sampling results, it appears that only active rainfall reduces asbestos air concentrations, although further study would be needed to define the exact conditions necessary to reduce dust generation and asbestos exposure."

The EPA results are contrary to the common and accepted practice in mining where water trucks wet haul roads to reduce the airborne dust. Dust is suppressed not just from the spray of the water truck, but also because of the increase in moisture content of the soil.

Using rainfall patterns and on-site observation, EPA Region 9 defines three riding conditions for its 2008 study:

1. Dry with little or no precipitation in the months prior to the sampling event.
2. Moist with two or three inches of rain in the two weeks before the sampling event.
3. Wet with rain immediately before and during the sampling event.

Table 2. Twenty-nine air samples were collected on adult motorcycle riders to determine the airborne asbestos concentration during the three weather conditions – dry (Sep 2004 & Sep 2005), moist (Nov 2004) and wet (Feb 2005) and compared to the mean for the 33 air samples collected on motorcycles in all positions.

Adult Rider Position	Mean Asbestos Concentration (f/mL) (Number of Air Samples)			Mean of All Adult Motorcycle Air Samples
	Dry	Moist	Wet	
Lead	0.0247 (4)	0.051 (3)	0.010 (1)	0.0329
First Trailing	0.4465 (4)	0.3076 (5)	0.0199 (1)	
Second Trailing	0.699 (5)	0.2744 (5)	0.0598 (1)	
Mean All Positions	0.390 (13)	0.211(13)	0.0299 (3)	0.3071(33)

Major Findings of EPA Region 9 2008 Report

1. Twenty-nine ambient air samples were collected to characterize the background concentration of airborne asbestos in CCMA and the mean of these measurements was 0.00278 f/mL (Table 3).

2. The mean for three air samples taken during motorcycle riding under wet conditions was 0.0299 f/mL; about 10-fold above background and about 10-fold below the mean for all motorcycle air samples (Table 2).

3. The “wet” conditions are characterized by just three air samples while for “dry” and “moist” conditions, each have 13 air samples (Table 2). The “wet” conditions were under sampled.

4. The asbestos exposures on the “wet” day are the lowest for all three positions (Table 2).

5. The mean exposure for the motorcycle riders (in all positions) on a “dry” days is more than 25% higher than the mean for all the motorcycle samples (Table 2 herein and Table G-1 in EPA Region 9 2008 report).

6. When the IERF team conducted air sampling for its study, it had rained shortly before the air sampling days, but not on the sampling days. The IERF exposure concentration results (described in Section 4 of this report) for lead and trailing motorcycle riders are similar to those reported in the EPA Region 9 2008 report for lead and trailing rider air samples collected when conditions were described as “wet.”

How often asbestos exposures from motorcycle riding at CCMA will be similar to those measured by IERF has not been fully explored. While we have limited data for comparison with the past, we suggest that continuous attention to detailed management may be necessary to keep the level of airborne asbestos similar to what we are reporting.

Table 3. Airborne fiber counts by EPA Region 9 for the motorcycle riders, ATV riders and, SUV drivers. The PCME were determined by ATEM assuming the morphology of greater than or equal to 5 microns in length and widths equal to or less than 3 microns—an aspect ratio (length to width) of 3:1 or greater. The PCME fiber concentration is used to estimate the cumulative asbestos exposure in the risk assessment. (Adapted from EPA Region 9 2008 Report, Tables G-1, G-2 and G-200)

Vehicles	**Position of Rider**	**№ of Air Samples Adult Child**	**Adult f/mL**	**Child f/mL**
Motorcyclists	Lead	9	0.0329	
	All Positions	33 29	0.3071	0.3671
ATV Riders	Lead	9	0.0624	
	All Positions	18 17	0.3174	0.4404
SUV Drivers	Lead	15	0.1040	
	All Positions	29 25	0.1841	0.2605
Activity				
Camping		11 12	0.0874	0.0460
Hiking		15 13	0.0183	0.0260
Ambient		**№ of Air Samples**		
Mean		29	0.00278	

2. Comparison of the Airborne Asbestos Exposure at CCMA Reported by Cooper *et al.* 1979 and the EPA Region 9 2008 Report

1. Cooper *et al.* 1979 report the mean exposure for riding six motorcycles in CCMA as 3 ±1.5 f/mL while EPA Region 9 reports an order of magnitude lower airborne asbestos exposure of 0.3071 f/mL for three adult motorcycle riders.

2. The lead adult motorcycle riders in both studies had markedly lower exposures compared to the trailing riders.

3. All 18 of the air samples collected by Cooper *et al.* 1979 and 13 of the 29 motorcycle air samples collected by EPA Region 9 used to characterize the "dry," "moist," and "wet" conditions were collected at a time of year when CCMA has been seasonally closed (Table 1 and Table 2). Cooper *et al.* 1979 collected their samples on June 18, 1979 and the EPA Region 9 collected 13 samples in September of 2004 and 2005. These samples, collected at a time when the CCMA has been seasonally closed, represent more than 50% of the adult motorcycle samples collected at CCMA and provide support for the summer closing. However, these same samples, collected in the hot and dry weather when CCMA has been seasonally closed, have not been shown to be representative of other times of the year and should not be considered to evaluate keeping CCMA open from mid-October to the end of May.

3. Background for the International Environment Research Foundation (IERF) Study of the CCMA

The CCMA is named for the picturesque creek that runs through it (Figure 1). On entering CCMA the roads are unpaved (Figure 2) and signs inform visitors of the presence of asbestos that "could be hazardous to their health" (Figure 3). The features of the land are steep serpentinite hills with varying amounts of foliage (Figures 4, Figure 5, and Figure 6). There are 242 miles of public trails, some of which are fenced in, preventing off-trail riding. All of the IERF air samples were collected in the western part of CCMA in San Benito County.

The CCMA is in the serpentinite of New Idria, California. The chrysotile in this serpentinite differs from other commercial chrysotile deposits in two important ways. First, other commercial deposits contain only 5-10% chrysotile occurs as cross or slip fiber while commercial chrysotile in the New Idria deposit has greater than 50% recoverable chrysotile and second, no veins are found (Mumpton and Thompson 1975, Ross *et al.* 2008).

We decided to do personal air sampling only on adult motorcycle riders as they have been reported to experience the highest asbestos exposures (Cooper *et al.* 1979). EPA Region 9 exposures for ATVs were 3% higher than for motorcycle riders, but EPA asbestos exposures on both types of OHVs are nearly 10-fold lower than Cooper *et al.* 1979 (EPA Region 9, 2008).

The air samples are called personal because the air is collected in the "breathing zone" of the person. This is the chest area close to the mouth and nose. We note that the motorcycle riders wore helmets (Figure 7). The extent to which the helmet may reduce the concentration of airborne particles remains an open question.

We limited our air sampling to motorcycle riders only, as we expect exposures to persons in other types of vehicles to be either similar (ATVs) or lower. For air sampling, we separated the two riders by 15 to 20 feet (Figure 8). Earlier reports indicate the trailing motorcycle rider is passing through a cloud of dust raised by the lead rider, and both earlier studies reported higher exposures for trailing riders (Cooper *et al.* 1979, EPA Region 9, 2008).

In our study, we saw little, if any, visible dust from the lead or trailing rider (Figure 9 and Figure 10). This was likely due in part to the time of year when sampling was conducted, April 22-23, 2010, and to precipitation that occurred in the days prior to our collecting air samples, as well as the riding practice of keeping space between the riders.

The routes the riders took are shown in the four attached maps (Appendix 2). The motorcyclists spent time on both the county road and on the smaller trails, as shown on the maps.

In addition, we took three other types of air samples:

1) Ambient air samples collected near the main road of CCMA to determine background airborne asbestos concentrations (Figure 11).

2) Personal samples collected on a hiker (Figure 12).

3) Air samples collected from an air sampler affixed to the outside of a vehicle that was operated within CCMA. We assume these samples to be comparable to the Cooper *at al.* 1979 BLM ranger samples (Figure 13).

4. Major findings of IERF Results of for Airborne Asbestos Concentration at CCMA

We limit the summary to a description of the analyzed airborne fibers that are 5µm or longer as exposure to these fibers are used in the asbestos-related cancer risk assessment.

1. The subtotal asbestos exposure for motorcycle Rider-1 for both days was 12 fibers in 784mL of air or 0.015 f/mL, and for the trailing rider (Rider-2) it was 12 fibers in 1,085mL of air or 0.011 f/mL (Table 4 and Table 5). For the eight air samples taken during motorcycle riding there were 24 fibers identified in 1,869mL of air or 0.013 f/mL (Table 4 and Table 5).

2. The trailing IERF motorcycle rider had a lower asbestos exposure than the lead rider.

3. None of the air samples from any activity exceeded the current OSHA occupational PEL of 0.1f/mL (Table 4 and Table 5).

4. Of the fibers ≥ 5µm in length, 13 were chrysotile and 12 were tremolite fragments (Table 5). Tremolite fragments with lengths ≥ 5µm were found in five of the eight motorcycle air samples collected for the IERF study.

5. The tremolite was identified only on the similarity of the energy dispersive spectra to other tremolite specimens we have examined. The thickness of the fibers prevented selected area electron diffraction patterns from being obtained; these patterns are needed to prove the fragments are amphiboles (Langer *et al.* 1974).

6. Tremolite fragments were found only in the motorcycle samples and represents 50% of the fibers found in these eight air samples collected on motorcycle samples (Table 5).

7. The mean of the two area ambient air samples used to estimate ambient or background exposure is ≤ 0.003 f/mL. The subtotal of the two ambient air samples was 0.00137 f/mL, based on finding one fiber in 728mL of air (Figure 11).

8. For the two hiker air samples (460mL) no asbestos fibers were found the subtotal the volume of air from the two hiker samples was 460mL of air or less than 0.002 f/mL for all three samples less than 0.0018 f/mL (Figure 12).

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9. The asbestos concentration outside the moving vehicle no asbestos fibers were found 85mL of ≤ 0.012 f/mL. We assume that this is similar to a BLM ranger on patrol (Figure 13).

10. The airborne chrysotile in the personal samples at CCMA was about 50% fiber/fibrils and 50% fiber bundles. The formation of polyfilamentous fiber bundles is an important feature of asbestos minerals (Figure 14, Ross *et al.* 2008).

11. None of the airborne tremolite at CCMA occurred as fiber bundles (Figure 15). For comparison, the morphological appearance of tremolite-actinolite asbestos is shown in Figure 16 (Campbell *et al.* 1979, Dorling and Zussman 1987, Ross *et al.* 2008).

12. The total mass of airborne dust during motorcycle riding was ≤ 0.07 to 0.35mg/m^3, with a mean value of 0.17 mg/m^3. The total concentration of airborne dust is consistent with the observation that the motorcycle riding produced little, if any; visible dust on the days IERF collected air samples (Table 4, Figure 8, Figure 9, and Figure 10).

13. The airborne mass of total dust found by IERF was 100-fold less than the concentration reported by Cooper e*t al.* 1979 (Table 1 and Table 4). This corresponds well with the 250-fold lower concentration of airborne asbestos found in the IERF study (Table 5).

14. Two other airborne amphiboles were found in addition to the tremolite fragments. One has an elemental composition consistent with grunerite asbestos, commercially known as amosite. It was less than 5µm in length (Figure 17). The other has an elemental composition consistent with anthophyllite or talc and a width of about 0.8µm, with a needle-like or acicular morphology (Campbell *et al.* 1979, Dorling and Zussman 1987). Neither amphibole was included in the airborne asbestos concentrations. The amosite was too short to be considered, and the detected anthophyllite or talc was an incidental finding in a grid field not used in the fiber count.

15. The IERF study made an effort to have the trailing motorcycle rider ride in such a way as to avoid or minimize exposure to dust generated by the lead rider. This may not have been practiced during the other earlier studies as neither stated any steps were taken to minimize asbestos exposure.

Table 4. The results of air sampling by the IERF to quantify the ambient asbestos exposures and exposures when riding motorcycles, hiking, driving a truck at CCMA, in San Benito County, California. Among the air samples IERF collected at CCMA, 25 fibers greater than 5µm in length were identified, with 52% of the fibers having elemental compositions consistent with chrysotile and 48% consistent with tremolite. The morphology of the tremolite indicated these were acicular amphibole fragments. For a worst scenario risk analysis the tremolite was assumed to be asbestos.

	Day 1			**Day 2**			
	Run 1 (30 minutes)		**Run 2 (60 minutes)**	**Run 3 (140 minutes)**		**Run 4 (120 minutes)**	
Position of Rider	**f/mL§**	**Total Dust mg/m^3**	**f/mL**	**f/mL**	**Total Dust mg/m^3**	**f/mL**	**Total Dust mg/m^3**
Rider 1	0.006	0.16	≤0.007	0.038	0.18	≤0.004	0.10
Rider 2	≤0.015	≤0.07	0.007	0.011		0.020	0.35
Sub-Total§	**≤0.005**			**≤0.023**		**≤0.012**	
Hiker	≤0.004			≤0.004			
Driving Vehicle				≤0.012			
Ambient or Background Asbestos Levels	≤0.003	≤0.06		0.002	0.08		

§ For the motorcycle air samples the total number of fibers counted was divided by the total volume of the air sample, a subtotal rather than average together samples with different detection limits. Data in Cooper *et al.* 1979 and the EPA Region 9, 2008 report are presented in such a way that only the mean values of the air samples can be calculated.

In our analysis, 25 fibers with lengths equal to or larger than 5µm were found in thirteen air samples, where 3,142mL of air was scanned. The mean concentration of airborne fibers in the total air sampled was less than 0.008 f/mL (Table 5).

In six of the 13 air samples no fibers were found in 1,066mL of air. The subtotal of these six air samples corresponds to an airborne asbestos concentration of less than 0.0009 f/mL (Table 5).

All but one of the 25 fibers was found in the eight motorcycle riding air samples. A chrysotile was found in an area sample on the second day.

For comparative purposes, it should be considered that the World Health Organization (WHO) reported that the background asbestos concentration in urban air—worldwide—for asbestos fibers ≥ 5µm long is between < 0.001 and 0.01 f/mL (WHO, 1986).

Table 5. Summary of the analysis of the thirteen air samples and two controls collected in the CCMA, California on April 22-23, 2010, analyzed by ATEM.

Air Filter №	Type, Collection Site or Activity for Air Samples	Milliliters of Air Scanned	Tremolite Fragment №. of Fibers Detected		Exposure to Airborne Tremolite Fragments f/ml (≥5µm)	Chrysotile Asbestos №. of Fibers Detected		Exposure to Airborne Chrysotile Asbestos f/ml (≥5µm)
			<5µm	≥5µm		<5µm	≥5µm	
F-1	Area-1	312	0	0	≤0.003	2	0	≤0.003
F-2	Personal Hiker-1	235	0	0	≤0.004	6	0	≤0.004
F-3	*Personal Rider-1 Lead*	*156*	*0*	*0*	*≤0.045*	*2*	*1*	*0.006*
F-5	*Personal Rider-1 Lead*	*142*	*0*	*0*	*≤0.007*	*10*	*0*	*≤0.007*
	Personal Rider-1 Lead	***298***	***0***	***0***	***≤0.003***	***12***	***1***	***≤0.003***
F-4	*Personal Rider-2 Behind*	*67*	*0*	*0*	*≤0.015*	*5*	*0*	*≤0.015*
F-6	*Personal Rider-2 Behind*	*144*	*11*	*4*	*0.028*	*188*	*1*	*0.007*
	Personal Rider-2 Behind	***211***	***11***	***4***	***0.019***	***193***	***1***	***0.005***
F-7	BLM Ranger (Outside Truck)	85	0	0	≤0.012	4	0	≤0.012
F-11	Area-2	416	0	0	≤0.003	0	1	0.002
F-10	*Personal* Hiker- 2	225	0	0	≤0.004	0	0	≤0.004
F-8	*Personal Rider-1 Lead*	*262*	*3*	*6*	*0.023*	*11*	*3*	*0.012*
F-12	*Personal Rider-1 Lead*	*224*	*2*	*0*	*≤0.005*	*5*	*1*	*0.005*
	Personal Rider-1 Lead	***486***	***5***	***6***	***0.012***	***16***	***4***	***0.008***
F-9	*Personal Rider-2 Behind*	*571*	*2*	*1*	*0.002*	*17*	*2*	*0.004*
F-13	*Personal Rider-2 Behind*	*303*	*2*	*1*	*0.003*	*10*	*4*	*0.013*
	Personal Rider-2 Behind	***874***	***4***	***2***	***0.002***	***27***	***6***	***0.007***
Total		**3,142**	**20**	**12**	**0.004**	**252**	**13**	**0.004**
Control-1			0	0		0	0	
Control-2			0	0		0	0	

5. Preliminary Conclusions about Asbestos Exposures from Motorcycle Riding in the CCMA

The asbestos exposures we measured from motorcycle riding at CCMA were about 10-fold higher than was found in the background samples we collected. The other CCMA activities were associated with airborne asbestos concentrations at levels close to the low end of background for asbestos in the ambient urban air worldwide (WHO, 1986) (Table 4 and Table 5).

