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Evaluation of PCB Concentrations in Archived Small Mammal Samples from Sandia Canyon

(LA-UR-99-5891)

by

Kathryn Bennett, James Biggs, and Gilbert Gonzales

ABSTRACT

During the summer of 1996, concerns developed about polychlorinated biphenyls (PCBs) within Sandia Canyon, Los Alamos National Laboratory, Los Alamos, New Mexico. Archived small mammal samples (voles, *Microtus* spp.; harvest mouse, *Reithrodontomys megalotis*; vagrant shrews, *Sorex vagrans*; and deer mouse, *Peromyscus maniculatus*) comprised of adipose tissue and internal organs from 1995 (thirty samples) and 1996 (thirty-four samples) were submitted for analysis of PCB mixtures known as Aroclors. During the summer of 1998, a reference site in South Fork Canyon of the Jemez Mountains was selected and thirty samples of small mammal adipose tissue and internal organs were analyzed for seven PCBs. Nine samples from 1995 and nineteen samples from 1996 had detectable or estimated concentrations of Aroclor-1260, whereas no samples from the reference site (background) had detectable levels. Aroclor-1260 concentrations found in the samples collected from Sandia Canyon ranged from 49 to 19,000 µg/kg. Preliminary evaluation of the data indicates that maximum levels of Aroclor-1260 approach minimum levels for which effects have been noted.

1.0 INTRODUCTION

During the summer of 1996, concerns developed about polychlorinated biphenyls (PCBs) within Sandia Canyon at Los Alamos National Laboratory (LANL), Los Alamos, New Mexico. Earlier, soil sampling conducted by Fresquez (1993) found PCBs in soil ranging from 1.6 to 9600 ppm. Later, the Environmental Restoration Program also found PCBs in soil samples in the same general area.

In 1996 the LANL Water Quality Group contacted the Ecology Group (ESH-20) to determine if there were archived samples of small mammals collected from Sandia Canyon that could be screened for PCBs. During the summer of 1995 and 1996, ESH-20 conducted a small mammal study in the wetland in upper Sandia Canyon. As part of the study, all small mammals (voles, *Microtus* spp. and harvest mouse, *Reithrodontomys megalotis*) captured during the last trapping night of 1995 were collected and euthanized for confirmation of species identification. The animals were stored in a freezer at ESH-20. Additionally, samples (voles; harvest mouse; shrews, *Sorex vagrans*; and deer mouse, *Peromyscus maniculatus*) were also available from a recently completed 1996 study in which all small mammals trapped were collected, euthanized, and stored in a freezer. This study was part of collaborative effort with University of New Mexico to study genetics of small mammals and Hantavirus. After the 1995 and 1996 samples were analyzed, a reference site in South Fork Canyon of the Jemez Mountains was selected and trapped in 1998. This site had no previous history of PCB contamination and served as a baseline for comparing the 1995 and 1996 samples. Although the small mammal study was not originally designed to evaluate potential PCB uptake in small mammals, we believed the frozen

animals could be used as a first-level screen to determine if additional studies should be conducted to examine PCB uptake in small mammals.

PCBs are mixtures of synthetic organic chemicals, consisting of two 6-carbon rings, with one bond joining a carbon from each ring and chlorine attaching to any of the other 10 carbons. Because of their inflammability, chemical stability, and insulating properties, commercial PCB mixtures had been used in many industrial applications. These chemical properties, however, also contribute to the persistence of PCBs after they are released into the environment. PCBs are widespread in the environment and can accumulate selectively in living organisms. PCBs are highly soluble in lipids and are absorbed by fish and other animals, including small mammals. Studies have shown increases in some types of cancers from chronic exposure to PCBs.

ESH-20 working with Paragon Laboratories and Rocky Mountain Arsenal, developed a procedure for an appropriate sample composition to serve as a screen for PCBs. Rocky Mountain Arsenal analyzed numerous small mammal samples for PCBs and found that submission of the entire animal diluted the sample because PCBs tended to concentrate in organs and adipose tissue. Therefore, we performed dissections on the small mammals and submitted samples composed of only adipose tissues and internal organs (including brain). This sample composition would then contribute to a conservative screen.

2.0 ENVIRONMENTAL SETTING

2.1 General Setting

Sandia Canyon is located within the boundaries of LANL. The Laboratory is located in north-central New Mexico on the Pajarito Plateau, approximately 80 mi north of Albuquerque and 25 mi west of Santa Fe (Fig. 1). The plateau is an apron of volcanic rock stretching 20 to 25 mi in a north-south direction and 5 to 10 mi from east to west. The average elevation of the plateau is 7500 ft. It slopes gradually eastward from the edge of the Jemez Mountains, a complex pile of volcanic rock situated along the northwest margin of the Rio Grande rift. From an elevation of approximately 1890 meters (6200 ft) at White Rock, the plateau scarp drops to 1646 meters (5400 ft) at the Rio Grande. Intermittent streams flowing southeastward have dissected the plateau into a number of finger-like mesas separated by deep, narrow canyons. The bedrock consists of Bandelier tuff that erupted from the Jemez Mountains about 1.1 to 1.4 million years ago. The tuff overlaps other volcanics that in turn overlay the Puye Foundation conglomerate. The conglomerate intermixes with Chino basalts along the Rio Grande (LANL 1988).

The LANL area is characterized by a semiarid, temperate mountain climate. In the summer months, temperatures typically range from a daily low of around 50° F to a high of 80° F. Winter temperatures range from near 14° F to about 50° F during a 24-h period. Annual precipitation varies from 13 to 18 in. with most of it falling as rain in July and August (Bowen 1990).

2.1.1 Description of the Sandia Canyon and Wetland Area

The head of Sandia Canyon is near the University House in Technical Area 3 (TA-3) of LANL and extends southeastward to the Rio Grande. The area of the drainage basin is approximately