1. Because the cumulative asbestos exposures were so low, we need not address the risk of developing asbestosis. The EPA has not developed a model for developing asbestosis and the low asbestos exposures IERF measured at CCMA are not known to cause asbestosis. PTI reached a similar conclusion in their 1992 study of CCMA (PTI, 1992).

2. We will only consider asbestos-related cancers—mesothelioma and lung cancer—in the risk assessment.

3. Typically, regulatory authorities consider the increase in risk from the exposure per year, even if the activity only occurs a few days per year. We will calculate the risk of asbestos-related cancer for five days of riding, but assume the exposure occurred over one year.

4. Finding the tremolite fragments only in the motorcycle air samples indicates the tremolite is not uniformly distributed in the serpentinite. The motorcycle air samples were collected over separate and more extensive areas than those from the hiker and the pickup truck.

5. Although bundles of chrysotile fibers were a common finding in the air samples, none of the CCMA tremolite occurs as polyfilamentous bundles of fibrils (Figure 14, Figure 15, and Figure 16). The tremolite found does not have morphology consistent with asbestos.

6. The morphology of the tremolite fragments is needle-like (Figure 15). The geological term used to describe such particles is acicular (Campbell *et al.* 1979, Dorling and Zussman 1987). The mean length was 8.2µm and the width was 0.75µm. Tremolite asbestos rarely, if ever, displays a width this large. Tremolite-actinolite asbestos of this width would have polyfilamentous morphology, and display long, distinct and flexible fibers (Figure 15 and Figure 16). It is unlikely any of the detected tremolite in our air samples is asbestos.

7. Despite our analysis of the tremolite morphology for the preliminary risk assessment, the acicular tremolite fragments will be assumed to have potency similar to an "average asbestos" fiber in the calculation of the cumulative asbestos exposure. This assumption produces a worst-case risk assessment.

8. The IERF motorcycle riders were asked to ride in a manner to minimize the generation of and their exposure to airborne dust. We accomplished this by instructing our two riders to maintain a separation of 15 to 20 feet and instructing the trailing rider, when possible; to avoid riding through any visible dust the leading motorcycle might generate (Figure 9).

9. Compared to the study of Cooper *et al.* 1979 and the EPA Region 9 2008 report, the safe riding practices described above, along with not riding when the conditions are very dry, are the likely reasons for the markedly lower exposures to both airborne asbestos and total dust in the IERF study. Except for the "wet" condition of EPA Region 9 shown in Table 2, where the airborne asbestos concentrations are similar to those found by IERF (Table 4).

10. The conditions for motorcycle riding at the CCMA for the Cooper *et al.* 1979 study appear to have been dry, leading to higher levels of airborne dust than found in the IERF study.

11. All of the air samples for Cooper *et al.* 1979 were collected on June 18, 1978. Reports on the local rainfall (from stations in Coalinga, Paicines, and Priest Valley, California) indicate there had been little or no rain for six weeks prior to collecting the air samples (Appendix 3).

Since 2006, CCMA has been closed from June 1 to October 15th (see http://www.blm.gov/ca/st/en/info/fed_reg_archives/2006/08/seasonal_closure_of_serpentine_acec.print.html). The closure avoids riding in dry and dusty summer conditions. Between Cooper *et al.* (1979), the EPA Region 9 2008 report, and our study, 59 air samples were collected to characterize the adult motorcycle rider's asbestos exposure at CCMA. Thirty-one samples were collected during the summer closure period months (Cooper *et al.* 1979, EPA Region 9 2008). The remaining 28 samples were collected outside of the June 1 to October 15 window. Of those 28 samples, IERF collected and analyzed 8 samples, which represents 29% of all the samples collected from motorcycle riders when conditions are not considered seasonally dry.

6. Assumptions Being Made in this Risk Assessment for Asbestos-Related Cancer

There are six different types of asbestos (actinolite, amosite, anthophyllite, chrysotile, crocidolite, and, tremolite) that are regulated by EPA as a single substance. For our initial risk assessment, we will assume an average carcinogenic potency for the different asbestos-types. EPA methods for estimating asbestos-related cancer do not differentiate among the different asbestos types. The EPA assessment is based on the increase in asbestos-related cancer from occupational asbestos exposures, and it is also the most protective in that it assumes a no threshold, linear dose-response. Accordingly, using average carcinogenic potency is a good starting point and the most pessimistic approach.

7. Preliminary Risk Assessment

The type of motorcycle riding that occurred at the CCMA is recreational, conducted by individuals a few days per year. Based on a discussion with two motorcycle riders who have extensive riding experience at CCMA, an enthusiastic rider would ride a total of 8 hours per day for 5 days per year. Earlier reports indicated that asbestos exposures among the trailing riders were 5 to 10-fold higher than for the lead rider (Table 1 and Table 2). In the IERF study the mean asbestos exposures for lead and trailing riders were 0.015 f/mL and 0.011 f/mL, respectively. In the IERF study the lead rider's exposure was about 36% higher than the trailing rider.

From the air sampling data in Table 5, we calculate a subtotal for both riders' asbestos exposure:

№ of Tremolite fragments ≥5μm in length = 12
№ of Chrysotile asbestos fibers ≥5μm in length = 12

We must now estimate the quantity of air in which these 12 fibers were found. For each air sample, all the airborne fibers were entrained on the surface of a 385mm^2 membrane filter. We counted the number of fibers that were ≥ 5μm in a given area of the filter. By proportion we calculated the number of milliliters of air that contained the 24 fibers. The total exposure, expressed as the number of asbestos fibers per unit of air, for the lead and trailing motorcycle riders is 24 fibers in 1,869mL of air or 0.013 f/mL. This is assumed to be the mean exposure to airborne asbestos over the 8 hours of trail bike riding.

8. Comparison of Airborne Asbestos Concentration at CCMA with Commonly Accepted Standards

Currently, OSHA has a PEL of 0.1 f/mL for asbestos. This is for occupational exposure, assumed to occur over 8 hours per day, 240 days per year for a maximum of 40 years, for an employee starting employment at about age 20. The cumulative asbestos exposure for forty years of work, at one-tenth the current OSHA PEL would be less than 0.4f/mL multiplied by 40 years, assuming an occupational asbestos exposure was always kept an order of magnitude below the PEL. We will assume enthusiastic recreational motorcycle riders at CCMA will be exposed for eight hours per day for five days in the course of one year.

In the United States, there is no ambient air PEL for asbestos for the general public.

However, the Russian Federation has such a PEL for asbestos exposure, which is 0.06 f/mL per year (Shcherbakov *et al.* 2001). It assumes that if the general population's lifetime exposure is below this amount no asbestos-related disease will occur. The mean asbestos exposure at CCMA for all the air samples was less than 0.008f/mL (Table 4). This is below the Russian Federation's ambient exposure standard, and the duration of exposure is about 40 hours per year (five days of riding for 8 hours per day). The Russian standard for asbestos in the ambient air, thought to be safe, is for 24 hours per day, 365 days per year. Some would argue that this level of asbestos exposure could already be considered as safe, without further calculation.

The WHO reports the background concentration of airborne asbestos in urban air worldwide is between < 0.001 and 0.01f/mL (WHO, 1986). A lifetime of this exposure, 70 years, would lead to a cumulative asbestos exposure of < 0.07 to 0.7 f/mL multiplied by 70 years, assuming an environmental exposure that occurred 24 hours per day for 365 days per year. We converted this 70-year lifetime exposure to an occupational exposure for comparison with the OSHA and Russian PEL standards and our own measured concentrations (Table 6).

Table 6. Comparison of Airborne Asbestos Concentration at CCMA with Commonly Accepted Asbestos Standards.

Asbestos Reference Exposure Standards	Cumulative Occupational Asbestos Exposure (f/mL x years)
World Health Organization (1986) Background Urban Air†	0.294 to 2.94
Russian Federation Standard for Asbestos in the Ambient Air †	17.6
OSHA Asbestos Standard §	0.40
Motorcycle Riding at Clear Creek: Cumulative Asbestos Exposure from 5-days average over 1-years	
Cooper *et al.* (1979)	0.06
IERF (2010)	0.00025

† Assumes a 70 year lifetime. § Assumes a 40 year working career an order of magnitude below the PEL and no background asbestos exposure.

To convert to an occupational exposure, one would assume the exposure occurred over a 40 hour workweek. Therefore, 24 hours per day, 7 days per week is 168 hour per week divided by 40 hours per week is 4.2. Using the 4.2 multiplier to convert the environmental exposure to occupational exposure, the cumulative occupational asbestos exposure becomes 0.294 to 2.94 mL multiplied by years of exposure.

Tables 6, above, shows the asbestos exposures at CCMA are much lower than lifetime exposures to background asbestos and the OSHA PEL

9. Risk Assessment using the EPA (1986) Airborne Asbestos Health Assessment Update (not yet updated to 2010)

We now use the assumption, that what matters for estimating risk of mesothelioma or lung cancer is the average cumulative asbestos exposure over a long period of time. To do this, we will extrapolate the exposure from five days of riding to a period of one year. For this, we will consider the asbestos exposure for the mean exposure of 0.013 asbestos fibers per milliliter of air for lead and trailing motorcycle riders, during eight hours of motorcycle riding for five days for one year in the CCMA (Table 5). We average the lead and trailing position as riders are likely to spend a similar amount of time in both positions.

For risk assessment purposes, we use Tables 6-1 and 6-2 in the 1986 EPA Airborne Asbestos Health Assessment Update, (found in Appendix 4 of this report—the relevant information is highlighted in red). The 1986 EPA Health Assessment Update was published seven years after the first study of airborne asbestos in CCMA, making this information unavailable to Cooper and his colleagues. This document provides, in part, the guidance Cooper *et al*. 1979 asked for concerning dose-response for asbestos exposure (see point 6 on page 5 of this report).

We will also assume the motorcycle rider is a non-smoker and the first asbestos exposure began when the rider was 30 years of age (the effect of age at first exposure is discussed later in Section 11).

From the two EPA tables, we find the lifetime risk for asbestos- related cancer per 100,000 persons with one year of continuous exposure to ambient air containing 0.01 f/mL of asbestos fibers can be determined (Table 7, EPA 1986 their Tables 6-1[females] and 6-2 [males]).

We assume the motorcycle rider is, or will be, exposed to 0.013 f/mL of asbestos for eight hours for each of the five days he or she rides each year. To compare this exposure to the 1986 EPA Health Assessment Update, we will assume the motorcycle rider's cumulative exposure to have occurred over one year.

The motorcycle rider's asbestos exposure is adjusted to a cumulative exposure over one year:

0.013f/mL x 1/3 of the day x 1/365 x 5-days per year = 0.000059f/mL

The motorcycle rider has a cumulative environmental asbestos exposure of 0.000059 f/mL per year. This assumes that in each of the five days in the year a rider would measure 24 fibers in the same volume 1,869 mL or air, but in that year he or she will have breathed much more. The motorcycle rider's exposure from riding for eight hours per day for five days at CCMA is equivalent to being exposed to 0.000059 f/mL continuously for one year. This is more than 1,000-fold lower than the Russian Federation's standard or if we assume the background asbestos concentrations are 25% of the upper background concentration of 0.01 f/hmL the estimate background would be 0.0025 f/mL more than 40-fold lower than the motorcycle rider cumulative exposure (Table 6).

The lifetime risk of mesothelioma and lung cancer for *continuous ambient asbestos exposure of 0.01 f/mL for 1-year* is given in Table 7 below (adapted from Tables 6-1 and 6-2 in the 1986 EPA Health Assessment Update, found in Appendix 4 herein). The values shown for male and female are 169-fold higher than the cumulative exposure of the enthusiastic motorcycle rider in CCMA. Assuming a linear no-threshold effect for asbestos-related cancer, the motorcycle rider's lifetime asbestos-related cancer risks would be 169-fold lower than the EPA values shown below.

Table 7. Shows EPA's lifetime risks per 100,000 non-smoking males and females of death from mesothelioma and lung cancer from continuous exposure to 0.01f/mL of asbestos for one year with exposure starting at 30 years of age.

Type of Asbestos-Related Disease	Lifetime Risk
Male	
mesothelioma	2.4 per 100,000 people
lung cancer	0.3 per 100,000 people
Sum of mesothelioma and lung cancer risk	**2.7 per 100,000 people**
Female	
mesothelioma	3.1 per 100,000 people
lung cancer	0.3 per 100,00 people
Sum of mesothelioma and lung cancer risk	**3.4 per 100,000 people**
Average Risk for both male and female	***3.1 per 100,000 people***

This leads to a lifetime risk of asbestos-related mesothelioma for a male, riding at CCMA eight hours per day for five days for one year of:

2.4/169 per 100,000 = 0.014 per 100,000
or 0.14 per million male non-smokers (the first entry in Table 8, below).

Table 8. Lifetime risks now expressed as a number of deaths from cancers in a million motorcycle riders. This is shown as death from mesothelioma and lung cancer for non-smoking males and females. This is from continuous exposure to 0.000059f/mL of asbestos for one year, as averaged based on riding eight hours per day for five days, under the conditions we observed, for a motorcycle rider whose first exposure occurs at age 30.

Type of Asbestos-Related Disease	Lifetime Risk
Male	
mesothelioma	0.14 per 1,000,000 people
lung cancer	0.018 per 1,000,000 people
Sum of mesothelioma and lung cancer risk	**0.16 per 1,000,000 people**
Female	
mesothelioma	0.18 per 1,000,000 people
lung cancer	0.018 per 1,000,00 people
Sum of mesothelioma and lung cancer risk	**0.20 per 1,000,000 people**
Average Risk for both male and female	***0.18 per 1,000,000 people***

The other entries from male lung cancer and female mesothelioma and lung cancer are determined in a similar manner, dividing by 169 and multiplying by 10 for lifetime risk per million motorcycle riders (Table 8). The average risk for both asbestos-related cancers for both sexes riding in the lead and trailing position is 0.18 per million motorcycle riders.

This is less than one asbestos-related cancer among one million motorcycle riders from five days in one year of riding at CCMA under the conditions we observed. For perspective, this is approximately the equivalent lifetime risk of death from smoking less than one cigarette over the same period. The lifetime risk of death from smoking two cigarettes over a year is one in a million (including death from lung cancer and heart disease). Other “One in a million risks” are shown in Table 9 (see Wilson R, Crouch EAC (2001) Risk-Benefit Analysis, Harvard University Press, Cambridge, pp 209 for a list of other “One in a million risks”).

We can also compare this with the annual risk from engaging in other activities (Table 9). None of the recreational activities in Table 9 is as low as riding a motorcycle at CCMA under conditions similar to our sampling period.

Table 9. Some Risks of "One in a Million" from *Risk-Benefits Analysis* (2001) Wilson R, Crouch EAC, Center for Risk Analysis, Harvard University, Cambridge, MA.

Time (or Action) to Accumulate a Risk of One Death in a Million Lifetimes from the Cause Indicated (Historically Calculated)

Motor Vehicle Accident	100 miles
Falls (average over life)	6 days
Falls (average over 70 years of age)	15 hours
Drowning	19 days
Fires	13 days
Firearms	3 days
Electrocution	200 days
Tornadoes	5½ years
Floods	2 years

Involving Uncertain Dose-Response

Smoking two cigarettes in a lifetime (risk of lung cancer heart disease included)
Drinking thirty diet sodas with saccharin
Drinking seventy pints of beer a year (cancer risk of alcohol§)
One quarter of a typical diagnostic chest X-ray

Recreational Risks	*Average Annual Risk per Million*	*Average Annual Deaths*
Mountain Recreation		
Hiking	64	
Casual Climbing	570	
Mountaineering	600	34
Dedicated Climbing	6,000	
Himalayas per ascent	130,000	
White Water Boating		
Experienced	2,700	27
Inexperienced	700	36
Scuba Diving	420	126
Snow Skiing	120	41
Sky Diving (US)	580	29
Snowboarding	2.5	5
Swimming	30	2,600

§ According to the International Agency for Research on Cancer (IARC) ethanol in alcoholic beverages is a know human carcinogen (Group 1) and appears on the same list as asbestos (see http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf).

10. Comparison of the parentage of Mesothelioma Deaths in the US General Population with the Motorcycle Riders at CCMA

The asbestos-related mesothelioma risk for the motorcycle riders can also be compared to the risk of death from mesothelioma in the general population. In the US, mesothelioma deaths are 0.18% and 0.04% of all deaths among males and females respectively (Table 10, SEER 2003, Price and Ware 2009). While the percentage of deaths for both sexes were 0.11%. For the males and females motorcycle riders with 40 hours in one year of riding at CCMA, 0.000016% of all deaths would be from mesothelioma, more than 6,500-fold lower than the percentage in the general population (Table 10).

Table 10.The percentage of deaths due to mesothelioma in the US general population for males and females between 1975 and 2005, for both males and females is 0.11% while the risk from the cumulative asbestos exposure while motorcycle riding at CCMA, eight hours for five days in one year is 0.000016%.

	Average Population In Period Of Interest	Deaths Per 1,000	Period of Interest	Deaths/year	Mesothelioma Deaths per 1,000 Deaths In General Population	Total № of Pleural Mesothelioma Deaths/year	Percentage of Deaths in the General Population from Mesothelioma
United States		8.27†	1975-2005				
Males	125,075,244			1,034,373	1.8[a]	1,863	**0.18%**
Females	129,373,315			1,069,917	0.4	428	**0.04%**
Both Sexes							**0.11%**
CCMA Motorcycle Rider							
Males					0.00014	0.14§	**0.000014%**
Females					0.00018	0.18	**0.000018%**
Both Sexes					0.00016	0.16	**0.000016%**

[a] Surveillance, Epidemiology, End Results (SEER) US National Cancer Institute.
§ Assume a million motorcycle riders per year.

11. Discussion of the Risk Assessment

We note that the routes where we collected the air samples are only a small sample of many different routes that are possible on the 242 miles of public trails and roads in the CCMA. The number of days each year when the motorcycle riding conditions are CCMA are similar to those observed by IERF has not been determined.

Risk to Younger Riders and to Accompanying Families

The 1986 EPA Airborne Asbestos Health Assessment Update shows that the difference in risk borne by younger riders is exclusively an increase in the risk of developing mesothelioma. This is because mesothelioma, unlike lung cancer, is a disease where the risk increases exponentially with time since first exposure. The overall increase in asbestos-related mesothelioma risk for a 10-year-old motorcycle rider is four times that of a 30-year-old for both males and females. The lung cancer risk for both males and females would be the same even if the asbestos exposure began at birth.

The IERF study team has no indication of how often, and for how long, teenagers might visit CCMA. It is likely that they would ride for half the time an enthusiastic adult would. If so, their lifetime risk is equivalent to smoking about one cigarette in a year.

It would seem attractive for a family to come and camp for the day at one of the many small areas with picnic tables adjacent to the road. If the families engaged in activities similar to those during our visit, the personal sample on the hiker and the area samples for background, their asbestos exposures would be less than 0.0008f/mL based on finding one fiber in the 1,188 mL of air (Table 5). The statistical accuracy is limited as only one fiber (greater than 5μm in length) was found. The CCMA background concentration of asbestos in the ambient air is at the low end of the background range worldwide for asbestos in the ambient air of <0.001 to 0.01f/mL (WHO 1986).

12. Discussion of the EPA Risk Coefficient

In the 1986 EPA Airborne Asbestos Health Assessment Update, the EPA deliberately assumed that all types of asbestos fibers are equally carcinogenic. This is based on the exposures-response relationships of insulation workers in the United States with occupational exposure to amphibole asbestos and chrysotile. Updates of this risk assessment by Berman and Crump (2008a,b) in the USA by Hodgson and Darnton (2000) in the UK, and Gibbs and Berry (2008) in Canada and Australia, all suggest that the risks of the chrysotile asbestos is considerably overestimated in the 1986 EPA assessment.

Although the information on acicular tremolite fragments is limited, sufficient information is available to show their carcinogenic potency is less than the commercial types of amphibole asbestos (Wilson *et al.* 2008, Gamble and Gibbs 2008). The size distribution of twelve acicular fragments is not consistent with tremolite asbestos (the type of fibers that are known to cause cancer). However, we assumed the acicular tremolite to have the same potency as asbestos and included it the cumulative exposure for a worst-case scenario.

13. Conclusions

Although it is not for the IERF study team to decide what, if anything, to do about riding and hiking on the trails in the CCMA, we believe that this preliminary study provides a spot check on the two earlier studies and shows that the risk to health from inhaling asbestos from trail riding and hiking at certain times can be very small.

It is, however, desirable to study further the following:

1. The tremolite fragments were found only in the motorcycle air samples indicating it is not uniformly distributed in the serpentinite. Additional studies to strengthen our conclusion that tremolite asbestos or other amphibole asbestos types are not present would be useful.

2. It might be helpful to verify that at any one of the day camp areas the level of fibers is indeed as low as we reported here for the area samples.

3. The airborne asbestos levels observed in this study are similar to background for asbestos in the ambient air. The number of days per year when similar condition will exist at CCMA has not been determined.

4. Since the conclusions of this preliminary study conflict with conclusions of the other published studies, it would be useful to examine the two other studies in more detail, including examination of samples collected for the other studies using ATEM to see whether there is a real discrepancy and if so how these discrepancies can be resolved.

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Figure 1. View of Clear Creek in the late afternoon, April 2010.

Figure 2. The unpaved road on entering the Clear Creek Management Area.

Figure 3. A sign, cautions visitors to Clear Creek that the asbestos present in the soil, air, and water "could be hazardous to health".

Figure 4. The steep serpentinite hills with little foliage develop a crust along the surface.

Figure 5. Here the bare serpentinite hills are visible, as are the more heavily forested hills in the distance. Fences are a common feature of Clear Creek, which require visitors to remain on the path and not walk in the steep serpentinite hills.

Figure 6. . Most of the park is fenced in such a way as to encourage visitors to walk or ride along paths, only a small area of the park is accessible to visitors.

Figure 7. The industrial hygienist is placing air-sampling pumps (with air filter cassettes) on the two riders. The personal air samples were collected about chest high as the two rode the trails. It is assumed, collecting airborne particle here is equivalent to the air they are breathing, but the motorcycle helmets the riders wear may mean this assumption is incorrect.

Figure 8. The two riders leave the staging area and no dust is visible behind either the lead or trailing rider.

Figure 9. The two motorcycle riders quickly establish a 15 to 20 foot space between themselves and no airborne dust was visible behind either the lead or trailing rider.

Figure 10. On the trail, the riders maintained the 15-20 foot between themselves and again no visible dust was observed.

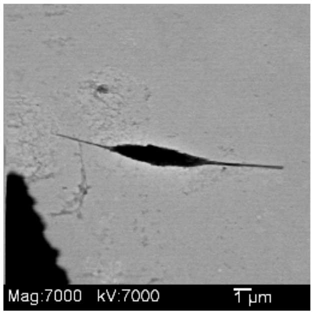
Figure 11. . Two area samples, collected on the side of the unpaved road using a stationary air sampling pump, found one chrysotile fiber (greater than 5μm in length) in 728 milliliters of air, indicating the background level of airborne asbestos during the study in Clear Creek was 0.00137f/mL.

Figure 12. Two personal air samples collected while hiking in Clear Creek found one chrysotile fiber (greater than 5µm in length) in 460 milliliters of air or 0.002f/mL.

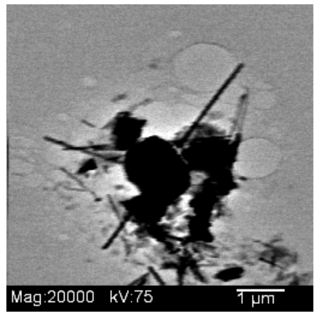
Figure 13. An air sample collected outside a pick-up truck riding the trails of Clear Creek, to simulate a park range on patrol, found no airborne asbestos fiber (greater than 5µm in length) in 85 milliliters or less than 0.012f/mL.

Figure 14. Analytical Transmission Electron Photomicrographs of the Airborne Chrysotile Asbestos collected from personal air samplers on motorcycle riders in Clear Creek, note the presence of fibers, fibrils, and fiber bundles.

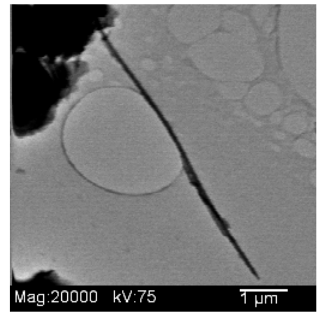
Fibers/Fibrils



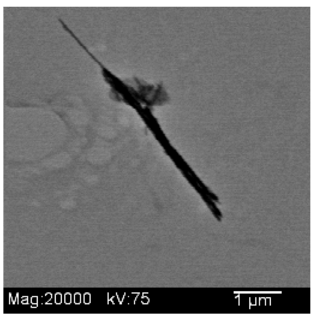
F3_1



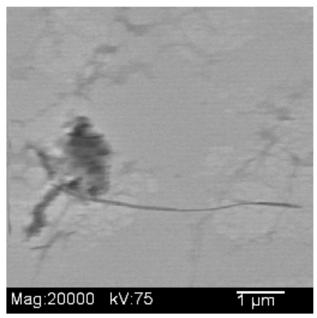
F6_5



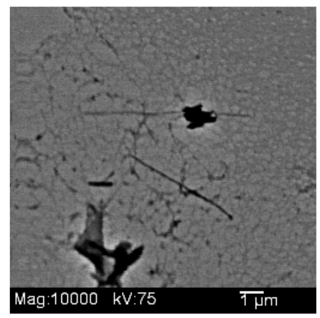
F8_7



F8_8

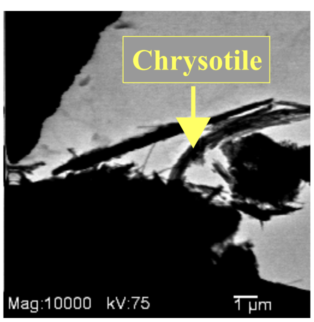


F9_3

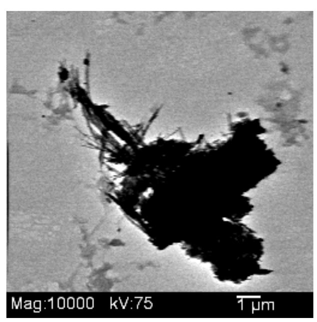


F13_2

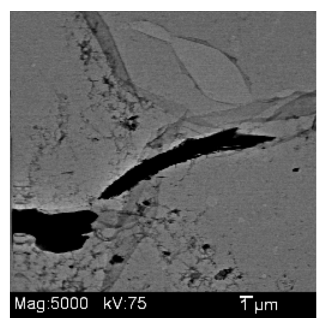
Fiber Bundles



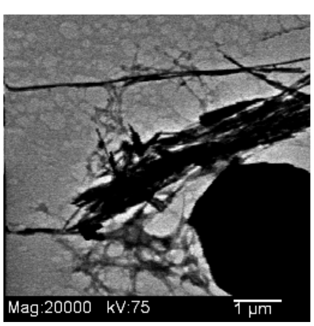
F8_6b



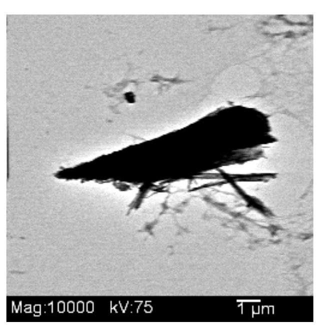
F9_2



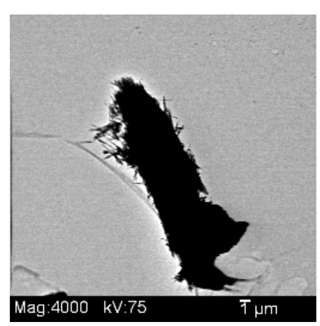
F12_1a



F13_5



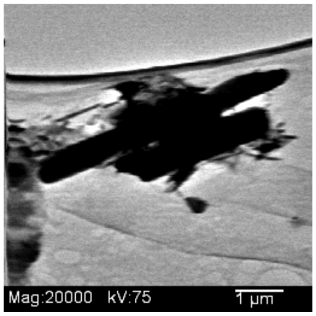
F13_3



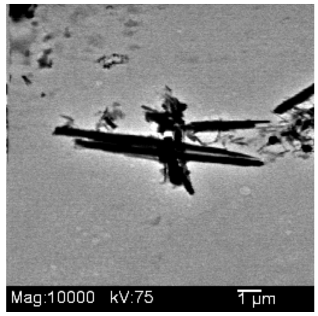
F13_4

Figure 15. The airborne tremolites are best described as needle-like meaning acicular form crystals, note there are no fiber bundles or any of the tremolite crystal showing flexibility.