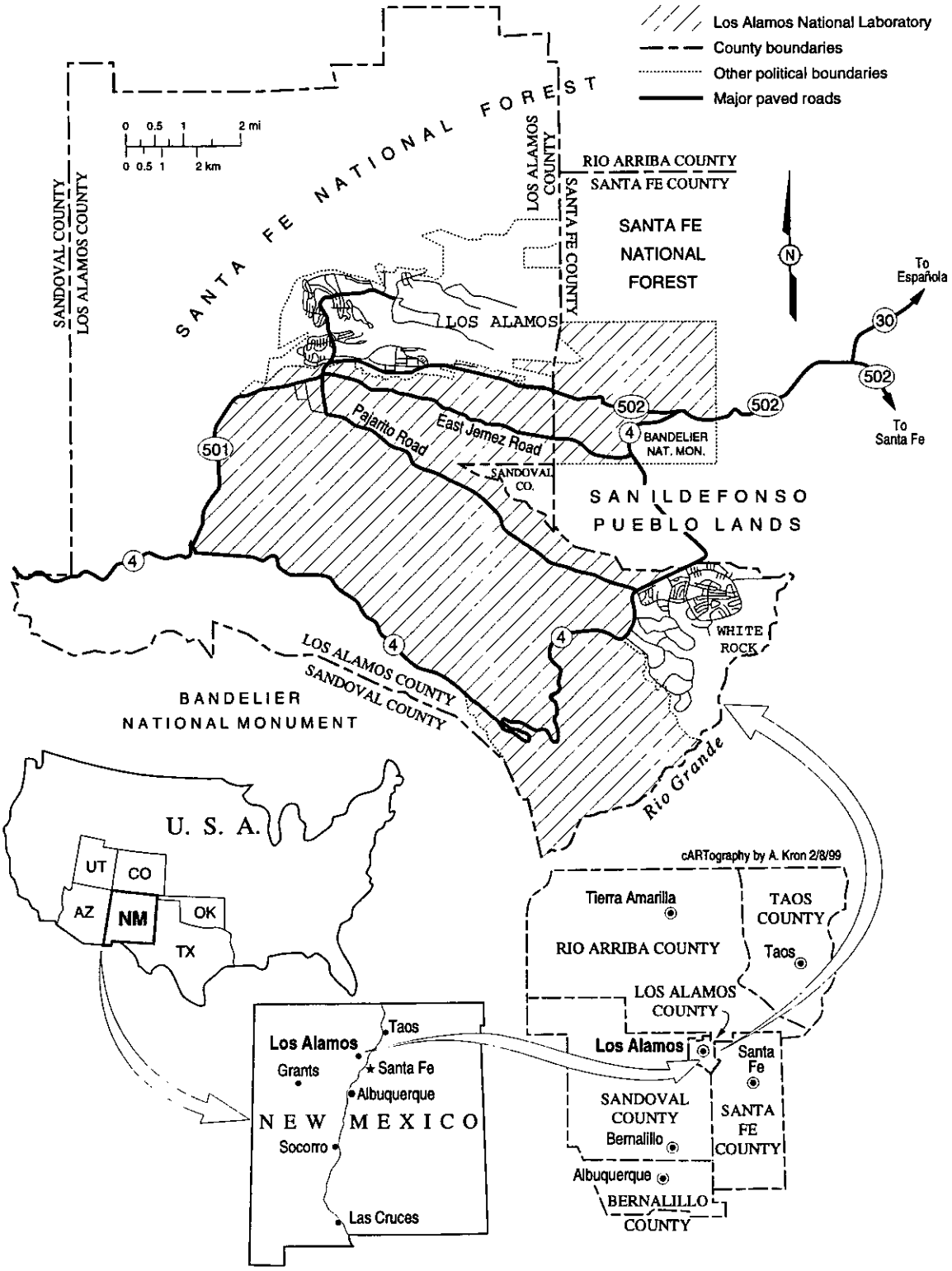

Figure 1. Location of Los Alamos National Laboratory

13.5 km^2 (5.6 mi^2). Industrial and sanitary effluents from LANL activities maintain stream flow in portions of Sandia Canyon year-round.

In the upper portion of the canyon situated below TA-3, a large cattail marsh of roughly six acres has developed. This wetland has been classified as a "persistent artificially flooded, palustrine wetland" by the US Fish and Wildlife Service in their National Wetland Inventory (Cowardin et al. 1979). The wetland has received effluent from a steam power plant, a sewage treatment plant, and an asphalt plant. Additional sources of effluent included treated cooling water and noncontact cooling water. Storm water runoff and snowmelt also contributed to the stream seasonally. This wetland area is bounded on the west by a rubble landfill, to the north by the Los Alamos County sanitary landfill, to the south by a developed technical area, and down gradient from several potential release sites (PRSs) (Fig. 2). PCBs were a contaminant of concern within at least one of these PRSs.

2.1.2 Reference Site, South Fork Canyon, Jemez Mountains.

A reference site was selected in South Fork Canyon within the Jemez Mountains on U.S. Forest Service property just off of Forest Service Road 376. The area had no known PCB contamination. The South Fork Canyon site was approximately two miles from the intersection of 376 and State Road 126, approximately 3 miles north of La Cueva, New Mexico, and about 40 miles northwest of LANL (Fig. 3). The site was characterized as a wet meadow with many wetland grasses and pockets of cattails. A permanent stream runs through the reference site. Small mammal species composition was similar to the Sandia Canyon samples.

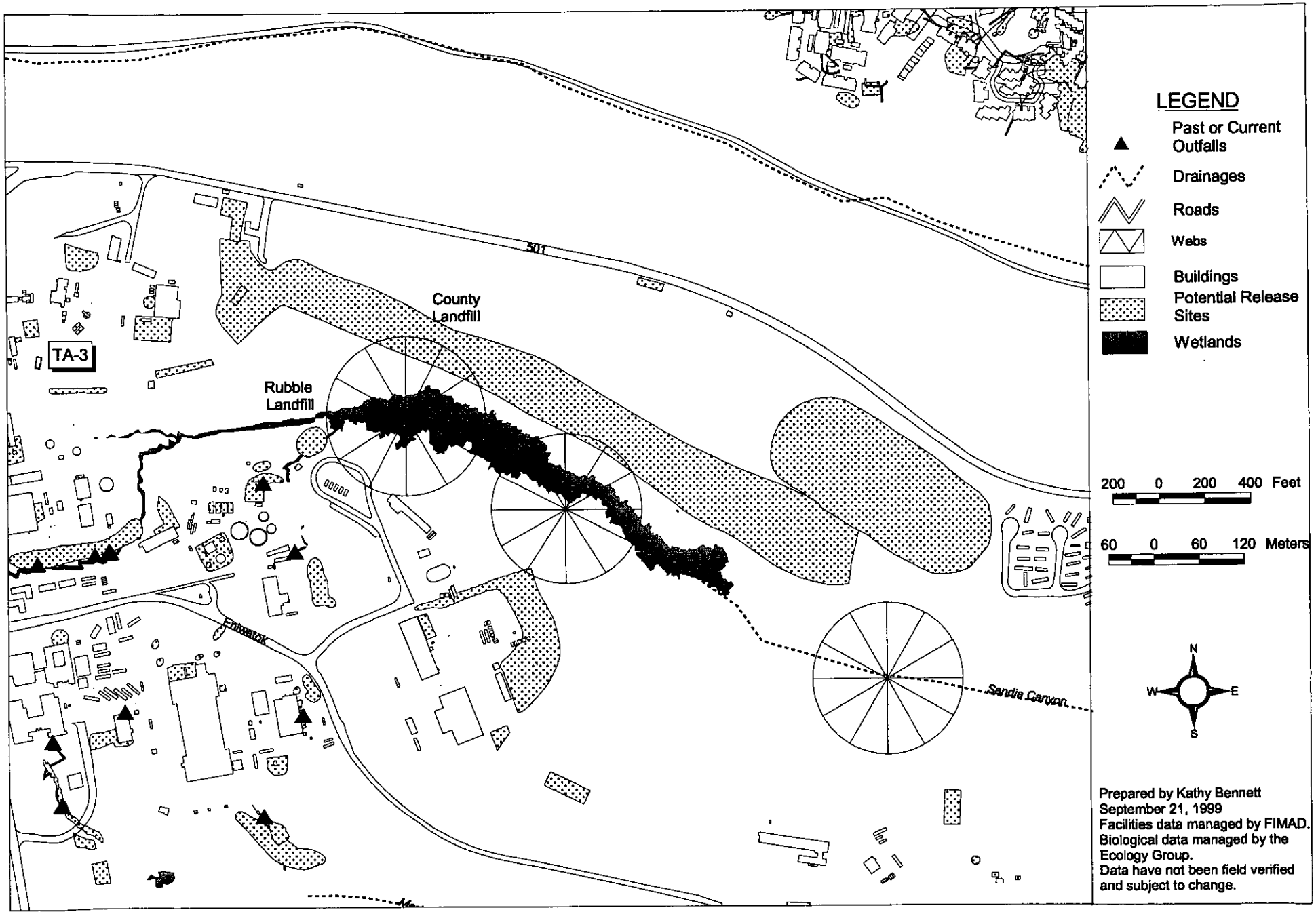

Fig. 2. Location of Sandia Canyon and trapping area.