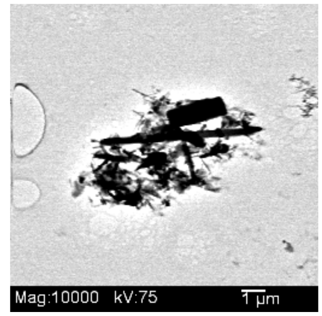
Needle-like or Acicular Morphology



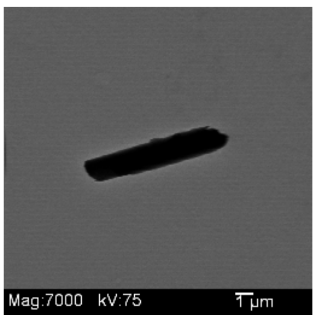
F6_1



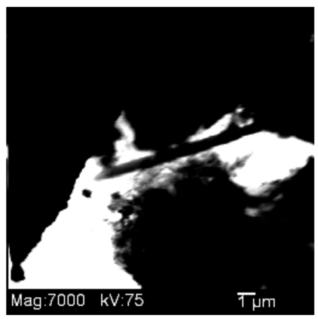
F6_2



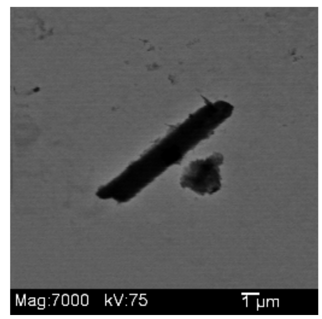
F6_3



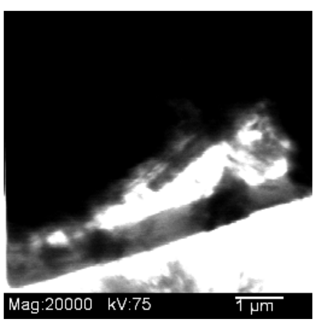
F8_1



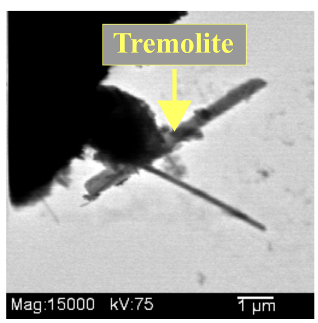
F8_2



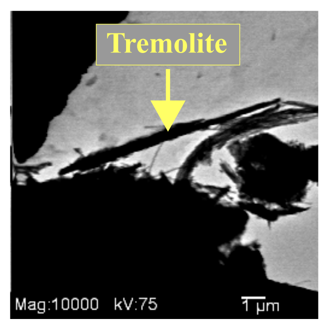
F8_3



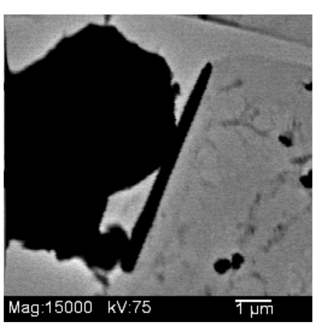
F8_4



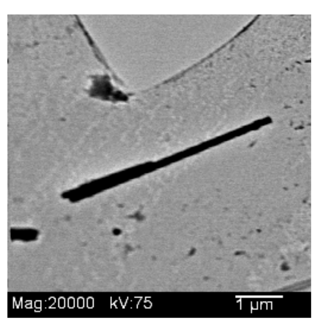
F8_5a



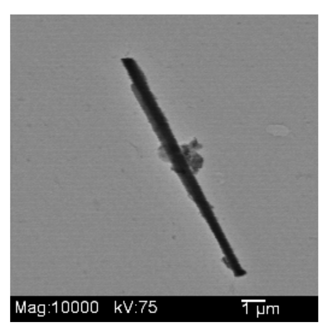
F8_6a



F9_1a

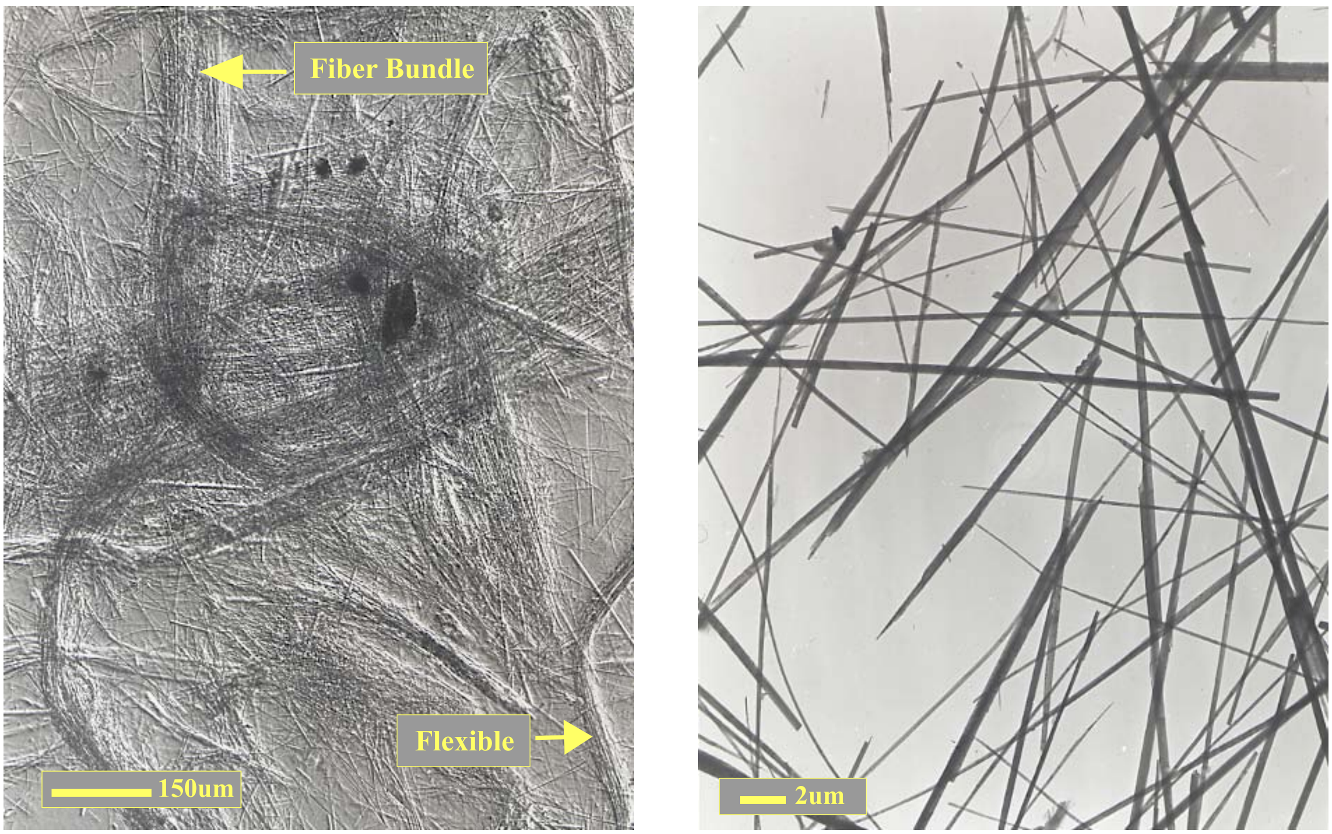


F12_2



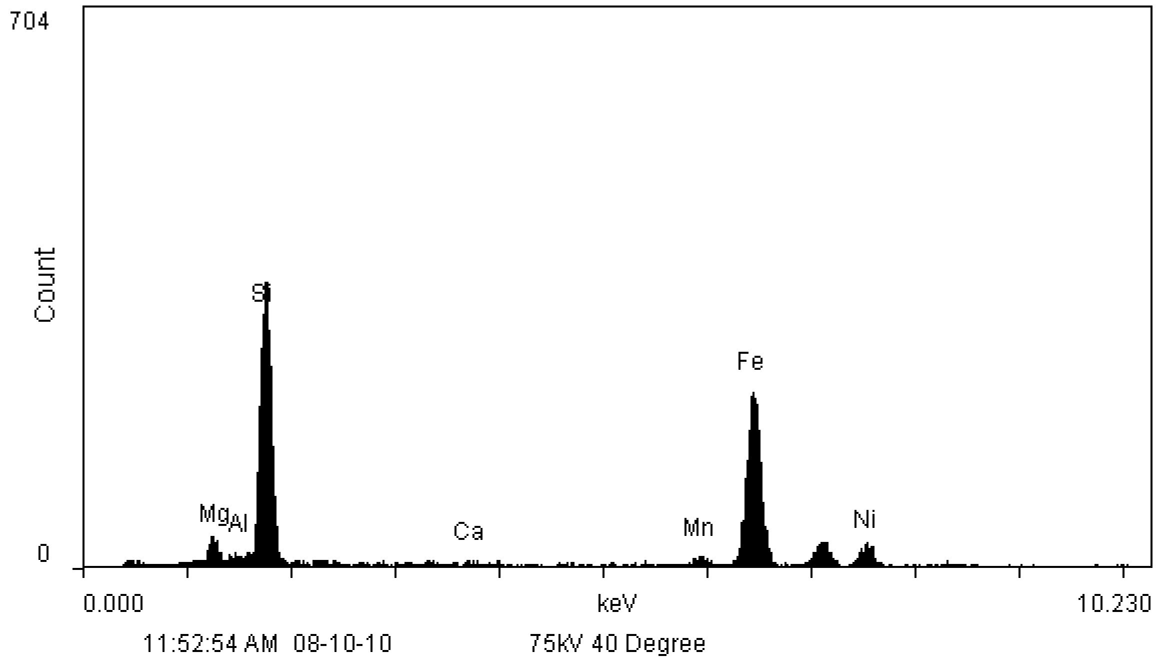
F13_1

Figure 16a,b: Actinolite Asbestos from Devon, England (a) Light photomicrograph taken with Hoffman Modulation Contrast Interference optics showing the fiber bundles and flexibility of the tremolite asbestos. (b) Analytical transmission electron photomicrograph showing that tremolite asbestos is highly fibrous.



a. **b.**

Figure 17: A grunerite fiber found in personal air sample (F12_2) of Motorcycle Rider-1 in the lead on the second day. The fiber did not meet the minimum length to be counted in the asbestos exposure as it is slightly less than 5μm in length.



Identification result: Spectrum 1

Mg	1.270 keV
Al	1.500 keV
Si	1.730 keV
Ca	3.701 keV
Mn	5.891 keV
Fe	6.390 keV
Ni	7.480 keV

Image 2--Scan Done F12_BH567649 - Image - 000010

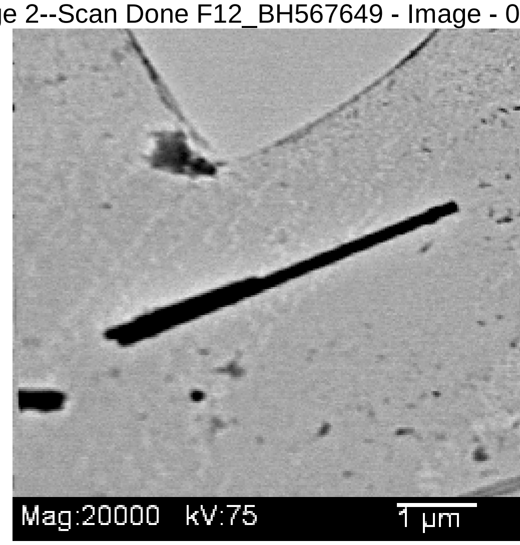
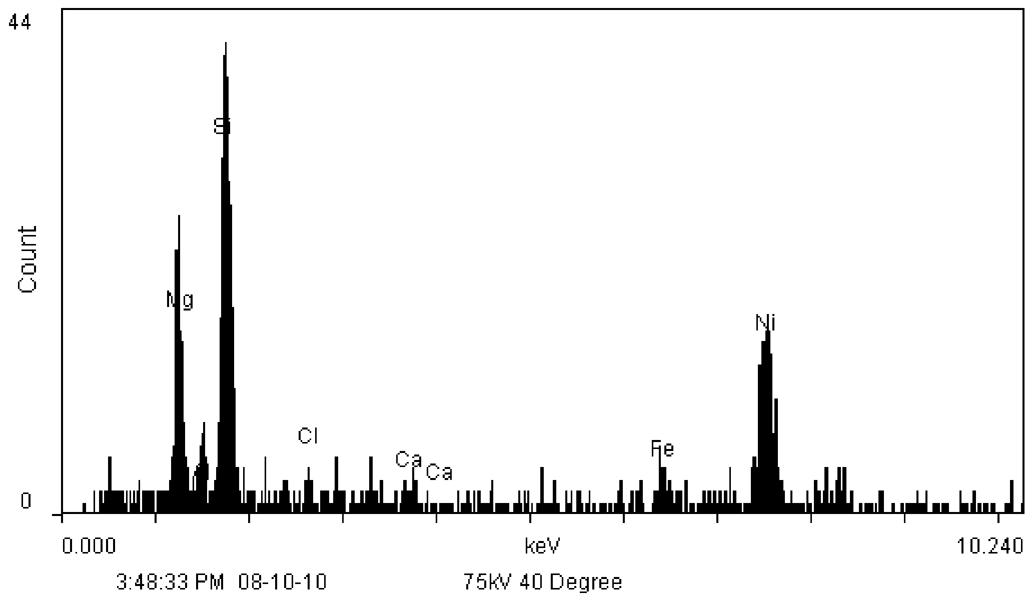


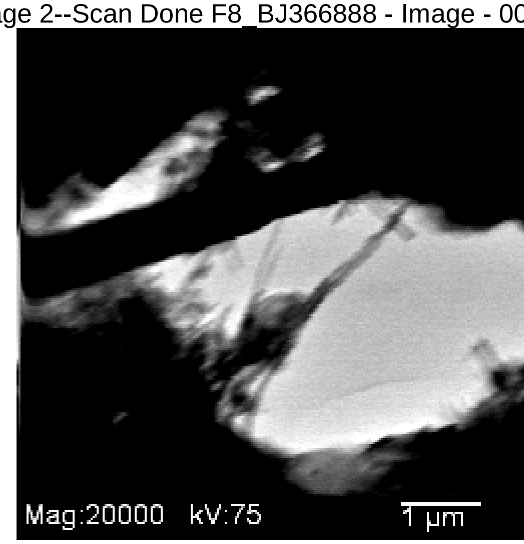
Figure 18: Possibly an anthophyllite fiber found in the personal air sample (F8_ 9) on Rider-1 in lead position on Day-2.



Identification result: Spectrum 1

Mg	1.270 keV
Al	1.500 keV
Si	1.730 keV
Cl	2.630 keV
Ca	3.701 keV
Ca	4.021 keV
Fe	6.390 keV
Ni	7.480 keV

Image 2--Scan Done F8_BJ366888 - Image - 000022



Appendix 1

NIOSH 7400 Method

ASBESTOS and OTHER FIBERS by PCM 7400

FORMULA: Various MW: Various CAS: see Synonyms RTECS: Various

METHOD: 7400, Issue 2 **EVALUATION: FULL** **Issue 1: Rev. 3 on 15 May 1989**
Issue 2: 15 August 1994

OSHA: 0.1 asbestos fiber (> 5 µm long)/cc; 1 f/cc, 30 min excursion; carcinogen
MSHA: 2 asbestos fibers/cc
NIOSH: 0.1 f/cc (fibers > 5 µm long), 400 L; carcinogen
ACGIH: 0.2 f/cc crocidolite; 0.5 f/cc amosite; 2 f/cc chrysotile and other asbestos; carcinogen

PROPERTIES: solid, fibrous, crystalline, anisotropic

SYNONYMS [CAS #]: actinolite [77536-66-4] or ferroactinolite [15669-07-5]; amosite [12172-73-5]; anthophyllite [77536-67-5]; chrysotile [12001-29-5]; serpentine [18786-24-8]; crocidolite [12001-28-4]; tremolite [77536-68-6]; amphibole asbestos [1332-21-4]; refractory ceramic fibers [142844-00-6]; fibrous glass

SAMPLING

SAMPLER: FILTER (0.45- to 1.2-µm cellulose ester membrane, 25-mm; conductive cowl on cassette)

FLOW RATE*: 0.5 to 16 L/min

VOL-MIN*: 400 L @ 0.1 fiber/cc
-MAX*: (step 4, sampling)

*Adjust to give 100 to 1300 fiber/mm^2

SHIPMENT: routine (pack to reduce shock)

SAMPLE STABILITY: stable

BLANKS: 2 to 10 field blanks per set

ACCURACY

RANGE STUDIED: 80 to 100 fibers counted

BIAS: see EVALUATION OF METHOD

OVERALL PRECISION ($\hat{S}_{rT}$): 0.115 to 0.13 [1]

ACCURACY: see EVALUATION OF METHOD

MEASUREMENT

TECHNIQUE: LIGHT MICROSCOPY, PHASE CONTRAST

ANALYTE: fibers (manual count)

SAMPLE PREPARATION: acetone - collapse/triacetin - immersion method [2]

COUNTING RULES: described in previous version of this method as "A" rules [1,3]

EQUIPMENT:
1. positive phase-contrast microscope
2. Walton-Beckett graticule (100-µm field of view) Type G-22
3. phase-shift test slide (HSE/NPL)

CALIBRATION: HSE/NPL test slide

RANGE: 100 to 1300 fibers/mm^2 filter area

ESTIMATED LOD: 7 fibers/mm^2 filter area

PRECISION ($\bar{S}_r$): 0.10 to 0.12 [1]; see EVALUATION OF METHOD

APPLICABILITY: The quantitative working range is 0.04 to 0.5 fiber/cc for a 1000-L air sample. The LOD depends on sample volume and quantity of interfering dust, and is <0.01 fiber/cc for atmospheres free of interferences. The method gives an index of airborne fibers. It is primarily used for estimating asbestos concentrations, though PCM does not differentiate between asbestos and other fibers. Use this method in conjunction with electron microscopy (e.g., Method 7402) for assistance in identification of fibers. Fibers < ca. 0.25 µm diameter will not be detected by this method [4]. This method may be used for other materials such as fibrous glass by using alternate counting rules (see Appendix C).

INTERFERENCES: If the method is used to detect a specific type of fiber, any other airborne fiber may interfere since all particles meeting the counting criteria are counted. Chain-like particles may appear fibrous. High levels of non-fibrous dust particles may obscure fibers in the field of view and increase the detection limit.

OTHER METHODS: This revision replaces Method 7400, Revision #3 (dated 5/15/89).

REAGENTS:

1. Acetone,* reagent grade.
2. Triacetin (glycerol triacetate), reagent grade.

*See SPECIAL PRECAUTIONS.

EQUIPMENT:

1. Sampler: field monitor, 25-mm, three-piece cassette with ca. 50-mm electrically conductive extension cowl and cellulose ester filter, 0.45- to 1.2-µm pore size, and backup pad.
   NOTE 1: Analyze representative filters for fiber background before use to check for clarity and background. Discard the filter lot if mean is ≥ 5 fibers per 100 graticule fields. These are defined as laboratory blanks. Manufacturer-provided quality assurance checks on filter blanks are normally adequate as long as field blanks are analyzed as described below.
   NOTE 2: The electrically conductive extension cowl reduces electrostatic effects. Ground the cowl when possible during sampling.
   NOTE 3: Use 0.8-µm pore size filters for personal sampling. The 0.45-µm filters are recommended for sampling when performing TEM analysis on the same samples. However, their higher pressure drop precludes their use with personal sampling pumps.
   NOTE 4: Other cassettes have been proposed that exhibit improved uniformity of fiber deposit on the filter surface, e.g., bellmouthed sampler (Envirometrics, Charleston, SC). These may be used if shown to give measured concentrations equivalent to sampler indicated above for the application.
2. Personal sampling pump, battery or line-powered vacuum, of sufficient capacity to meet flow-rate requirements (see step 4 for flow rate), with flexible connecting tubing.
3. Wire, multi-stranded, 22-gauge; 1" hose clamp to attach wire to cassette.
4. Tape, shrink- or adhesive-.
5. Slides, glass, frosted-end, pre-cleaned, 25- × 75-mm.
6. Cover slips, 22- × 22-mm, No. 1½, unless otherwise specified by microscope manufacturer.
7. Lacquer or nail polish.
8. Knife, #10 surgical steel, curved blade.
9. Tweezers.

EQUIPMENT (continued):

10. Acetone flash vaporization system for clearing filters on glass slides (see ref. [5] for specifications or see manufacturer's instructions for equivalent devices).
11. Micropipets or syringes, 5-µL and 100- to 500-µL.
12. Microscope, positive phase (dark) contrast, with green or blue filter, adjustable field iris, 8 to 10× eyepiece, and 40 to 45× phase objective (total magnification ca. 400×); numerical aperture = 0.65 to 0.75.
13. Graticule, Walton-Beckett type with 100-µm diameter circular field (area = 0.00785 mm^2) at the specimen plane (Type G-22). Available from Optometrics USA, P.O. Box 699, Ayer, MA 01432 [phone (508)-772-1700], and McCrone Accessories and Components, 850 Pasquinelli Drive, Westmont, IL 60559 [phone (312) 887-7100].
    NOTE: The graticule is custom-made for each microscope. (see APPENDIX A for the custom-ordering procedure).
14. HSE/NPL phase contrast test slide, Mark II. Available from Optometrics USA (address above).
15. Telescope, ocular phase-ring centering.
16. Stage micrometer (0.01-mm divisions).

SPECIAL PRECAUTIONS: Acetone is extremely flammable. Take precautions not to ignite it. Heating of acetone in volumes greater than 1 mL must be done in a ventilated laboratory fume hood using a flameless, spark-free heat source.

SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.
2. To reduce contamination and to hold the cassette tightly together, seal the crease between the cassette base and the cowl with a shrink band or light colored adhesive tape. For personal sampling, fasten the (uncapped) open-face cassette to the worker's lapel. The open face should be oriented downward.
   NOTE: The cowl should be electrically grounded during area sampling, especially under conditions of low relative humidity. Use a hose clamp to secure one end of the wire (Equipment, Item 3) to the monitor's cowl. Connect the other end to an earth ground (i.e., cold water pipe).
3. Submit at least two field blanks (or 10% of the total samples, whichever is greater) for each set of samples. Handle field blanks in a manner representative of actual handling of associated samples in the set. Open field blank cassettes at the same time as other cassettes just prior to sampling. Store top covers and cassettes in a clean area (e.g., a closed bag or box) with the top covers from the sampling cassettes during the sampling period.
4. Sample at 0.5 L/min or greater [6]. Adjust sampling flow rate, Q (L/min), and time, t (min), to produce a fiber density, E, of 100 to 1300 fibers/mm^2 (3.85×10^4 to 5×10^5 fibers per 25-mm filter with effective

collection area A_c = 385 mm^2) for optimum accuracy. These variables are related to the action level (one-half the current standard), L (fibers/cc), of the fibrous aerosol being sampled by:

$$t = \frac{A_c \times E}{Q \times L \times 10^3}.$$

NOTE 1: The purpose of adjusting sampling times is to obtain optimum fiber loading on the filter. The collection efficiency does not appear to be a function of flow rate in the range of 0.5 to 16 L/min for asbestos fibers [7]. Relatively large diameter fibers (>3 µm) may exhibit significant aspiration loss and inlet deposition. A sampling rate of 1 to 4 L/min for 8 h is appropriate in atmospheres containing ca. 0.1 fiber/cc in the absence of significant amounts of non-asbestos dust. Dusty atmospheres require smaller sample volumes (≤400 L) to obtain countable samples. In such cases take short, consecutive samples and average the results over the total collection time. For documenting episodic exposures, use high flow rates (7 to 16 L/min) over shorter sampling times. In relatively clean atmospheres, where targeted fiber concentrations are much less than 0.1 fiber/cc, use larger sample volumes (3000 to 10000 L) to achieve quantifiable loadings. Take care, however, not to overload the filter with background dust. If ≥50% of the filter surface is covered with particles, the filter may be too overloaded to count and will bias the measured fiber concentration.

NOTE 2: OSHA regulations specify a minimum sampling volume of 48 L for an excursion measurement, and a maximum sampling rate of 2.5 L/min [3].

5. At the end of sampling, replace top cover and end plugs.
6. Ship samples with conductive cowl attached in a rigid container with packing material to prevent jostling or damage.

   NOTE: Do not use untreated polystyrene foam in shipping container because electrostatic forces may cause fiber loss from sample filter.

SAMPLE PREPARATION:

NOTE 1: The object is to produce samples with a smooth (non-grainy) background in a medium with refractive index ≤ 1.46. This method collapses the filter for easier focusing and produces permanent (1–10 years) mounts which are useful for quality control and interlaboratory comparison. The aluminum "hot block" or similar flash vaporization techniques may be used outside the laboratory [2]. Other mounting techniques meeting the above criteria may also be used (e.g., the laboratory fume hood procedure for generating acetone vapor as described in Method 7400—revision of 5/15/85, or the non-permanent field mounting technique used in P&CAM 239 [3,7–9]). Unless the effective filtration area is known, determine the area and record the information referenced against the sample ID number [1,9–11].

NOTE 2: Excessive water in the acetone may slow the clearing of the filter, causing material to be washed off the surface of the filter. Also, filters that have been exposed to high humidities prior to clearing may have a grainy background.

7. Ensure that the glass slides and cover slips are free of dust and fibers.
8. Adjust the rheostat to heat the "hot block" to ca. 70 °C [2].

   NOTE: If the "hot block" is not used in a fume hood, it must rest on a ceramic plate and be isolated from any surface susceptible to heat damage.
9. Mount a wedge cut from the sample filter on a clean glass slide.
   a. Cut wedges of ca. 25% of the filter area with a curved-blade surgical steel knife using a rocking motion to prevent tearing. Place wedge, dust side up, on slide.

      NOTE: Static electricity will usually keep the wedge on the slide.
   b. Insert slide with wedge into the receiving slot at base of "hot block". Immediately place tip of a micropipet containing ca. 250 µL acetone (use the minimum volume needed to consistently clear the filter sections) into the inlet port of the PTFE cap on top of the "hot block" and inject the

acetone into the vaporization chamber with a slow, steady pressure on the plunger button while holding pipet firmly in place. After waiting 3 to 5 s for the filter to clear, remove pipet and slide from their ports.

CAUTION: Although the volume of acetone used is small, use safety precautions. Work in a well-ventilated area (e.g., laboratory fume hood). Take care not to ignite the acetone. Continuous use of this device in an unventilated space may produce explosive acetone vapor concentrations.

c. Using the 5-µL micropipet, immediately place 3.0 to 3.5 µL triacetin on the wedge. Gently lower a clean cover slip onto the wedge at a slight angle to reduce bubble formation. Avoid excess pressure and movement of the cover glass.

NOTE: If too many bubbles form or the amount of triacetin is insufficient, the cover slip may become detached within a few hours. If excessive triacetin remains at the edge of the filter under the cover slip, fiber migration may occur.

d. Mark the outline of the filter segment with a glass marking pen to aid in microscopic evaluation.

e. Glue the edges of the cover slip to the slide using lacquer or nail polish [12]. Counting may proceed immediately after clearing and mounting are completed.

NOTE: If clearing is slow, warm the slide on a hotplate (surface temperature 50 °C) for up to 15 min to hasten clearing. Heat carefully to prevent gas bubble formation.

CALIBRATION AND QUALITY CONTROL:

10. Microscope adjustments. Follow the manufacturer's instructions. At least once daily use the telescope ocular (or Bertrand lens, for some microscopes) supplied by the manufacturer to ensure that the phase rings (annular diaphragm and phase-shifting elements) are concentric. With each microscope, keep a logbook in which to record the dates of microscope cleanings and major servicing.
    a. Each time a sample is examined, do the following:
        (1) Adjust the light source for even illumination across the field of view at the condenser iris. Use Kohler illumination, if available. With some microscopes, the illumination may have to be set up with bright field optics rather than phase contract optics.
        (2) Focus on the particulate material to be examined.
        (3) Make sure that the field iris is in focus, centered on the sample, and open only enough to fully illuminate the field of view.
    b. Check the phase-shift detection limit of the microscope periodically for each analyst/microscope combination:
        (1) Center the HSE/NPL phase-contrast test slide under the phase objective.
        (2) Bring the blocks of grooved lines into focus in the graticule area.

        NOTE: The slide contains seven blocks of grooves (ca. 20 grooves per block) in descending order of visibility. For asbestos counting, the microscope optics must completely resolve the grooved lines in block 3 although they may appear somewhat faint, and the grooved lines in blocks 6 and 7 must be invisible when centered in the graticule area. Blocks 4 and 5 must be at least partially visible but may vary slightly in visibility between microscopes. A microscope which fails to meet these requirements has resolution either too low or too high for fiber counting.

        (3) If image quality deteriorates, clean the microscope optics. If the problem persists, consult the microscope manufacturer.
11. Document the laboratory's precision for each counter for replicate fiber counts.
    a. Maintain as part of the laboratory quality assurance program a set of reference slides to be used on a daily basis [13]. These slides should consist of filter preparations including a range of loadings and background dust levels from a variety of sources including both field and reference samples (e.g., PAT, AAR, commercial samples). The Quality Assurance Officer should maintain custody of the reference slides and should supply each counter with a minimum of one reference

slide per workday. Change the labels on the reference slides periodically so that the counter does not become familiar with the samples.

b. From blind repeat counts on reference slides, estimate the laboratory intra- and intercounter precision. Obtain separate values of relative standard deviation (S_r) for each sample matrix analyzed in each of the following ranges: 5 to 20 fibers in 100 graticule fields, >20 to 50 fibers in 100 graticule fields, and >50 to 100 fibers in 100 graticule fields. Maintain control charts for each of these data files.

NOTE: Certain sample matrices (e.g., asbestos cement) have been shown to give poor precision [9].

12. Prepare and count field blanks along with the field samples. Report counts on each field blank.

NOTE 1: The identity of blank filters should be unknown to the counter until all counts have been completed.

NOTE 2: If a field blank yields greater than 7 fibers per 100 graticule fields, report possible contamination of the samples.

13. Perform blind recounts by the same counter on 10% of filters counted (slides relabeled by a person other than the counter). Use the following test to determine whether a pair of counts by the same counter on the same filter should be rejected because of possible bias: Discard the sample if the absolute value of the difference between the square roots of the two counts (in fiber/mm²) exceeds $2.77XS_r'$ where X = average of the square roots of the two fiber counts (in fiber/mm²) and $S_r' = S_r / 2$ where S_r is the intracounter relative standard deviation for the appropriate count range (in fibers) determined in step 11. For more complete discussions see reference [13].

NOTE 1: Since fiber counting is the measurement of randomly placed fibers which may be described by a Poisson distribution, a square root transformation of the fiber count data will result in approximately normally distributed data [13].

NOTE 2: If a pair of counts is rejected by this test, recount the remaining samples in the set and test the new counts against the first counts. Discard all rejected paired counts. It is not necessary to use this statistic on blank counts.

14. The analyst is a critical part of this analytical procedure. Care must be taken to provide a non-stressful and comfortable environment for fiber counting. An ergonomically designed chair should be used, with the microscope eyepiece situated at a comfortable height for viewing. External lighting should be set at a level similar to the illumination level in the microscope to reduce eye fatigue. In addition, counters should take 10- to 20-minute breaks from the microscope every one or two hours to limit fatigue [14]. During these breaks, both eye and upper back/neck exercises should be performed to relieve strain.

15. All laboratories engaged in asbestos counting should participate in a proficiency testing program such as the AIHA-NIOSH Proficiency Analytical Testing (PAT) Program for asbestos and routinely exchange field samples with other laboratories to compare performance of counters.

MEASUREMENT:

16. Center the slide on the stage of the calibrated microscope under the objective lens. Focus the microscope on the plane of the filter.

17. Adjust the microscope (Step 10).

NOTE: Calibration with the HSE/NPL test slide determines the minimum detectable fiber diameter (ca. 0.25 µm) [4].

18. Counting rules: (same as P&CAM 239 rules [1,10,11]: see examples in APPENDIX B).

a. Count any fiber longer than 5 µm which lies entirely within the graticule area.

(1) Count only fibers longer than 5 µm. Measure length of curved fibers along the curve.

(2) Count only fibers with a length-to-width ratio equal to or greater than 3:1.

b. For fibers which cross the boundary of the graticule field:

(1) Count as ½ fiber any fiber with only one end lying within the graticule area, provided that the fiber meets the criteria of rule a above.

(2) Do not count any fiber which crosses the graticule boundary more than once.
(3) Reject and do not count all other fibers.

c. Count bundles of fibers as one fiber unless individual fibers can be identified by observing both ends of a fiber.
d. Count enough graticule fields to yield 100 fibers. Count a minimum of 20 fields. Stop at 100 graticule fields regardless of count.

19. Start counting from the tip of the filter wedge and progress along a radial line to the outer edge. Shift up or down on the filter, and continue in the reverse direction. Select graticule fields randomly by looking away from the eyepiece briefly while advancing the mechanical stage. Ensure that, as a minimum, each analysis covers one radial line from the filter center to the outer edge of the filter. When an agglomerate or bubble covers ca. 1/6 or more of the graticule field, reject the graticule field and select another. Do not report rejected graticule fields in the total number counted.

NOTE 1: When counting a graticule field, continuously scan a range of focal planes by moving the fine focus knob to detect very fine fibers which have become embedded in the filter. The small-diameter fibers will be very faint but are an important contribution to the total count. A minimum counting time of 15 s per field is appropriate for accurate counting.

NOTE 2: This method does not allow for differentiation of fibers based on morphology. Although some experienced counters are capable of selectively counting only fibers which appear to be asbestiform, there is presently no accepted method for ensuring uniformity of judgment between laboratories. It is, therefore, incumbent upon all laboratories using this method to report total fiber counts. If serious contamination from non-asbestos fibers occurs in samples, other techniques such as transmission electron microscopy must be used to identify the asbestos fiber fraction present in the sample (see NIOSH Method 7402). In some cases (i.e., for fibers with diameters >1 µm), polarized light microscopy (as in NIOSH Method 7403) may be used to identify and eliminate interfering non-crystalline fibers [15].

NOTE 3: Do not count at edges where filter was cut. Move in at least 1 mm from the edge.

NOTE 4: Under certain conditions, electrostatic charge may affect the sampling of fibers. These electrostatic effects are most likely to occur when the relative humidity is low (below 20%), and when sampling is performed near the source of aerosol. The result is that deposition of fibers on the filter is reduced, especially near the edge of the filter. If such a pattern is noted during fiber counting, choose fields as close to the center of the filter as possible [5].

NOTE 5: Counts are to be recorded on a data sheet that provides, as a minimum, spaces on which to record the counts for each field, filter identification number, analyst's name, date, total fibers counted, total fields counted, average count, fiber density, and commentary. Average count is calculated by dividing the total fiber count by the number of fields observed. Fiber density (fibers/mm^2) is defined as the average count (fibers/field) divided by the field (graticule) area (mm^2/field).

CALCULATIONS AND REPORTING OF RESULTS

20. Calculate and report fiber density on the filter, E (fibers/mm^2), by dividing the average fiber count per graticule field, F / n_f, minus the mean field blank count per graticule field, B / n_b, by the graticule field area, A_f (approx. 0.00785 mm^2):

$$E = \frac{(F/n_f - B/n_b)}{A_f}, \text{ fibers/mm}^2.$$

NOTE: Fiber counts above 1300 fibers/mm^2 and fiber counts from samples with >50% of filter area covered with particulate should be reported as "uncountable" or "probably biased." Other fiber counts outside the 100–1300 fiber/mm^2 range should be reported as having "greater than optimal variability" and as being "probably biased."

21. Calculate and report the concentration, C (fibers/cc), of fibers in the air volume sampled, V (L), using the effective collection area of the filter, A_c (approx. 385 mm^2 for a 25-mm filter):

$$C = \frac{EA_c}{V \times 10^3}.$$

NOTE: Periodically check and adjust the value of A_c, if necessary.

22. Report intralaboratory and interlaboratory relative standard deviations (from Step 11) with each set of results.

    NOTE: Precision depends on the total number of fibers counted [1,16]. Relative standard deviation is documented in references [1,15–17] for fiber counts up to 100 fibers in 100 graticule fields. Comparability of interlaboratory results is discussed below. As a first approximation, use 213% above and 49% below the count as the upper and lower confidence limits for fiber counts greater than 20 (Figure 1).