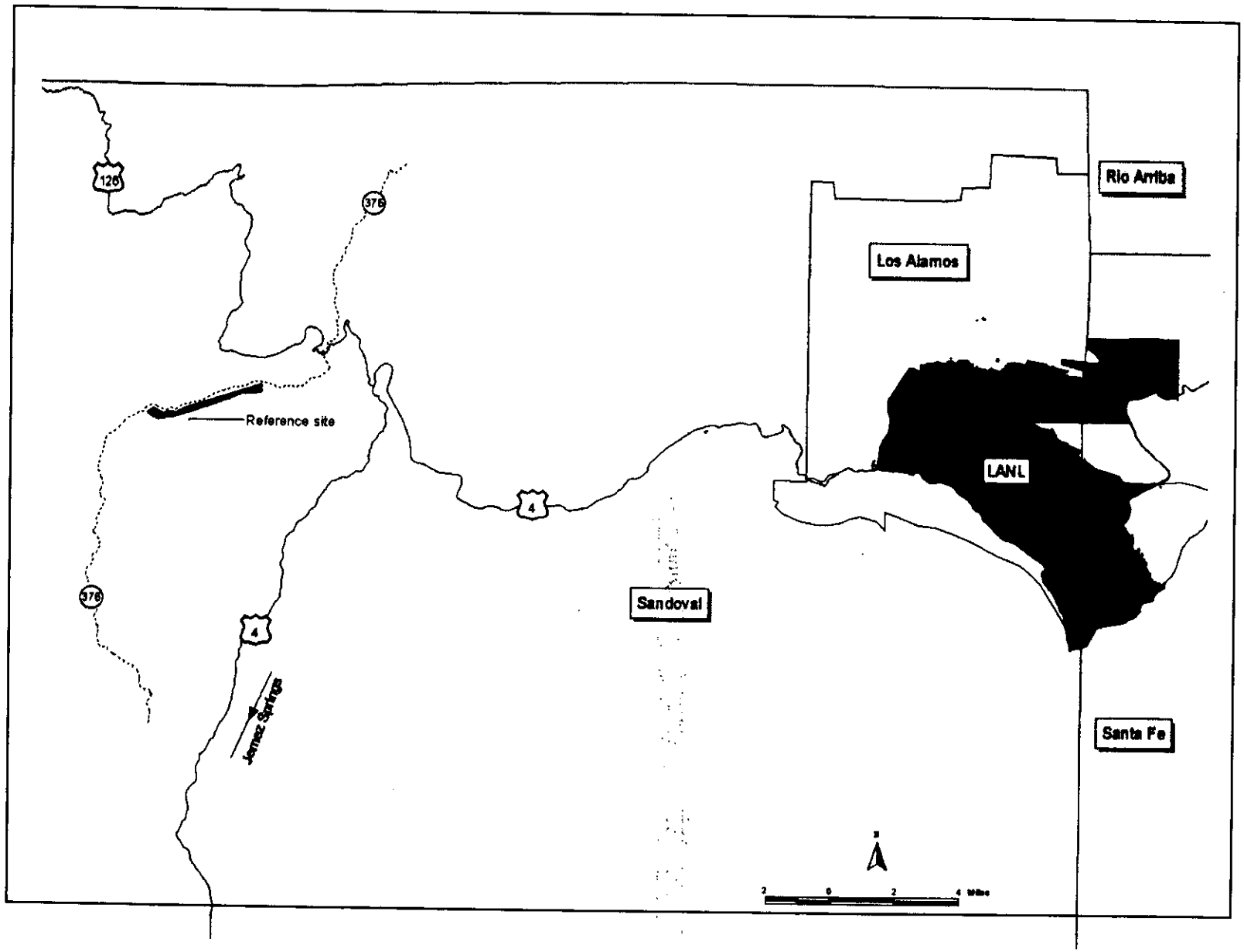

Figure 3. Location of reference site in the Jemez Mountains.

3.0 METHODS

3.1 Field Methods

3.1.1 Sandia Canyon

Capture-recapture and removal sampling of small mammals was performed within Sandia Canyon during 1995 and 1996. During 1995, capture-recapture methodology was used with a removal during the last day of capture, and in 1996, a removal method was used where all captures were removed the day of capture. The sampling was performed at three locations within the canyon. The first two webs were within the cattail marsh, and the third web was placed in a transition area between the cattail marsh and an intermittent stream channel.

A web method of 148 Sherman live traps was utilized. Each web consisted of 12 lines of traps spaced at 5- to 10-m intervals with 4 traps placed in the center (Parmenter 1994). Trapping took place over 4 to 8 consecutive nights or until no new captures (capture-recapture) or no animals (removal) were trapped within the first few rings of the web.

Trapping webs were used in an attempt to increase the accuracy of density estimates and reduce the amount of edge effect and overestimation of density that is common when a grid trapping configuration is used. The web configuration results in traps being placed in rings of increasing radius from the web center at set distances along each web line. All captures in each ring of traps are considered to be detections of objects at a specified distance from the center of the web. The distance data are analyzed as grouped data, such that the total number of captures arising from the same ring are grouped together. Trapping webs are applications of point transect sampling theory (Buckland et al. 1993).

Traps were baited in late afternoon with a molasses-coated horse feed and a dry mixture of peanut butter. The traps were checked in early morning to record only nocturnal species. Animals were marked with a size #FF rodent ear tag. Location of capture, species name, sex, weight, body length, tail length, ear length, foot length, and tag number were recorded. A blood sample was taken from each animal for Hantavirus testing. All incidental kills and final day removal from the 1995 capture-recapture study and all animals from the 1996 removal study were kept for species confirmation and Hantavirus genetic study. These animals were tagged and placed in a labeled Ziplock bag and then placed in a freezer for storage.

3.1.2 South Fork Canyon, Jemez Mountains

A reference site was selected in the Jemez Mountains with a similar species composition to Sandia Canyon. A grid trapping methodology was used because of topographical and roadway constraints prohibiting the use of a web. The grid was 5 by 200 with traps placed 10 meters apart. Traps were baited in the late afternoon with a molasses-coated horse feed and a dry mixture of peanut butter. The traps were checked in early morning to record nocturnal species. Animals were marked with a size #FF rodent ear tag. Species, name, sex, weight, body length, tail length, ear length, foot length, and tag number were recorded. A blood sample was taken from each animal for Hantavirus testing. A complete removal of target species was conducted. Target species included any species of the genus *Microtus, Peromyscus, Sorex* or *Reithrodontomys*. Species were euthanized, placed in labeled plastic bags, and placed on ice until sample processing occurred.

In addition to the use of Sherman live traps, five pitfall traps were used to target shrew species (*Sorex* spp.). A large hole was dug near the stream channel and a five-gallon bucket was placed in the hole. The top of the bucket was even with the ground surface and all gaps between the bucket and the hole were backfilled with soil. Shrews that fell into the bucket during the night were removed from the bucket the next morning. Species name, sex, weight, body length, tail length, ear length, and foot length were recorded. Shrews were not ear tagged (because of ear length size and tag size) and blood samples for Hantavirus were not taken. Hantavirus screening of shrews was unnecessary because there is no evidence that shrews carry the virus. All shrews were euthanized, placed in a labeled Ziplock bag, and placed on ice.

3.2 Sample Processing

Samples from the 1995 and 1996 studies had been archived in the ESH-20 freezer and removed from the freezer for sample processing in 1996 and 1997, respectively. Species were selected from Web 1 and Web 2 for both years. No animals were selected from Web 3 because of insufficient numbers of Web 3 archived animals. In order to provide a conservative screen, animals selected for analysis were species usually found in habitats of higher moisture content, such as voles and harvest mice. These animals would spend the majority of their life within the cattail marsh and associated stream channel.

The reference site samples were processed upon collection. Only target species were euthanized for processing, all other animals were released.

Adipose tissue and internal organs (including brain) were dissected from each animal for PCB analysis. In the case of shrews, a composite sample of adipose tissue and internal organs from five shrews were required to obtain a large enough sample for PCB analysis. Composite shrew samples were submitted from the 1996 samples and the reference site. Each small mammal was dissected with new or clean dissecting tools. All dissecting tools were thoroughly cleaned with alcohol and later decontaminated for Hantavirus minimization. For each small mammal processed, the internal organs and adipose tissue were placed in a labeled Ziplock bag. The label contained the sample identification number. After dissection, all animals were placed in the freezer and kept frozen until analyzed. All samples were submitted for analysis to Paragon Analytical, Inc. Only animals testing negative for Hantavirus were submitted.

3.3 Analytical Methods

Each sample including the plastic bag was weighed on a balance and the weight recorded. The sample was removed from the bag and placed in a large mortar with crushed dry ice. The amount of dry ice added was approximately twice the volume of the sample. The sample was kept on dry ice for approximately two minutes, then ground to a fine powder. Thirty grams of sodium sulfate was added to each samples' plastic bag and shaken to remove all liquid from the bag. The sodium sulfate was poured into the mortar with the powdered sample. The mixture was ground in the mortar and quantitatively transferred into a thimble for soxhlet extraction (US Environmental Protection Agency [USEPA] Method 3540). The plastic bags were then weighed and the sample weight was calculated by subtracting the weight of the bag from the total weight of the bag and sample. The powdered sample was extracted for sixteen hours with methylene chloride. The extracts were processed with a sulfuric acid cleanup by USEPA Method 3665 in

an attempt to remove potential interferences. Samples appearing to have a weathered Aroclor-1260 pattern present were quantified using only the peaks from the standard that matched the weathered pattern of the sample. The extracts were analyzed using Gas Chromatograph with electron capture detectors with a 1701 capillary column according to the protocols based on USEPA Method 8081. All positive results were confirmed on a RTX-50 column. The quantitation of each analyte was taken from the primary column unless interferences were encountered; in which case the secondary column was used (Paragon Analytical, Inc. 1997).

3.4 Preliminary Evaluation of Ecological Risk Implications

To assess the risk implications we evaluated existing literature on PCBs, wildlife responses to PCB exposures in general, and wildlife responses to particular levels of PCBs and how those levels compare to levels observed in this study.

4.0 RESULTS

Thirty small mammal samples (comprised of one small mammal to a sample) were submitted for PCB analysis during 1996 from the 1995 study. Animals selected for analysis came from either Web 1 or Web 2. These webs were closer to areas where known PCB contamination existed up gradient. Of the thirty samples submitted, twenty-five were from Web 1 and five from Web 2 (due to availability of archived samples). Twenty-seven voles and two harvest mice were submitted. Of these samples, nine samples (seven voles and one harvest mouse) had detectable levels of PCBs (Aroclor-1260) and were from seven different trap locations within Web 1. No detectable levels of PCBs were found in Web 2 samples. Detectable levels ranged from 49 μg/kg

to 2500 µg/kg of PCBs (Aroclor-1260) in small mammal adipose tissue and organs (Table 1 and Fig. 4). No other Aroclor had detectable levels.

Thirty-five samples were submitted for analysis in 1997 from the 1996 samples. Thirty-four samples were analyzed. One sample was misprocessed at the analytical lab and did not yield results. Animals selected for analysis came from either Web 1 or Web 2 (see Fig. 5). No animals were selected from Web 3. Each sample was comprised of adipose tissue and organs from one animal with the exception of shrew samples. Shrew samples were composite samples of adipose tissue and internal organs from five animals. Three samples of shrews representing fourteen animals were analyzed. In addition, seventeen voles, twelve harvest mice, and two deer mice were analyzed. Twenty-three samples, including two shrew samples were analyzed from Web 1. Eleven samples, includes one shrew sample, were analyzed from Web 2. Thirty percent of the Web 1 samples had values greater than the reporting level, nine percent had estimated values just less than the reporting level, and the remaining sixty-one percent had values less than the reporting level (not detected). Whereas, Web 2 had eighty-two percent of the samples with higher than the reporting level, nine percent had values estimated just less than the reporting level, and nine percent had values less than the reporting level (not detected). Detectable levels ranged from 110 to 19000 µg/kg of PCBs (Aroclor-1260) in small mammal adipose tissue and organs. All three shrew samples had detectable levels of PCBs, and the highest levels were found in shrew samples. All detectable levels were of Aroclor-1260. Data from sample analysis and trapping efforts are shown in Table 2 and Figure 5.

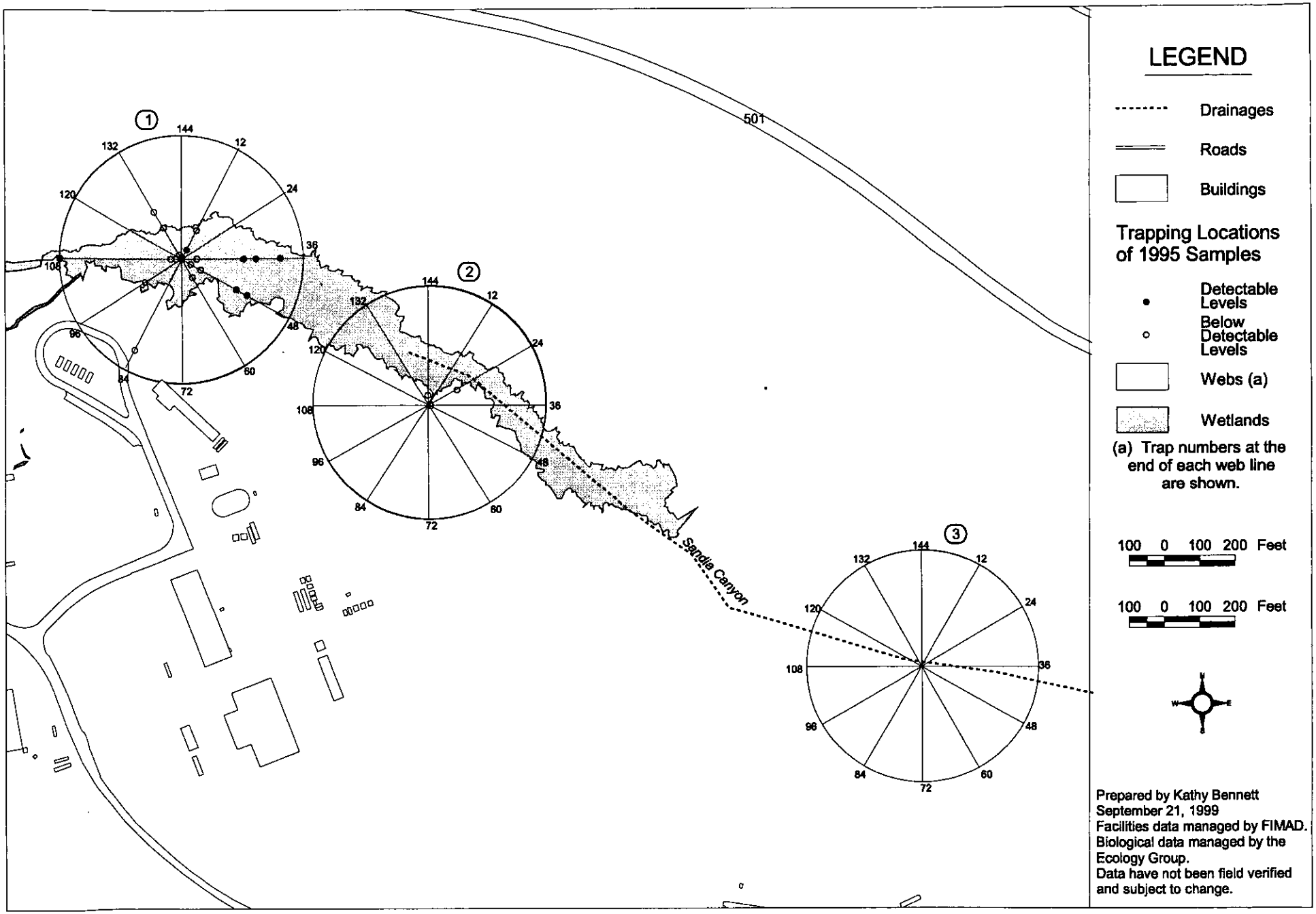

Fig. 4. Location of the 1995 samples.

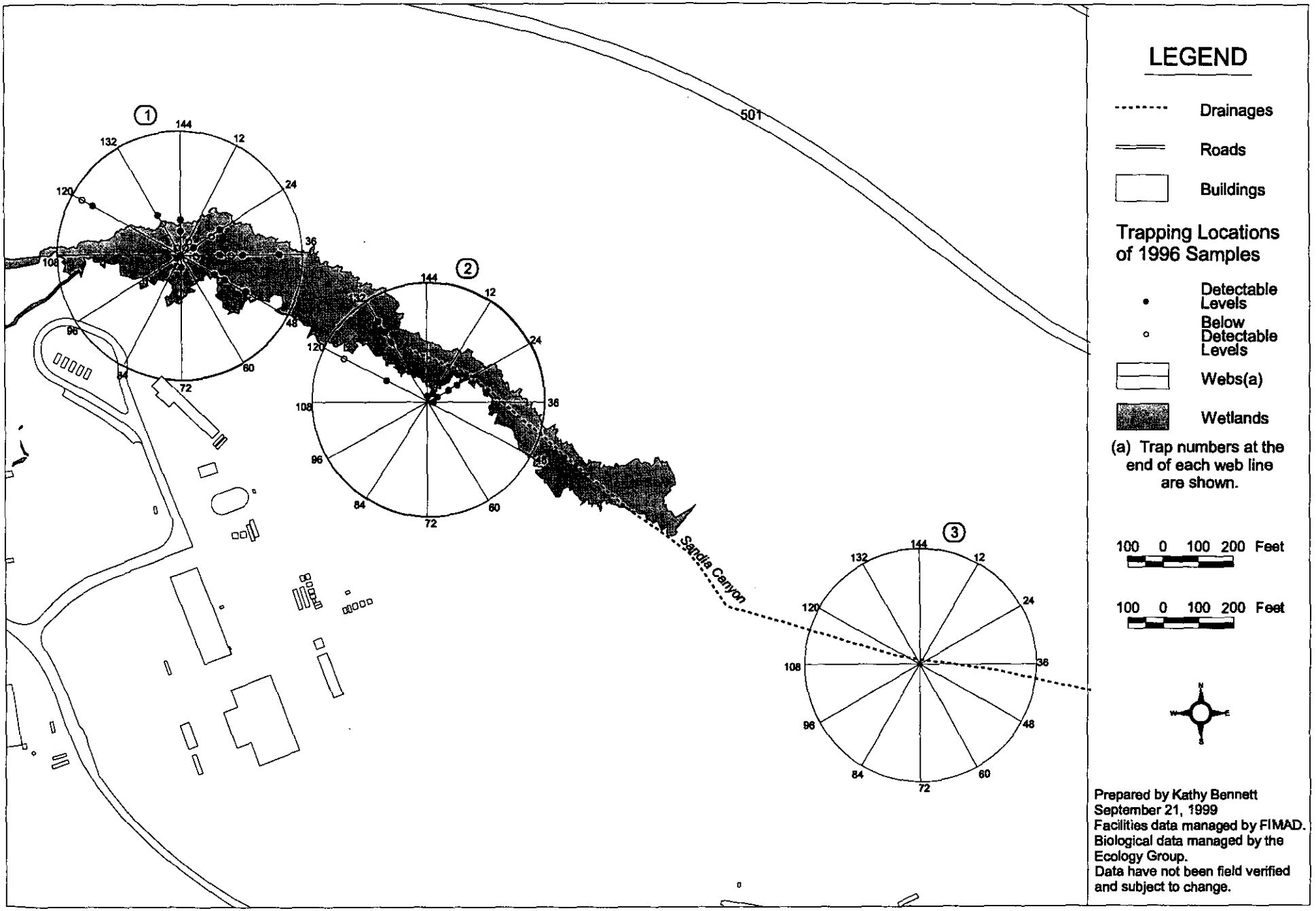

Fig. 5. Location of the 1996 samples.