EVALUATION OF METHOD:

Method Revisions:

This method is a revision of P&CAM 239 [10]. A summary of the revisions is as follows:

1. Sampling:
   The change from a 37-mm to a 25-mm filter improves sensitivity for similar air volumes. The change in flow rates allows for 2-m^3 full-shift samples to be taken, providing that the filter is not overloaded with non-fibrous particulates. The collection efficiency of the sampler is not a function of flow rate in the range 0.5 to 16 L/min [10].
2. Sample preparation technique:
   The acetone vapor-triacetin preparation technique is a faster, more permanent mounting technique than the dimethyl phthalate/diethyl oxalate method of P&CAM 239 [2,4,10]. The aluminum "hot block" technique minimizes the amount of acetone needed to prepare each sample.
3. Measurement:
   a. The Walton-Beckett graticule standardizes the area observed [14,18,19].
   b. The HSE/NPL test slide standardizes microscope optics for sensitivity to fiber diameter [4,14].
   c. Because of past inaccuracies associated with low fiber counts, the minimum recommended loading has been increased to 100 fibers/mm^2 filter area (a total of 78.5 fibers counted in 100 fields, each with field area = 0.00785 mm^2.) Lower levels generally result in an overestimate of the fiber count when compared to results in the recommended analytical range [20]. The recommended loadings should yield intracounter S_r in the range of 0.10 to 0.17 [21–23].

Interlaboratory Comparability:

An international collaborative study involved 16 laboratories using prepared slides from the asbestos cement, milling, mining, textile, and friction material industries [9]. The relative standard deviations (S_r) varied with sample type and laboratory. The ranges were:

Rules	Intralaboratory S_r	Interlaboratory S_r	Overall S_r
AIA (NIOSH A Rules)*	0.12 to 0.40	0.27 to 0.85	0.46
Modified CRS (NIOSH B Rules)†	0.11 to 0.29	0.20 to 0.35	0.25

*Under AIA rules, only fibers having a diameter less than 3 µm are counted and fibers attached to particles larger than 3 µm are not counted. NIOSH A Rules are otherwise similar to the AIA rules.

†See Appendix C.

A NIOSH study conducted using field samples of asbestos gave intralaboratory S_r in the range 0.17 to 0.25 and an interlaboratory S_r of 0.45 [21]. This agrees well with other recent studies [9,14,16].

At this time, there is no independent means for assessing the overall accuracy of this method. One measure of reliability is to estimate how well the count for a single sample agrees with the mean count from a large number of laboratories. The following discussion indicates how this estimation can be carried out based on measurements of the interlaboratory variability, as well as showing how the results of this method relate to the theoretically attainable counting precision and to measured intra- and interlaboratory S_r. (NOTE: The following discussion does not include bias estimates and should not be taken to indicate that lightly loaded samples are as accurate as properly loaded ones).

Theoretically, the process of counting randomly (Poisson) distributed fibers on a filter surface will give an S_r that depends on the number, N, of fibers counted:

$$S_r = 1/N^{1/2}.$$

Thus S_r is 0.1 for 100 fibers and 0.32 for 10 fibers counted. The actual S_r found in a number of studies is greater than these theoretical numbers [17,19–21].

An additional component of variability comes primarily from subjective interlaboratory differences. In a study of ten counters in a continuing sample exchange program, Ogden [15] found this subjective component of intralaboratory S_r to be approximately 0.2 and estimated the overall S_r by the term:

$$\frac{[N + (0.2 \times N)^2]^{1/2}}{N}.$$

Ogden found that the 90% confidence interval of the individual intralaboratory counts in relation to the means were $+2\ S_r$ and $-1.5\ S_r$. In this program, one sample out of ten was a quality control sample. For laboratories not engaged in an intensive quality assurance program, the subjective component of variability can be higher.

In a study of field sample results in 46 laboratories, the Asbestos Information Association also found that the variability had both a constant component and one that depended on the fiber count [14]. These results gave a subjective interlaboratory component of S_r (on the same basis as Ogden's) for field samples of ca. 0.45. A similar value was obtained for 12 laboratories analyzing a set of 24 field samples [21]. This value falls slightly above the range of S_r (0.25 to 0.42 for 1984–85) found for 80 reference laboratories in the NIOSH PAT program for laboratory-generated samples [17].

A number of factors influence S_r for a given laboratory, such as that laboratory's actual counting performance and the type of samples being analyzed. In the absence of other information, such as from an interlaboratory quality assurance program using field samples, the value for the subjective component of variability is chosen as 0.45. It is hoped that the laboratories will carry out the recommended interlaboratory quality assurance programs to improve their performance and thus reduce the S_r.

The above relative standard deviations apply when the population mean has been determined. It is more useful, however, for laboratories to estimate the 90% confidence interval on the mean count from a single sample fiber count (Figure 1). These curves assume similar shapes of the count distribution for interlaboratory and intralaboratory results [16].

For example, if a sample yields a count of 24 fibers, Figure 1 indicates that the mean interlaboratory count will fall within the range of 227% above and 52% below that value 90% of the time. We can apply these percentages directly to the air concentrations as well. If, for instance, this sample (24 fibers counted) represented a 500-L volume, then the measured concentration is 0.02 fibers/mL (assuming 100 fields counted, 25-mm filter, 0.00785 mm^2 counting field area). If this same sample were counted by a group of laboratories, there is a 90% probability that the mean would fall between 0.01 and 0.08 fiber/mL. These limits should be reported in any comparison of results between laboratories.

Note that the S_r of 0.45 used to derive Figure 1 is used as an estimate for a random group of laboratories. If several laboratories belonging to a quality assurance group can show that their interlaboratory S_r is smaller, then it is more correct to use that smaller S_r. However, the estimated S_r of 0.45 is to be used in the absence of such information. Note also that it has been found that S_r can be higher for certain types of samples, such as asbestos cement [9].

Quite often the estimated airborne concentration from an asbestos analysis is used to compare to a regulatory standard. For instance, if one is trying to show compliance with an 0.5 fiber/mL standard using a single sample on which 100 fibers have been counted, then Figure 1 indicates that the 0.5 fiber/mL standard must be 213% higher than the measured air concentration. This indicates that if one measures a fiber concentration of 0.16 fiber/mL (100 fibers counted), then the mean fiber count by a group of laboratories (of which the compliance laboratory might be one) has a 95% chance of being less than 0.5 fibers/mL; i.e., $0.16 + 2.13 \times 0.16 = 0.5$.

It can be seen from Figure 1 that the Poisson component of the variability is not very important unless the number of fibers counted is small. Therefore, a further approximation is to simply use +213% and −49% as the upper and lower confidence values of the mean for a 100-fiber count.

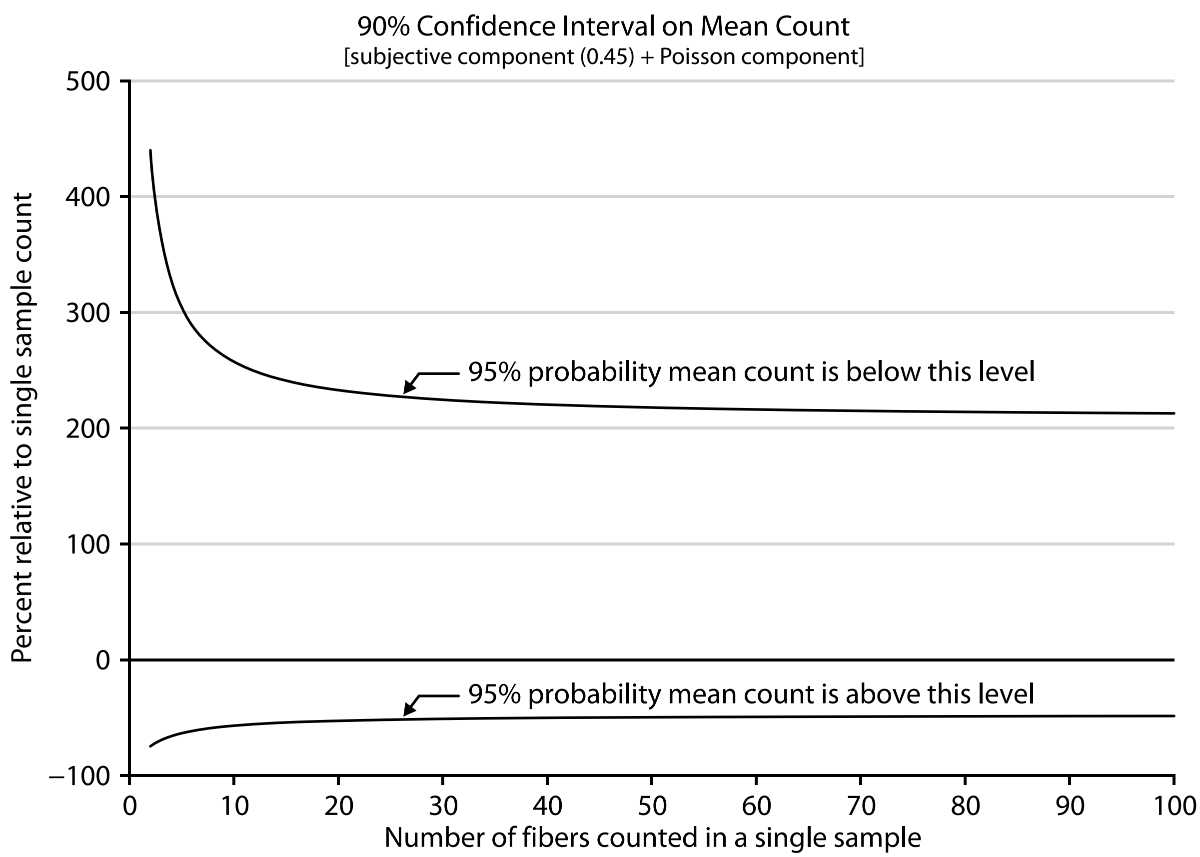


Figure 1. Interlaboratory precision of fiber counts.

The curves in Figure 1 are defined by the following equations:

$$U_{CL} = \frac{2X + 2.25 + [(2.25 + 2X)^2 - 4(1 - 2.25S_r^2)X^2]^{1/2}}{2(1 - 2.25S_r^2)} \text{ and}$$

$$L_{CL} = \frac{2X + 4 - [(4 + 2X)^2 - 4(1 - 4S_r^2)X^2]^{1/2}}{2(1 - 4S_r^2)},$$

where S_r = subjective interlaboratory relative standard deviation, which is close to the total interlaboratory S_r when approximately 100 fibers are counted,
X = total fibers counted on sample,
L_{CL} = lower 95% confidence limit, and
U_{CL} = upper 95% confidence limit.

Note that the range between these two limits represents 90% of the total range.

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APPENDIX A. CALIBRATION OF THE WALTON-BECKETT GRATICULE

Before ordering the Walton-Beckett graticule, the following calibration must be done to obtain a counting area (*D*) 100 µm in diameter at the image plane. The diameter, d_c (mm), of the circular counting area and the disc diameter must be specified when ordering the graticule.

1. Insert any available graticule into the eyepiece and focus so that the graticule lines are sharp and clear.
2. Set the appropriate interpupillary distance and, if applicable, reset the binocular head adjustment so that the magnification remains constant.
3. Install the 40 to 45× phase objective.
4. Place a stage micrometer on the microscope object stage and focus the microscope on the graduated lines.
5. Measure the magnified grid length of the graticule, L_o (µm), using the stage micrometer.
6. Remove the graticule from the microscope and measure its actual grid length, L_a (mm). This can best be accomplished by using a stage fitted with verniers.
7. Calculate the circle diameter, d_c (mm), for the Walton-Beckett graticule:

$$d_c = \frac{L_a}{L_o} \times D.$$

   Example: If L_o = 112 µm, L_a = 4.5 mm, and D = 100 µm, then d_c = 4.02 mm.
8. Check the field diameter, *D* (acceptable range 100 µm ± 2 µm) with a stage micrometer upon receipt of the graticule from the manufacturer. Determine field area (acceptable range 0.00754 mm^2 to 0.00817 mm^2).

APPENDIX B. COMPARISON OF COUNTING RULES

Figure 2 shows a Walton-Beckett graticule as seen through the microscope. The rules will be discussed as they apply to the labeled objects in the figure.

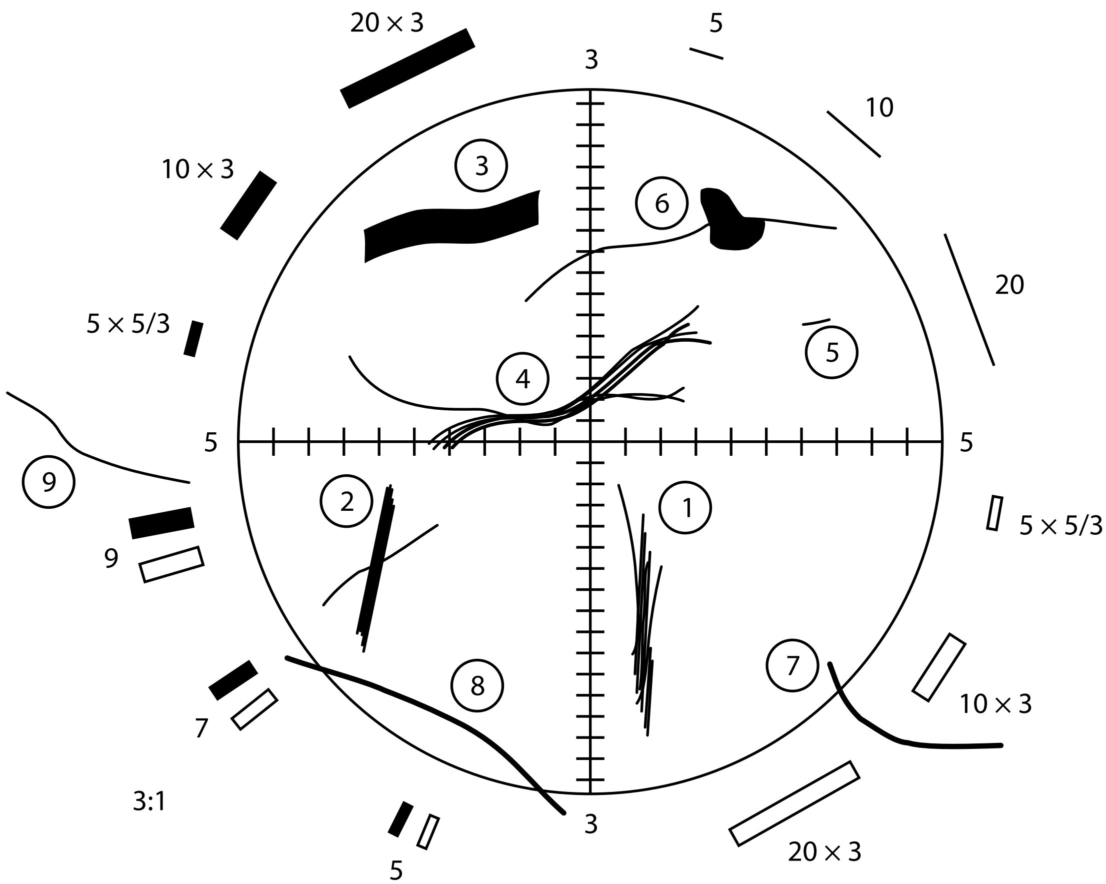


Figure 2. Walton-Beckett graticule with fibers.

These rules are sometimes referred to as the "A" rules:

Object	Count	Discussion
1	1 fiber	Optically observable asbestos fibers are actually bundles of fine fibrils. If the fibrils seem to be from the same bundle, the object is counted as a single fiber. Note, however, that all objects meeting length and aspect ratio criteria are counted whether or not they appear to be asbestos.
2	2 fibers	If fibers meeting the length and aspect ratio criteria (length >5 µm and length-to-width ratio > 3 to 1) overlap, but do not seem to be part of the same bundle, they are counted as separate fibers.
3	1 fiber	Although the object has a relatively large diameter (>3 µm), it is counted as fiber under the rules. There is no upper limit on the fiber diameter in the counting rules. Note that fiber width is measured at the widest compact section of the object.
4	1 fiber	Although long fine fibrils may extend from the body of a fiber, these fibrils are considered part of the fiber if they seem to have originally been part of the bundle.
5	Do not count	If the object is ≤ 5 µm long, it is not counted.
6	1 fiber	A fiber partially obscured by a particle is counted as one fiber. If the fiber ends emanating from a particle do not seem to be from the same fiber and each end meets the length and aspect ratio criteria, they are counted as separate fibers.
7	½ fiber	A fiber which crosses into the graticule area one time is counted as ½ fiber.
8	Do not count	Ignore fibers that cross the graticulate boundary more than once.
9	Do not count	Ignore fibers that lie outside the graticule boundary.