Table 1: Results from the 1995 small mammals submitted for PCB analysis. Results are given for the analyte Arochlor-1260 in units of µg/kg. No other Arochlors (Arochlor-1016, -1221, -1232, -1242, -1248, or -1254) yielded detectable limits. Samples with detectable levels are shaded.

Sample #	Animal #	Web #	Trap #	Species Code	Sex	Weight (g)	Body Length (cm)	Tail Length (cm)	Ear Length (cm)	Foot Length (cm)	Result	Reporting Limit
12	2365	1	5	MIMO	M	37	8.3	4.1	1.4	1.9	ND	81
14	3204	1	27	MIMO	M	36	10	1.4	1.3	1.9	ND	110
18	1728	1	38	MIMO	F	36	12	4	1.4	1.6	ND	88
19	3203	1	40	MILO	F	36	9.7	5.5	1.4	1.9	ND	85
25	2362	1	40	MIMO	M	25.5	9.6	4.1	0.9	2	ND	130
29	3228	1	64	MILO	F	35.5	11.5	4.5	1.2	1.5	ND	74
3	2354	1	82	MILO	F	53	13.2	7	1.4	2	ND	40
8	2371	1	82	MIMO	M	12	6.8	0.04	1.2	1.8	ND	310
24	2450	1	86	MIMO	F	31	10.5	3	1.2	1.7	ND	100
5	2382	1	97	MIMO	M	31.5	10.3	3.5	1.6	2	ND	110
26	3212	1	98	MIMO	M	21	8.9	4.1	1.3	1.5	ND	140
27	2363	1	108	MILO	M	24.5	0.08	5.3	1.2	1.8	ND	160
15	3244	1	121	MIMO	F	36.5	11.5	3.8	1	1.6	ND	91
30	2356	1	126	MILO	M	30	8.5	5.4	1.3	1.9	ND	110
1	2397	1	127	MIMO	M	13	7.9	4.3	1	1.8	ND	290
4	2364	1	133	REME	M	8	6.8	2.4	1	1.5	ND	620
16	2381	2	1	MIMO	M	47.5	11.4	4.2	1.4	1.8	ND	89
28	2413	2	1	MIMO	F	43	12.3	3.5	1.4	1.8	ND	70
21	1953	2	17	MILO	F	48	11.8	4.2	1.9	1.9	ND	48
6	2398	2	25	MILO	M	30	9.5	4.5	1.8	1.7	ND	100
10	2355	2	134	MIMO	F	42	12.2	4.5	1.5	1.9	ND	53

ND = Not Detected
Species Code: MILO = *Microtus longicaudus* (Long-tailed vole); MIMO = *Microtus montanus* (Montane vole); REME = *Reithrodontomys megalotis* (Western harvest mouse).
J = Estimated Level.

Table 2: Results from the 1996 small mammals submitted for PCB analysis. Results are given for the analyte Arochlor 1260 in units of µg/kg. No other Arochlors (Arochlor 1016, 1221, 1232, 1242, 1248, or 1254) yielded detectable limits. Samples with levels greater than the reporting limit are shaded.

Sample #	Animal #	Web #	Trap #	Species Code[a]	Sex	Weight (g)	Body[b]	Tail[b]	Ear[b]	Foot[b]	Result	Reporting Limit	Result Qualifier
1	806961002	1	2	REME	M	10.41	7.1	6.0	1.7	1.6	570	570	U
2	807961125	1	125	PEMA	F	15.42	7.1	7.2	1.9	1.8	320	320	U
3	806961122	1	122	PEMA	F	20.16	7.7	7.8	1.7	1.9	140	140	U
4	807962004	2	4	REME	M	11.42	7.6	6.1	1.4	1.8	820	460	
5	809962026	2	26	REME	M	8.8	5.6	6.4	1.4	1.7	430	470	J
6	809961018	1	18	REME	M	9.7	6.0	6.8	1.4	1.5	610	610	U
7	806961126	1	126	REME	M	13.36	7.5	7.1	1.4	1.8	980	350	
8	806961015	1	15	REME	M	10.58	7.8	6.9	1.9	1.6	390	440	J
9	809961085	1	85	REME	M	10.43	5.9	6.6	1.5	1.6	300	330	J
10	809962016	2	16	MILO	M	41.59	11.6	5.5	1.5	2.1	410	82	
11	806962129	2	129	MIMO	M	34.24	11.1	4.4	1.9	2.0	810	230	
12	809962129	2	129	MILO	M	41.9	12.2	6.0	1.6	1.6	380	94	
13	807961119	1	119	MILO	M	41.8	11.8	6.6	1.6	1.2	96	96	U
14	807961118	2	118	MILO	M	30.23	10.9	5.9	1.6	2.3	110	110	U
15	807961017	1	17	MIMO	M	20.08	8.4	4.9	1.2	2.0	N/A	N/A	N/A
16	806961118	1	118	MILO	M	43.27	12.5	6.7	1.5	2.2	130	99	
17	809961017	1	17	MILO	M	18.48	7.2	5.2	1.4	1.9	200	200	U
18	809961030	1	30	MILO	F	31.9	11.9	5.5	1.9	1.8	120	120	
19	809961084	1	84	MILO	M	37.9	10.5	6.2	1.5	2.1	170	86	
20	807961029	1	29	MILO	M	20.51	9.6	5.1	1.9	1.8	200	200	U
21	807961030	1	30	MILO	M	22.4	9.7	5.4	0	1.4	150	150	U
22	809961027	1	27	MIMO	M	24.5	10.0	3.5	1.7	1.8	140	140	U
23	806961074	1	74	MIMO	M	40.99	10.7	3.8	1.5	1.7	95	95	U
24	806962017	2	17	MISP	M	37.61	12.3	4.5	1.6	2.0	530	210	
25	809962044	2	44	MILO	F	31.65	10.1	6.2	1.5	2.0	110	92	
26	807961126	1	126	MILO	F	43.55	9.9	5.3	1.5	2.0	45	45	U
27	806961044	1	44	MILO	M	39.82	10.1	6.8	1.5	2.0	790	220	
28	807961062	1	62	SOVA	M	16.6	6.0	4.0	0.8	1.2	10,000	2,000	
28	807961136	1	136	SOVA	M	6.3	6.9	3.7	0.7	1.2	10,000	2,000	
28	807961137	1	137	SOVA	UNK	3.8	6.1	4.3	0.8	1.3	10,000	2,000	
28	807961044	1	44	SOVA	F	5.9	5.9	3.7	0.7	1.8	10,000	2,000	
28	806961136	1	136	SOVA	M	6.0	6.6	3.5	0.7	1.1	10,000	2,000	
29	807961041	1	41	SOVA	F	4.2	5.8	4.2	0.8	1.3	19,000	3,600	
29	807961042	1	42	SOVA	F	4.1	5.9	4.2	0.9	1.4	19,000	3,500	

29[c]	806961018	1	18	SOVA	F	7.2	5.9	4.1	0.6	1.2	19,000	3,600	
29[c]	806961031	1	31	SOVA	M	6.1	5.8	4.1	0.6	0	19,000	3,500	
29[c]	806961029	1	29	SOVA	F	4.6	7.0	4.3	0.7	1.3	19,000	3,500	
30[c]	806962114	1	114	SOVA	M	5.1	6.2	4.4	0.3	1.2	8,400	1,500	
30[c]	807961002	2	2	SOVA	F	4.3	6.0	4.4	0.4	1.3	8,400	1,500	
30[c]	807962128	2	128	SOVA	F	6.1	7.1	4.3	0.8	1.2	8,400	1,500	
30[c]	809962130	2	130	SOVA	M	5.2	5.5	4.5	0.7	1.1	8,400	1,500	
31	807961085	1	85	REME	M	11.49	7.0	6.5	1.7	1.6	920	340	
32	807961003	1	3	REME	F	13.24	7.2	6.4	1.4	1.8	320	320	U
33	807961018	1	18	REME	F	11.58	6.0	6.8	1.6	1.7	390	390	U
34	807962130	2	130	REME	F	10.19	7.2	6.9	1.7	1.8	460	390	
35	806962014	2	14	REME	M	10.94	7.4	6.8	1.6	1.6	500	390	

[a]Species Code: MILO = *Microtus longicaudus* (Long-tailed vole); MIMO = *Microtus montanus* (Montane vole); REME = *Reithrodontomys megalotis* (Western harvest mouse), PEMA = *Peromyscus maniculatus* (Deer mouse), *SOVA* = *Sorex vagrans* (Vagrant shrew).

[b]Length in cm.

[c]Composite sample

J = Estimted Value

U = Less than the Reporting Limit

N/A = Not available

Forty samples were submitted to Paragon Laboratory for PCB analysis from the reference site in South Fork Canyon, but only thirty samples yielded results due to a laboratory misprocessing (vials broke during processing). Of the thirty samples analyzed, one sample was a composite shrew sample, seven samples were deer mice, and 22 samples were voles. All samples were less than the reporting value (Table 3).

Table 3. Results from the 1998 reference site in South Fork Canyon. Results are given for Arochlor1260 in units of µg/kg.

Sample #	Animal #	Species Code[a]	Sex	Weight (g)	Body[b]	Tail[b]	Ear[b]	Foot[b]	Result	Reporting Limit	Result Qualifier
1	1	MIMO	M	20.5	9.4	3.8	1.3	1.9	330	330	U
2	2	PEMA	M	12.5	8.0	7.4	1.5	1.9	N/A	N/A	N/A
3	3	PEMA	F	12.0	7.5	6.2	1.8	1.9	190	190	U
4	4	PEMA	M	14.0	8.1	7.0	1.8	1.9	110	110	U
5	5	MIMO	M	19.0	9.7	3.0	1.5	1.6	N/A	N/A	N/A
6	6	PEMA	M	14.0	9.3	6.1	1.7	2.0	160	160	U
7	7	PEMA	M	19.5	9.3	7.5	2.0	2.1	68	68	U
8	8	PEMA	M	12.0	8.1	5.7	1.7	1.8	210	210	U
9	18	PEMA	F	18.5	9.1	7.5	1.9	2.0	N/A	N/A	N/A
10	19	MIMO	M	19.0	8.0	3.4	1.3	1.7	N/A	N/A	N/A
11	20	MIMO	F	27.0	9.8	4.3	1.2	1.9	N/A	N/A	N/A
12	22	PEMA	M	15.0	8.7	6.7	1.8	2.0	170	170	U
13	23	MIMO	M	20.0	9.4	3.5	1.2	1.9	N/A	N/A	N/A
14	25	MIMO	M	34.0	12.4	4.0	1.5	1.8	N/A	N/A	N/A
15	26	MIMO	M	30.5	10.0	3.5	1.3	2.0	N/A	N/A	N/A
16	27	MIMO	F	32.0	11.0	3.9	1.4	1.7	160	160	U
17	28	MIMO	M	22.0	9.5	4.0	1.5	2.0	210	210	U
18	29	MIMO	M	29.0	10.5	4.0	1.4	2.0	180	180	U
19	30	MIMO	F	36.5	11.7	4.0	1.5	2.1	120	120	U
20	31	MIMO	F	32.5	9.7	4.5	1.4	1.6	N/A	N/A	N/A
21	32	MIMO	M	N/A	8.5	3.6	1.4	1.8	130	130	U
22	33	MIMO	M	37.0	12.7	4.4	1.5	1.9	180	180	U
23	34	MIMO	M	35.0	11.4	4.1	1.4	2.0	320	320	U
24	35	MIMO	F	24.0	11.2	3.9	1.5	1.8	110	110	U
25	36	PEMA	M	11.0	8.0	6.1	1.8	2.0	210	210	U
26	37	MIMO	F	50.0	10.4	4.0	1.4	1.8	240	240	U
27	38	MIMO	M	15.0	8.0	3.0	1.2	1.5	220	220	U
28	39	MIMO	M	32.0	10.8	3.7	1.5	1.7	N/A	N/A	N/A
29	40	MIMO	F	35.0	9.6	3.4	1.1	1.8	430	430	U
30	41	MIMO	M	27.0	10	3.5	0.8	1.5	350	350	U
31	42	MIMO	F	21.0	8.7	3.2	1.2	1.9	590	590	U

32	45	MIMO	M	19.0	8.8	3.1	1.3	1.8	320	320	U
33	46	MIMO	M	16.0	7.0	2.9	1.1	1.7	300	300	U
34	50	MIMO	M	20.0	9.1	3.0	1.6	1.7	230	230	U
35	54	MIMO	M	20.0	10.2	3.5	1.5	1.8	380	380	U
36	57	MIMO	M	13.0	7.9	2.9	1.2	1.8	190	190	U
37	58	MIMO	F	33.0	10.0	4.0	1.2	1.8	200	200	U
38	59	MIMO	M	31.5	11.1	3.7	1.4	1.8	110	110	U
39	60	MIMO	F	36.5	11.6	3.6	1.4	1.6	130	130	U
40[c]	47	SOVA	N/A	6.0	6.1	4.0	0.6	1.2	84	84	U
40[c]	48	SOVA	N/A	N/A	6.5	4.0	N/A	1.2	84	84	U
40[c]	49	SOVA	N/A	N/A	6.0	3.7	N/A	1.2	84	84	U
40[c]	51	SOVA	M	4.0	4.7	4.0	0.5	1.2	84	84	U
40[c]	52	SOVA	F	5.5	6.0	4.0	0.6	1.2	84	84	U

[a]Species Code: MILO = *Microtus longicaudus* (Long-tailed vole); MIMO = *Microtus montanus* (Montane vole); REME = *Reithrodontomys megalotis* (Western harvest mouse), PEMA = *Peromyscus maniculatus* (Deer mouse), *SOVA* = *Sorex vagrans* (Vagrant shrew).
[b]Length in cm.
[c]Composite sample
U = Less than the Reporting Limit
N/A = Not available

ECOLOGICAL RISK IMPLICATIONS

5.1 Introduction

Since data collection for this study first began, risk assessments of threatened and endangered species at LANL have indicated that risk to non-human biota from contaminants is dominated by organic contaminants, with PCBs identified as one of the key contaminant types (Gonzales et al. 1998a, b, and c; Gonzales et al. 1997). This prompted us to investigate the risk implications of the results obtained in the study area.

This section discusses preliminary risk implications to wildlife from PCBs in the study area. To assess the risk implications we evaluated existing literature on

- PCBs,
- Wildlife responses to PCB exposures in general,
- Wildlife responses to particular levels of PCBs and how those levels compare to levels observed in this study.

The majority of the literature cited below is from Eisler (1986).

As previously stated, of the suite of seven PCB mixtures analyzed for in this study, only Aroclor-1260 was detected in the seven species of small mammals that were captured. Aroclor-1254 has been detected most frequently in other field studies that are ongoing at other locations of LANL. These studies include organics in fish in the Rio Grande (Gonzales et al. 1999) and organics in soils, earthworms, arthropods, and birds in the Pueblo and Los Alamos Canyon areas (personal communication, Gonzales, 1999). Widespread use of Aroclor-1254 and more limited use of Aroclor-1260 have been documented for other regions of the U.S. (Rohrer et al. 1982).

Eisler reported on an extensive historical review of literature on PCB hazards to wildlife in 1986 (Eisler, 1986). To cover the period of 1987 to the present a literature search was conducted and the abstracts of relevant articles of literature were reviewed. Much of the recent literature on PCBs addresses Aroclor-1254, not Aroclor-1260, and PCB congeners, therefore the pre-1987 literature was more relevant to Aroclor-1260.