APPENDIX C. ALTERNATE COUNTING RULES FOR NON-ASBESTOS FIBERS

Other counting rules may be more appropriate for measurement of specific non-asbestos fiber types, such as fibrous glass. These include the "B" rules given below (from NIOSH Method 7400, Revision #2, dated 8/15/87), the World Health Organization reference method for man-made mineral fiber [24], and the NIOSH fibrous glass criteria document method [25]. The upper diameter limit in these methods prevents measurements of non-thoracic fibers. It is important to note that the aspect ratio limits included in these methods vary. NIOSH recommends the use of the 3:1 aspect ratio in counting fibers.

It is emphasized that hybridization of different sets of counting rules is not permitted. Report specifically which set of counting rules are used with the analytical results.

"B" Counting Rules

1. Count only *ends* of fibers. Each fiber must be longer than 5 µm and less than 3 µm diameter.
2. Count only ends of fibers with a length-to-width ratio equal to or greater than 5:1.
3. Count each fiber end which falls within the graticule area as one end, provided that the fiber meets rules 1 and 2 above. Add split ends to the count as appropriate if the split fiber segment also meets the criteria of rules 1 and 2 above.
4. Count visibly free ends which meet rules 1 and 2 above when the fiber appears to be attached to another particle, regardless of the size of the other particle. Count the end of a fiber obscured by another particle if the particle covering the fiber end is less than 3 µm in diameter.

5. Count free ends of fibers emanating from large clumps and bundles up to a maximum of 10 ends (5 fibers), provided that each segment meets rules 1 and 2 above.
6. Count enough graticule fields to yield 200 ends. Count a minimum of 20 graticule fields. Stop at 100 graticule fields, regardless of count.
7. Divide total end count by 2 to yield fiber count.

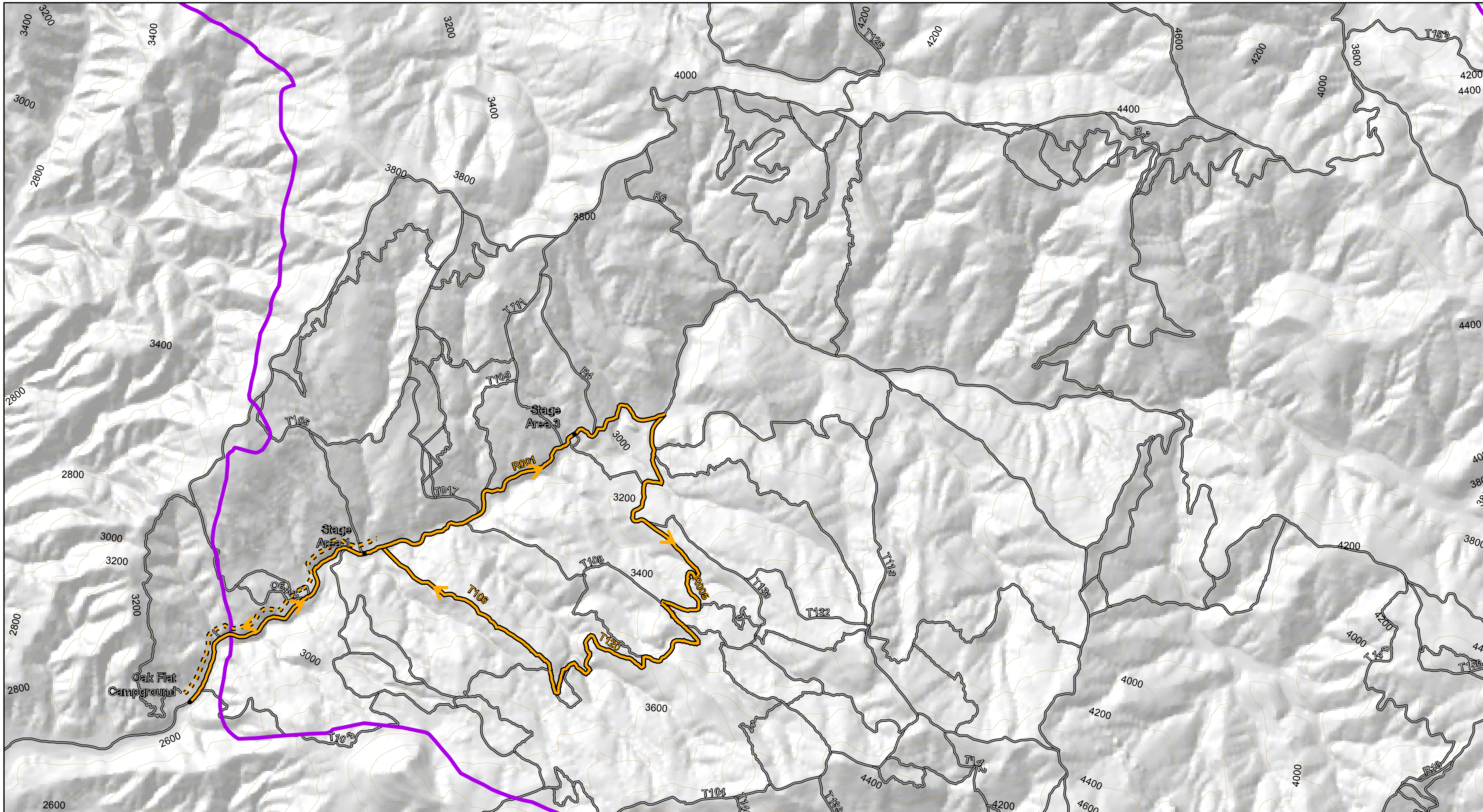
APPENDIX D. EQUIVALENT LIMITS OF DETECTION AND QUANTITATION

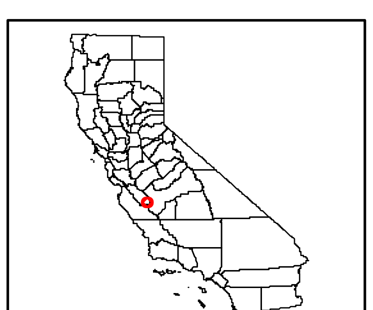
Fiber density on filter*			Fiber concentration in air, f/cc	
	Fibers per 100 fields	Fibers/mm^2	400-L air sample	1000-L air sample
	200	255	0.25	0.10
	100	127	0.125	0.05
LOQ	80.0	102	0.10	0.04
	50	64	0.0625	0.025
	25	32	0.03	0.0125
	20	25	0.025	0.010
	10	12.7	0.0125	0.005
	8	10.2	0.010	0.004
LOD	5.5	7	0.00675	0.0027

*Assumes 385 mm^2 effective filter collection area, and field area = 0.00785 mm^2, for relatively "clean" (little particulate aside from fibers) filters.

Appendix 2

Maps of the Routes the Motorcycle Riders took on April 22-23, 2010





• locations

Air Sampling Day 1, 30 minutes

Hazardous Asbestos Area

0 0.5 1 Miles

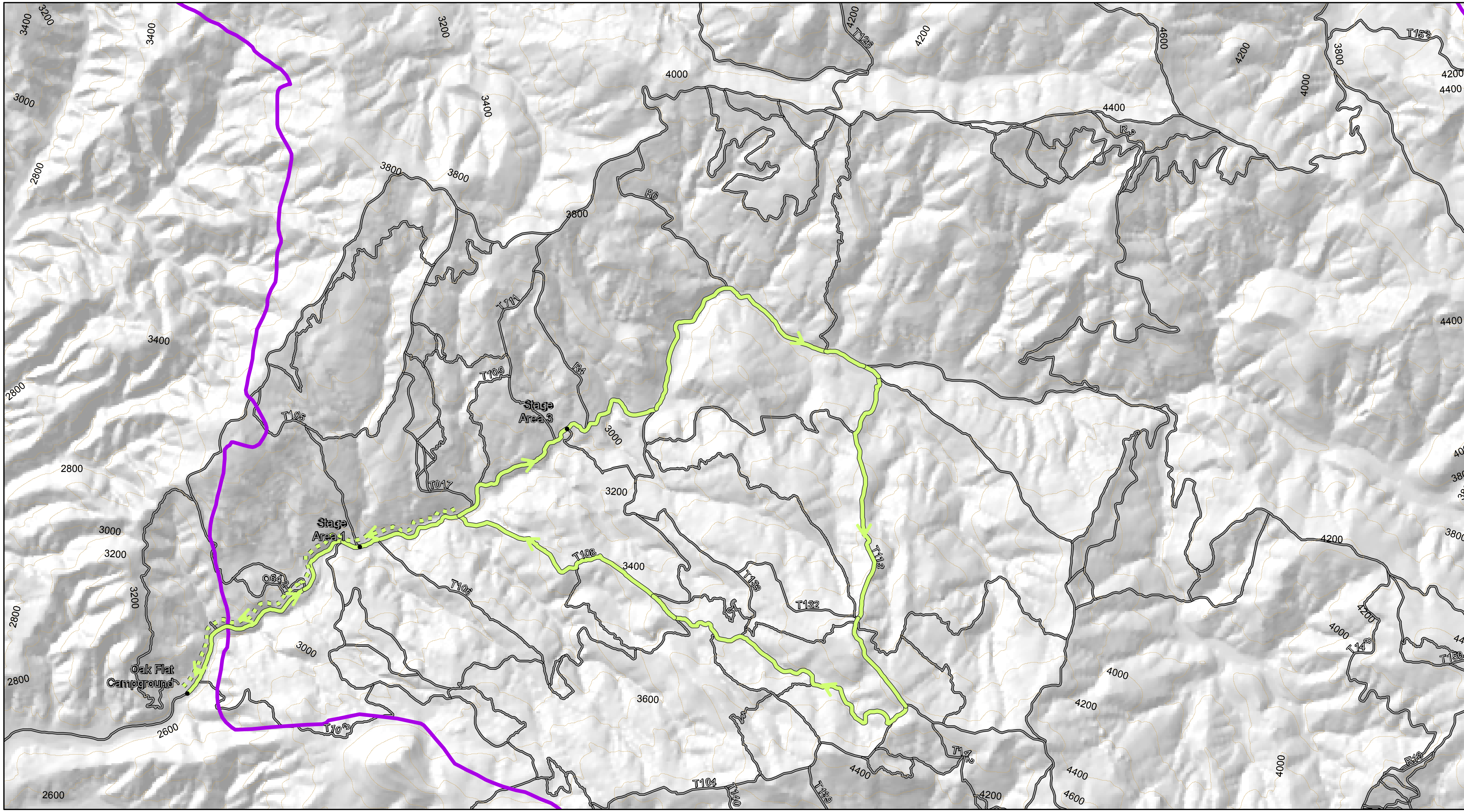
0 1,000 2,000 4,000 Feet

1:24,000

N

Motorcycle Route for Day One of Air Sampling 30 Minute Sample

San Benito County, California



- locations
- Offset_line_AS1_60mins
- Air Sampling Day 1, 60 minutes
- Hazardous Asbestos Area

0 0.5 1 Miles

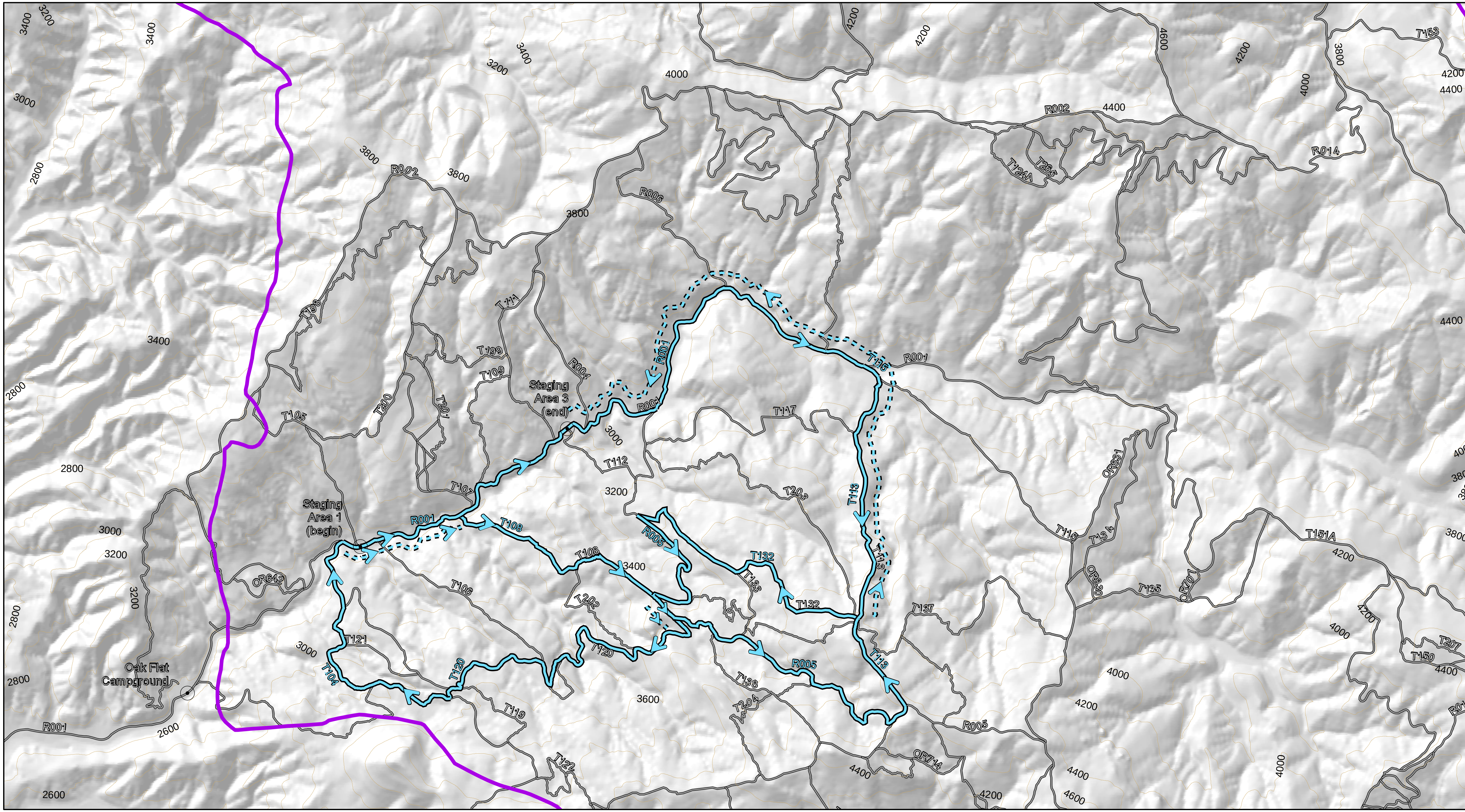
0 1,000 2,000 4,000 Feet

1:24,000

N

Motorcycle Route for Day One of Air Sampling 60 Minute Sample

San Benito County, California



Staging Areas

Air Sampling Day 2, 140 minutes

Offset Line for Overlapping Path

Hazardous Asbestos Area

0 0.5 1 Miles

0 1,000 2,000 4,000 Feet

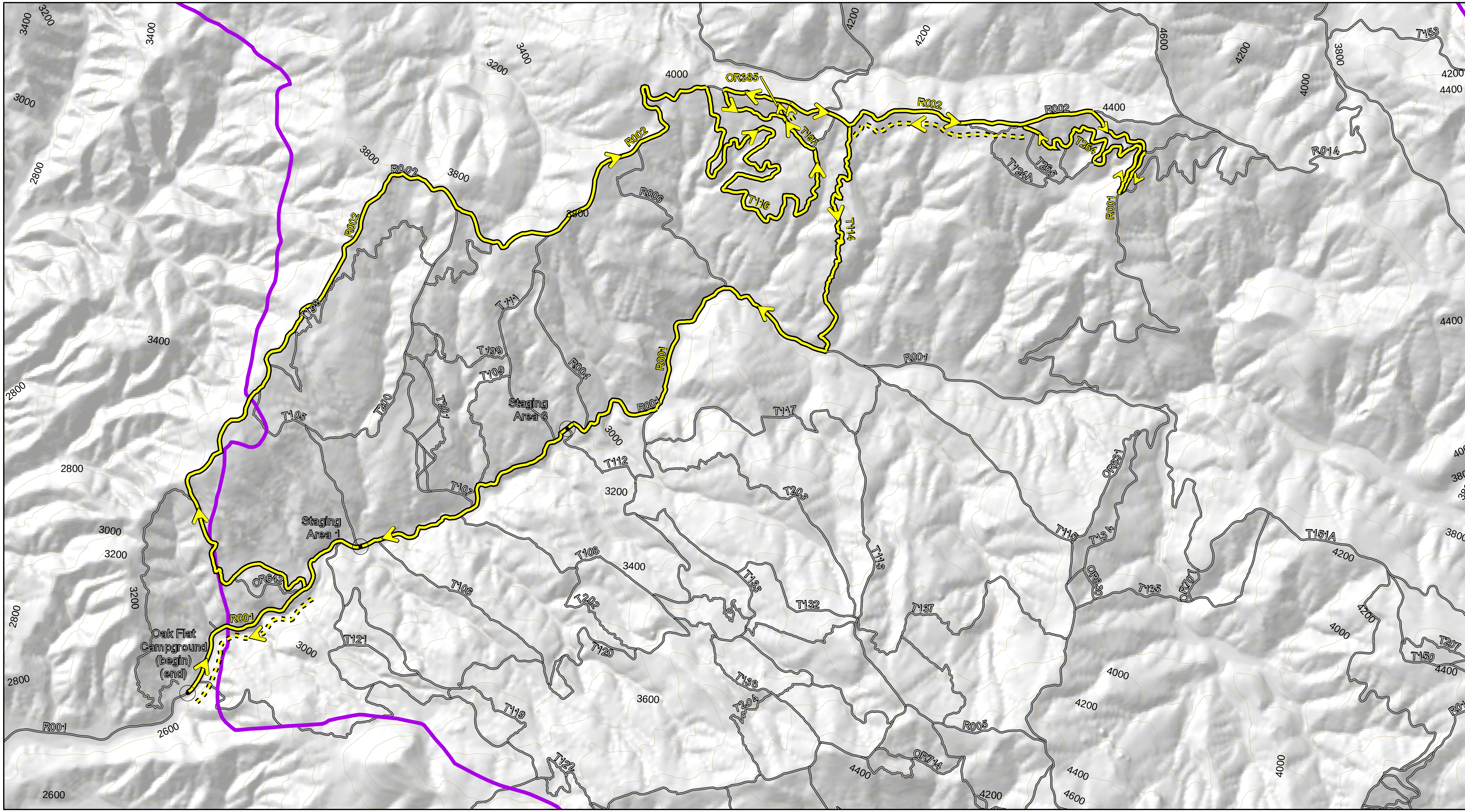
1:24,000

N

Motorcycle Route for Day Two of Air Sampling 140 Minute Sample

Clear Creek Management Area

San Benito County, California



- Staging Areas
- Air Sampling Day 2, 120 minutes
- Offset Line for Overlapping Path
- Hazardous Asbestos Area