5.2 PCB Chemistry and Toxicity

"PCBs are extremely stable compounds, and slow to chemically degrade under environmental conditions. Higher chlorobiphenyls, i.e., those with five or more chlorine atoms, are more persistent in the environment than those with three or less chlorine atoms; tetrachloro biphenyls are intermediate in persistence (EPA 1980)." Aroclor-1260 has 6.3 chlorine atoms on average, which is considered highly chlorinated. Microbial degradation of PCBs depends on the degree of chlorination and the position of the chlorine atom on the biphenyl molecule; lower chlorinated biphenyls are readily transformed by bacteria, but not the higher chlorinated compounds (NAS 1979). The solubility of Aroclor-1260 in water is also low – 3 μg/L – which may also influence biological and environmental properties of Aroclor-1260.

"PCBs elicit a variety of biologic and toxic effects including death, birth defects, reproductive failure, liver damage, tumors, and a wasting syndrome. They are known to bioaccumulate and to biomagnify within the food chain. As a result of legislation, virtually all uses of PCBs and their manufacture have been prohibited in the United States since 1979. In general, the ban has been accompanied by declines in PCB residues in fishery and wildlife resources. However, the current environmental burden of PCBs in water, sediments, disposal sites, deployed transformers, and

other PCB containers is now estimated at more than 82 million kg, much of it localized, and this continues to represent a potential hazard to associated fish and wildlife. The toxicological properties of individual PCBs are influenced primarily by two factors: the partition coefficient based on solubility in N-octanol/water (Kow); and steric factors, resulting from different patterns of chlorine substitution. In general, PCB isomers with high Kow values, and high numbers of substituted chlorines in adjacent positions, constitute the greatest environmental concern. Unfortunately, basic chemical information is lacking on many isomers. Also, biological responses to individual isomers or mixtures vary widely, even among closely related taxonomic species. The issue is further confounded by the presence of toxic impurities, such as polychlorinated dibenzofurans, which may have been formed during the PCB manufacturing process, or result from product usage. At this time, total PCB residues give a more reliable measure of environmental PCB contamination than do measurements of any Aroclor or other commercial mixtures. In view of the demonstrated differential toxicities within the array of PCB congeners, it may finally become necessary to modify existing standards and criteria based on the more toxic PCBs."

"The 209 PCB congeners and their metabolites show wide differences in biological effects. A significant part of the toxicity associated with commercial PCB mixtures is related to the presence of about 20 planar congeners, i.e., congeners without chlorine substitution in the ortho position. Adverse effects of planar PCBs on growth, survival, and reproduction are highly variable because of numerous biotic and abiotic modifiers, including interaction with other chemicals" (Eisler and Belisle 1996).

5.3 Biological Availability, Uptake, and Absorption

"Biological availability and uptake of individual PCBs from aqueous solution are influenced primarily by two factors: the partition coefficient (Kow) based on the solubilities of compounds in N-octanol/water; and steric factors resulting from different patterns of chlorine substitution. Log Kow values for various isomers of Aroclor-1242, -1254, and -1260 are high, varying from 4.0 to 9.35, indicating high biological uptake potential. Steric effect coefficients are based on the number of chlorine atoms in the biphenyl molecule and their arrangement (Shaw and Connell 1982). For example, three chlorines in the ortho positions were assigned a steric effect coefficient of 0.3; four chlorines in the ortho postions, 0.2; three or four adjacent chlorines on one ring 0.6, and on both rings 0.3; chlorines in the meta position on one ring 0.8, and on both rings 0.6. The product of log Kow and the steric effect coefficient seem to be directly related to bioaccumulation (Shaw and Connell 1982). Thus, maximum uptake is expected for penta- and hexachlorobiphenyls predominant in Aroclor-1254, which have high values for log Kow and for steric effect coefficients. Comparatively less uptake tends to occur for di-, tri-, and tetrachlorobiphenyls, typical of Aroclor-1242, which have lower values for log Kow, and with hepta- and octachlorobiphenyls, predominant in Aroclor-1260, which have lower steric effect coefficients." This has been substantiated in studies on plants. For example, Sawhney and Hankin (1984) demonstrated that uptake of Aroclors by beets (*Beta vulgaris*), turnips (*Brassica rapa*), and beans (*Phaseolus vulgaris*) was in the order 1248>1254>1260, indicating that lower chlorinated isomers (which are more soluble in water and more volatile) were more abundant in crop plants than higher chlorinated isomers such as Aroclor-1260.

"In mammals, PCBs are readily absorbed through the gut, respiratory system, and skin. Initally, PCBs concentrate in liver, blood, and muscle; eventually, accumulations are highest in adipose tissue and skin. Phenolic derivatives or dihydrodiols are the major metabolites, but susceptibility of individual PCB isomers to metabolism is a function of the number of chlorine atoms present on the biphenyl rings and their arrangement. In general, most readily metabolized PCBs are also rapidly excreted in urine and bile. The highly chlorinated isomers are difficult to metabolize and accumulate almost indefinitely." As indicated earlier, Aroclor-1260 is highly chlorinated.

5.4 Mutagenic, Carcinogenic, and Teratogenic Properties

"Mutagenic, carcinogenic, and teratogenic properties of PCBs are documented. Certain PCB congeners, such as 4-chlorobiphenyl, were highly mutagenic to *Salmonella typhimurium* in Ames tests (EPA 1980), however the levels necessary to elicit such effects were not identified in Eisler (1986). Aroclor-1221 was less mutagenic, while Aroclor-1254 and -1268 were essentially inactive. Albeit in rainbow trout, it was unexpectedly discovered that Aroclor-1254 can prevent carcinogenesis and mutagenesis (NAS 1979). In general, mutagenic activity tends to decrease with increasing chlorination (EPA 1980). The carcinogenic effects of PCBs have been established in mice and rats with various Aroclor and Kanechlor PCBs and these, in turn, may enhance the carcinogenicity of other chemicals (EPA 1980). Experimental data clearly shows that commercial PCBs cause liver damage which leads to putative preneoplastic changes and hepatocellular carcinomas; however, these lesions are observed only after lengthy (11 to 21 months) exposures to high doses (100 to 1200 ppm in diets) of these chemicals (NAS 1979; Safe 1984). Teratogenic effects of PCBs observed in monkeys and rabbits include abnormal skull

formation of fetuses exposed to high levels of Aroclor 1254 in utero, and retarded growth (EPA 1980)."

5.5 Impacts to Mammals

"The mink is one of the most sensitive wildlife species tested for which data are available. Diets containing 6.7 to 8.6 mg Aroclor-1254 and -1242/kg fresh weight killed 50% of the mink in 9 months; single dosages administered orally produced LD-50 values of 750 to 4000 mg/kg body weight, those administered intraperitoneally produced LD-50s between 500 and 2250 mg/kg body weight. Certain hexachlorobiphenyls (HCBP), such as 3,4,5,3',4',5' HCBP, are extremely toxic to mink; concentrations as low as 0.1 mg/kg fresh weight diet produced an LD-50 in 3 months, and completely inhibited reproduction in survivors (Aulerich et al. 1985). However, other HCBPS, such as 2,4,5,2',4',5' HCBP and 2,3,6,2',3',6' HCBP, were not fatal to mink under similar conditions, and did not produce adverse reproductive effects" (Aulerich et al. 1985). This contradiction demonstrates what has been broadly established whereby the toxicity of PCB congeners varies substantially from one congener to another. This is why it often is important to identify and assess potential effects of PCB congeners rather than PCB mixtures such as Aroclors.

Harris et al. (1993) found that when several Aroclors (1232, 1242, 1248, 1254, and 1260) were compared in immature, male Wistar rats, only Aroclor-1232 and -1248 were found to significantly inhibit body weight gain. None of these Aroclors were observed to cause any thymic atrophy in the rats, however.

In little brown bats (*Myotis lucifugus*), Clark and Krynitsky (1978) found that pups found dead at birth had significantly more Aroclor than live littermates; moreover, females with elevated Aroclor-1260 residues tended to produce litters with a greater frequency of stillbirths. The range of PCB concentrations cited by Eisler (1986) is 3.6 to 24 mg/kg-fresh weight (FW) in the adults and nondetect levels to 25 mg/kg-FW in the young, however it is unclear as to whether this range applies to the affected individuals or to all bats including those that were unaffected.

5.6 Impacts to Birds

"Birds seem relatively resistant to PCBs. Among sensitive species, female screech owls (*Otus asio*) fed 3.0 mg of PCBs/kg fresh weight diet laid eggs containing up to 17.8 mg/kg fresh weight; however, no other adverse effects were observed in either parents or progeny (McLane and Hughes 1980)." This study is the basis of the dietary criteria (<3.0 mg of PCBs/kg-FW in diet) proposed by Eisler (1986) for the protection of birds. "Higher dietary exposures of 5 mg/kg in chickens, and 10 mg/kg in mourning doves resulted in reproductive impairment (Tori and Peterle 1983; as quoted in Heinz et al. 1984). Fertilized eggs of ringed turtle-doves containing 16.0 mg PCBs/kg fresh weight showed delays in growth and development (Peakall et al. 1972), and residues of this magnitude should be considered as presumptive evidence of significant PCB contamination. Residues in brain appear to be good indicators of PCB exposure in birds. Concentrations in excess of 301 mg PCBs/kg brain fresh weight is strong evidence of PCB poisoning, while concentrations in excess of 54 mg/kg fresh weight were common in brain of various avian species that survived high PCB dosages (Stickel et al. 1984)."

5.7 Comparison of Study Results and Literature

PCB concentrations in field collections of selected species of mammals and birds measured elsewhere are shown in Table 4. The 1970s and 1980s are believed to represent the period of highest concentrations of PCBs in the environment.

Table 4. PCB concentrations in field collections of selected species throughout the U.S.

Species	Tissue Type	Concentration (ppm-frshwt)	Reference
Hare, *Lepas europans*	Fat	2.0	Brunn et al. 1985
Mink, *Mustela vison*	Liver	0.5–3.5	O'shea et al. 1981
"	Fat	6.0–60	Friedman et al. 1977
Long-eared owl, *Asio otus*	Liver	6.9–191	Koeman 1973
Great horned owl, *Bubo virginianus*	Brain	360	Stone and Okoniewski 1983
Kestrel, *Falco tinnunculus*	Liver	21–44	Swineford 1983 in Eisler 1986

Table 5 shows the range of detected Aroclor-1260 concentrations, by species, measured in this study at LANL. Studies in other parts of the U.S. show that Aroclor uptake can differ between species of small mammals. Johnson et al. (1996) found that the common shrew (*Sorex araneus*) retained a higher body concentration of congeners than wood mice (*Apodemus sylvaticus*) when exposed to Aroclors-1242, -1254, and -1260. However, the wood mice retained a higher body concentration than field voles (*Microtus agrestis*) when exposed to the same Aroclors. The different congeners were retained in varying proportions depending on diet of each species. Shrews retained the heavily chlorinated congeners, while the other two species retained more of the low-chlorinated congeners.

Table 5. Range of detected Aroclor-1260 concentrations by species in this study.

Species	Tissue Type	Concentration (ppm-frshwt)
Longtail vole, *Microtus longicaudus*	Adipose+organs	0.049–2.5
Mountain vole, *Microtus montanus*	Adipose+organs	0.23–2.0
Vole, *Microtus* spp.	Adipose+organs	0.22–0.53
Deer mouse, *Peromyscus maniculatus*	Adipose+organs	0
Harvest mouse, *Reithrodontomys megalotis*	Adipose+organs	0.35–0.92
Vagrant shrew, *Sorex vagrans*	Adipose+organs	10.0–19.0

For computing the arithmetic mean Aroclor-1260 concentration for all species combined, one-half the reporting limit was substituted for samples that had the analytical result of "not detected," "less than the reporting limit," or "estimated value." The arithmetic mean concentration for all species combined was 0.25 mg/kg (ppm) for treatment site number one (Web 1) and 5.9 mg/kg (ppm) for treatment site number two (Web 2). All analytical results for the control site were less than the reporting limit.

5.8 Risk Implications

Eisler (1986) proposed a criterion for the protection of birds from PCBs of <3.0 mg PCB/kg-FW in the diet. Assuming that carnivorous birds consume small mammals from the study site, adipose-plus-organ tissue of only the shrews contained Aroclor-1260 concentrations (10 – 19 mg/kg-FW) that exceed the conservative proposed criteria of <3.0 mg PCB/kg-FW. Maximum Aroclor-1260 concentrations measured in longtail voles and mountain voles also approach this limit. To make a less conservative comparison, the measured Aroclor-1260 concentrations in adipose tissue and organs can be grossly converted to muscle concentrations as follows. There appears to be a large disparity in PCB concentrations between high-fat tissue (e.g.m liver) and low-fat tissue (e.g., muscle) when concentrations are relatively high. O'shea et al. (1981)

measured 0.5–3.5 mg/kg-FW of PCBs in mink liver compared to 0.6-1.6 mg/kg-FW in muscle. Thus the concentration in muscle was between 83% and 46% of the concentration in liver. For low chlorinated PCBs, Brunn et al. (1985) measured 8.5 mg/kg-FW PCBs in the fat of hares compared to 0.02 mg/kg-FW in "nonfat." For highchlorinated PCBs, Brunn et al. measured 2.0 mg/kg-FW PCBs in the fat of hares compared to 0.003 mg/kg-FW in "nonfat." These ratios interpret to nonfat containing 0.23% and 0.15% of the PCB concentration in fat for low and high chlorinated PCBs, respectively.

Making gross assumptions and applying these ratios to our data, only the sampled shrews, again assuming they serve as the diet of raptors, may contain Aroclor-1260 concentrations higher than the proposed criterion of 3.0 mg/kg-FW in the diet of birds. Using the liver to nonliver ratio of PCBs for maximum PCB concentrations in mink, maximum muscle concentrations of Aroclor-1260 in shrews at Sandia Canyon would be 8.7 mg/kg-FW, higher than the <3.0 mg/kg-FW proposed to be protective of birds. Using the fat to nonfat ratio for highly chlorinated PCBs in hare, maximum muscle concentrations of Aroclor-1260 in shrews at Sandia Canyon would be 2.9 mg/kg-FW which approaches the <3.0 mg/kg-FW criteria. These comparisons are considered conservative because (1) the <3.0 mg/kg-FW criterion is based on a toxicological study where the only effect was eggs laid by the exposed contained up to 17.8 mg/kg-FW, but no adverse effects were observed in either parents or progeny (McLane and Hughes 1980); (2) the <3.0 criterion is based on Aroclor-1254 which appears to be more toxic than Aroclor-1260 (Eisler 1986). Higher dietary exposures, 5 – 16 mg/kg PCB, may be necessary to elicit adverse effects.

Numerous uncertainties exist about the potential ecological risk from PCBs in Sandia Canyon. These include, but are not limited to

1. Whole body concentrations of PCBs in small mammals, including pelt, were not measured in this study, making accurate estimates of exposure to predators and the related food web uncertain.
2. The relationship between the PCB levels in sediment and organisms at the study site has not been considered.
3. Full knowledge of the nature and extent of PCB contamination with regard to actual home ranges of organisms utilizing Sandia Canyon is incomplete.
4. The influence of actions, ongoing or planned, from multiple LANL programs (e.g., environmental restoration, ecosystem restoration, facility operations) on PCB transport, distribution, and levels in Sandia Canyon and the associated ecosystem is unknown. A specific example is an estimated 30% reduction in water discharge as a result of operation of the Strategic Computing Center.
5. The applicability to this study of the particular protective criteria used is an uncertainty.
6. Determining potential impact only on the basis of Aroclors is sometimes not sufficient because the biological behavior, or toxicology, of individual PCB congeners can vary substantially, risk assessment guidelines recommend the measurement of congener-specific PCBs, and Aroclor analyses are estimations that are prone to error. For protection of natural resources, most authorities now recommend (1) analysis of environmental samples for planar congeners (congeners without chlorine substitution in the ortho position); (2) exposure studies with representative species and specific congeners, alone and in combination with other environmental contaminants; (3) clarification of existing

structure-induction-metabolism relations; and (4) more research on physiological and biochemical indicators of PCB-stress (Eisler and Belisle 1996).

5.9 Recommended Action

A few of the measured and estimated Aroclor-1260 concentrations in small mammals at the study site approached the proposed protective criteria, however a great deal of uncertainty exists about the Aroclor-1260 concentrations, the applicability of the particular protective criteria to the particular study problem in Sandia Canyon, and the risk implications. Because of the findings and the uncertainties, the recommended action is to conduct a "tier 2" risk assessment (exposure assessment and effects assessment) with particular emphasis on reducing the uncertainties associated with (1) extrapolation from fat and liver to muscle/nonfat and (2) relevance and applicability of protective criteria to the specific conditions surrounding Sandia Canyon. If warranted by the tier 2 assessment, additional work may be necessary, including characterization of PCB congeners in order to address uncertainty number six above.

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