0 0.5 1 Miles

0 1,000 2,000 4,000 Feet

1:24,000

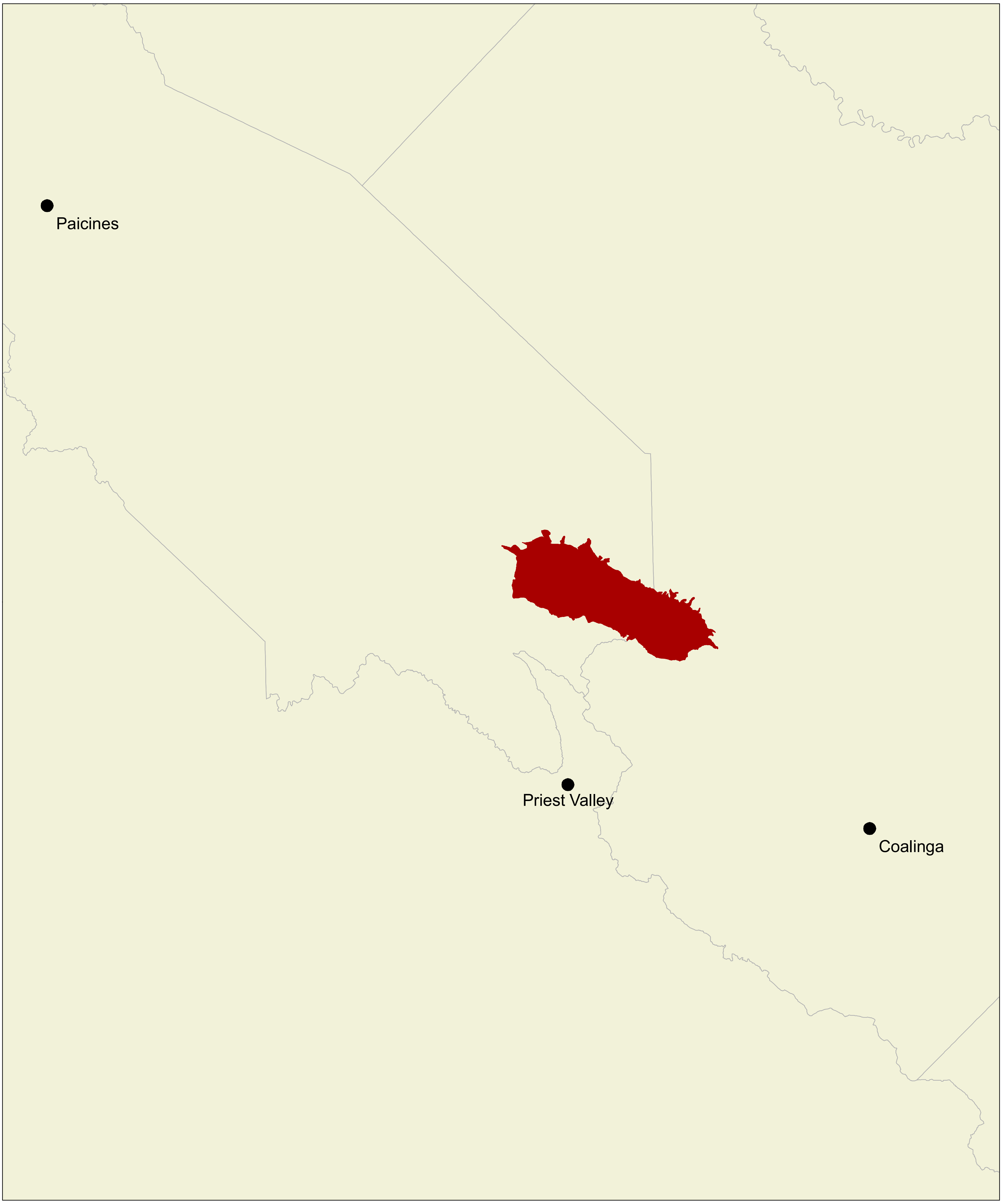
N

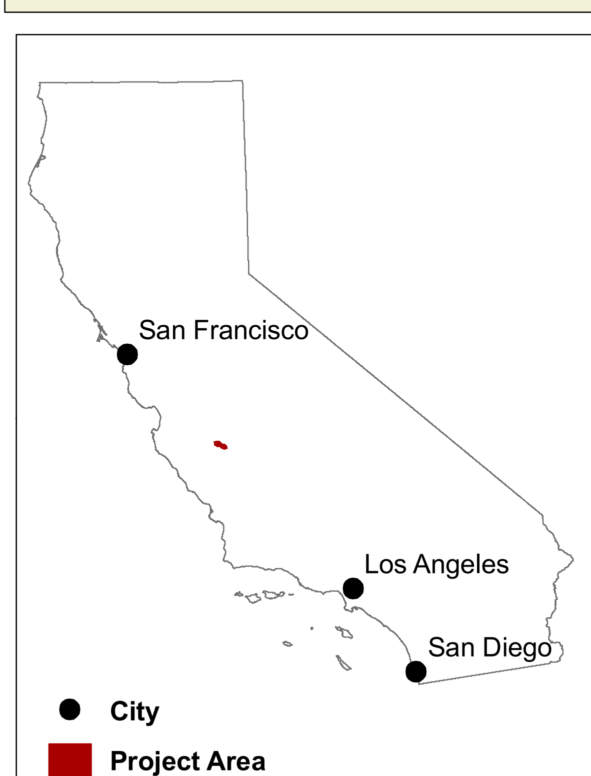
Motorcycle Route for Day Two of Air Sampling 120 Minute Sample

Clear Creek Management Area
San Benito County, California

Appendix 3

Rainfall for the Cooper *et al.* 1979 Study





Rain Gauge Locations

Rain Gauge Locations

Project Area

0 10 20

Miles

Monthly Precipitation Totals
Western Regional Climate Center
www.wrcc.dri.edu

Location	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coalinga	1976	0.00	2.22	0.72	1.27	0.00	0.00	0.00	0.32	3.81	0.04	0.79	0.62
	1977	0.39	0.02	0.43	0.00	1.51	0.06	0.00	0.00	0.00	0.10	0.19	4.37
	1978	0z	4.99	3.12	1.39	0.00	0.00	0.00	0.00	1.02	0.00	1.77	0.67
Pacines	1976	0.21	1.25	1.93	0.96	0.00	0.12	0.00	1.39	2.67	0.75	0.57	1.41
	1977	0.99	0.48	0.58	0.03	1.18	0.15	0.00	0.00	0.41	0.05	0.61	5.04
	1978	6.13	6.02	4.00	3.15	0.00	0.00	0.00	0.00	0.29	0.00	2.24	0.59
Priest Valley	1976	0.03	2.58	1.09	1.96	0.00	0.25	0.00	1.60	4.88	0.91	0.94	1.72
	1977	1.56	0.21	1.64	0.00	2.00	0.32	0.00	0.03	0.00	0.20	0.68	8.55
	1978	8.42	7.40	6.21	4.28	0.00	0.23	0.00	0.00	1.25	0.00	5.04	1.66

z = 26 or more days missing

Source: http://www.wrcc.dri.edu/index.html

Appendix 4

EPA Health Effects Update
Tables used for the Risk Assessment

United States
Environmental Protection
Agency

Office of Health and
Environmental Assessment
Washington, DC 20460

EPA/600/8-84/003F
June 1986

Research and Development

EPA

Airborne Asbestos Health Assessment Update

Appendix IV

EPA/600/8-84/003F
June 1986

Airborne Asbestos Health Assessment Update

Environmental Criteria and Assessment Office
Office of Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, N.C. 27711

DISCLAIMER

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names of commercial products does not constitute endorsement or recommendation for use.

TABLE 6-1. LIFETIME RISKS PER 100,000 FEMALES OF DEATH FROM MESOTHELIOMA AND LUNG CANCER FROM CONTINUOUS ASBESTOS EXPOSURES OF 0.0001 AND 0.01 f/ml ACCORDING TO AGE AT FIRST EXPOSURE, DURATION OF EXPOSURE, AND SMOKING[a]

	Concentration = 0.0001 f/ml years of exposure					Concentration = 0.01 f/ml years of exposure				
Age at onset of exposure	1	5	10	20	life-time	1	5	10	20	life-time
					Mesothelioma in Female Smokers					
0	0.1	0.6	1.2	1.9	2.5	13.9	64.0	115.1	186.2	252.0
10	0.1	0.4	0.7	1.1	1.4	9.0	40.3	71.4	112.0	142.8
20	0.1	0.2	0.4	0.6	0.7	5.3	23.5	40.7	61.3	72.8
30	0.0	0.1	0.2	0.3	0.3	2.8	12.3	20.6	29.4	32.8
50	0.0	0.0	0.0	0.0	0.0	0.6	2.0	2.9	3.5	3.5
					Lung Cancer in Female Smokers					
0	0.0	0.1	0.3	0.5	1.5	2.8	13.4	26.7	53.3	149.9
10	0.0	0.1	0.3	0.5	1.2	2.8	13.4	26.7	53.3	123.5
20	0.0	0.1	0.3	0.5	1.0	2.8	13.4	26.7	52.5	96.9
30	0.0	0.1	0.3	0.5	0.7	2.8	13.3	25.9	47.9	71.0
50	0.0	0.1	0.2	0.2	0.2	2.0	8.8	15.5	22.7	24.4
					Mesothelioma in Female Nonsmokers					
0	0.1	0.7	1.2	2.0	2.7	14.8	68.2	122.8	199.4	272.2
10	0.1	0.4	0.8	1.2	1.6	9.5	43.4	81.2	121.2	155.8
20	0.1	0.3	0.4	0.7	0.8	5.7	25.6	44.4	67.2	80.6
30	0.0	0.1	0.2	0.3	0.4	3.1	13.6	23.0	32.9	36.8
50	0.0	0.0	0.0	0.0	0.0	0.6	2.2	3.4	4.1	4.1
					Lung Cancer in Female Nonsmokers					
0	0.0	0.0	0.0	0.1	0.2	0.3	1.3	2.7	5.2	16.4
10	0.0	0.0	0.0	0.1	0.1	0.3	1.3	2.7	5.3	13.9
20	0.0	0.0	0.0	0.1	0.1	0.3	1.3	2.7	5.2	11.3
30	0.0	0.0	0.0	0.1	0.1	0.3	1.3	2.7	5.0	8.7
50	0.0	0.0	0.0	0.0	0.0	0.3	1.1	2.1	3.5	3.9

[a]The 95% confidence limit on the risk values for lung cancer for an unstudied exposure circumstance is a factor of 10. The 95% confidence limit on the risk values for lung cancer (the average determined from 11 unit exposure risk studies is a factor of 2.5. The 95% confidence limit on the risk values for mesothelioma for an unstudied exposure circumstance is a factor of 20. The 95% confidence limit on the risk values for mesothelioma for a studied circumstance can be reasonably averaged as a factor of 5. The values for continuous exposure were derived by multiplying 40 hr/wk risks, obtained from occupational exposures, by 4.2 (the ratio of hours in a week to 40 hours.)

TABLE 6-2. LIFETIME RISKS PER 100,000 MALES OF DEATH FROM MESOTHELIOMA AND LUNG CANCER FROM CONTINUOUS ASBESTOS EXPOSURES OF 0.0001 AND 0.01 f/ml ACCORDING TO AGE AT FIRST EXPOSURE, DURATION OF EXPOSURE, AND SMOKING[a]

	Concentration = 0.0001 f/ml years of exposure					Concentration = 0.01 f/ml years of exposure				
Age at onset of exposure	1	5	10	20	life-time	1	5	10	20	life-time
Mesothelioma in Male Smokers										
0	0.1	0.5	0.9	1.4	1.8	10.6	48.3	85.5	137.5	181.0
10	0.1	0.3	0.5	0.8	1.0	6.6	29.4	51.5	77.8	98.3
20	0.0	0.2	0.3	0.4	0.5	3.6	16.4	28.0	41.2	47.9
30	0.0	0.1	0.1	0.1	0.2	2.0	8.1	13.4	18.5	20.2
50	0.0	0.0	0.0	0.0	0.0	0.3	1.1	1.5	1.8	1.8
Lung Cancer in Male Smokers										
0	0.0	0.2	0.4	0.8	2.4	4.2	20.9	41.9	83.4	238.1
10	0.0	0.2	0.4	0.8	2.0	4.2	21.0	42.0	83.9	197.8
20	0.0	0.2	0.4	0.8	1.6	4.2	21.3	42.3	83.4	157.5
30	0.0	0.2	0.4	0.8	1.2	4.2	21.3	42.0	79.2	117.6
50	0.0	0.2	0.3	0.4	0.4	3.6	16.2	28.4	40.3	42.0
Mesothelioma in Male Nonsmokers										
0	0.1	0.6	1.0	1.6	2.2	12.5	57.0	102.3	164.5	220.1
10	0.1	0.4	0.6	1.0	1.2	7.8	35.3	62.6	97.3	122.6
20	0.0	0.2	0.4	0.5	0.6	4.5	20.4	35.1	52.4	61.7
30	0.0	0.1	0.2	0.2	0.3	2.4	10.5	17.5	24.6	26.9
50	0.0	0.0	0.0	0.0	0.0	0.4	1.5	2.2	2.7	2.7
Lung Cancer in Male Nonsmokers										
0	0.0	0.0	0.0	0.0	0.2	0.3	1.5	2.9	5.9	18.5
10	0.0	0.0	0.0	0.1	0.2	0.3	1.5	2.9	5.9	15.5
20	0.0	0.0	0.0	0.1	0.1	0.3	1.5	2.9	5.9	12.6
30	0.0	0.0	0.0	0.1	0.1	0.3	1.5	2.9	5.7	9.7
50	0.0	0.0	0.0	0.0	0.0	0.3	1.3	2.2	3.9	4.2

[a] The 95% confidence limit on the risk values for lung cancer for an unstudied exposure circumstance is a factor of 10. The 95% confidence limit on the risk values for lung cancer on the average determined from 11 unit exposure risk studies is a factor of 2.5. The 95% confidence limit on the risk values for mesothelioma for an unstudied exposure circumstance is a factor of 20. The 95% confidence limit on the risk values for mesothelioma for a studied circumstance can be reasonably averaged as a factor of 5. The values for continuous exposure were derived by multiplying 40 hr/wk risks, obtained from occupational exposures, by 4.2 (the ratio of hours in a week to 40 hours.)