CHAPTER 5
SEDIMENT RESOURCES

5.1 INTRODUCTION

This chapter presents data on the sediment resources of the Coeur d'Alene River basin. Sediments are materials deposited by water and include suspended sediments in the water column, and bed, bank, and floodplain sediments. Sediment resources are defined by DOI NRDA regulations both as geologic resources [43 CFR §11.14 (s)] and as a component of surface water resources [43 CFR § 11.14 (pp)].[1] However, because sediments represent a distinct component of the ecosystem, data on sediments are discussed separately from surface water.

The information presented in this chapter supports the following conclusions:

- Metals in streambeds, banks, and floodplains are remobilized through natural hydrologic processes such as scouring, erosion, and resuspension during high water events.

- Sediments of the Coeur d'Alene River basin downstream of mining and mineral processing facilities contain substantially elevated concentrations of hazardous substances, including cadmium, lead, and zinc. Sediment contamination is pervasive in the beds, banks, and floodplains of the basin.

- Concentrations of hazardous substances in Coeur d'Alene River basin sediments exceed thresholds associated with adverse effects for benthic invertebrates. As concentrations of hazardous substances in these sediments increase, concentrations of hazardous substances in biofilm (attached algae, bacteria, and associated fine detrital material that adheres to substrates in surface waters and is a food source for higher trophic level consumers), benthic invertebrates, and fish in the basin increase. Sites with the highest concentrations of metals in water, sediment, biofilm, and benthic invertebrates were also the sites where fish populations were reduced, mortality was observed, and tissues contained elevated concentrations of metals.

- Coeur d'Alene River basin sediments containing elevated concentrations of lead and other hazardous substances are ingested by migratory waterfowl. Ingestion of contaminated sediments causes death, physiological malfunction, and physiological deformation of wildlife resources. Sufficient concentrations of hazardous substances are

1. "Surface water resources means the waters of the United States, including the sediments suspended in water or lying on the bank, bed, or shoreline . . ." [43 CFR § 11.14 (pp)].

present in sediments to cause injury to biological resources, and therefore sediments are injured [43 CFR §11.62 (b)(1)(v)].

5.2 SEDIMENT RESOURCES ASSESSED

5.2.1 Definition of Sediment Resources

Sediments are derived naturally from chemical and physical weathering of rock and from soil erosion. Mineral sediments range in size from colloidal clays to large boulders. Sediments also include organic material such as leaves and detritus from the riparian zone (known as allochthonous material) carried by surface water. Because organic matter is decomposed by aquatic organisms to smaller and smaller fractions, organic sediment spans a wide range of size classes also.

Sediments provide substrate for vegetative growth, mineral nutrients and organic material necessary for primary productivity and nutrient cycling, and physical habitat for aquatic and semi-aquatic biota, including cover, feeding, and nesting habitat. Mineral sediments are a source of essential elements for biota, and organic material in sediments provides the major energy source for benthic invertebrates, which are prey items of fish and other aquatic and terrestrial organisms. The periodic inundation of floodplains results in a significant input of nutrients in deposited sediments, which stimulates primary production in riparian and wetland communities.

5.2.2 Sediment Resources of the Coeur d'Alene River Basin

Sediment resources of the Coeur d'Alene River basin include suspended, bed, bank, and floodplain sediments of the South Fork Coeur d'Alene River and its tributaries, the mainstem Coeur d'Alene River and lateral lakes, and Coeur d'Alene Lake. The focus of this chapter is on the current condition of sediments of the lower basin, although the current condition of sediments in the lower basin has been substantially influenced by releases of hazardous substances in the upper basin (Chapter 2). Information on injuries to riparian soils/floodplain sediments in the upper basin is presented in Chapter 9, Riparian Resources.

In the lower basin, downstream of Enaville and the confluence of the South and North Fork Coeur d'Alene rivers, the mainstem Coeur d'Alene River is a meandering, low gradient, deep river. The valley opens into a broad alluvial basin, and the floodplain is wider than one mile in places. The river is bordered by lake, riparian and palustrine and lacustrine wetland habitat (Campbell et al., 1999; Figure 5-1). The lakes are connected hydraulically to the river by natural and artificial channels. The Coeur d'Alene River discharges to Coeur d'Alene Lake, which is a natural submerged riverbed lake (Horowitz et al., 1992). The level of the lake is now controlled by the Post Falls Dam, and water level varies between 2,122 and 2,128 ft.

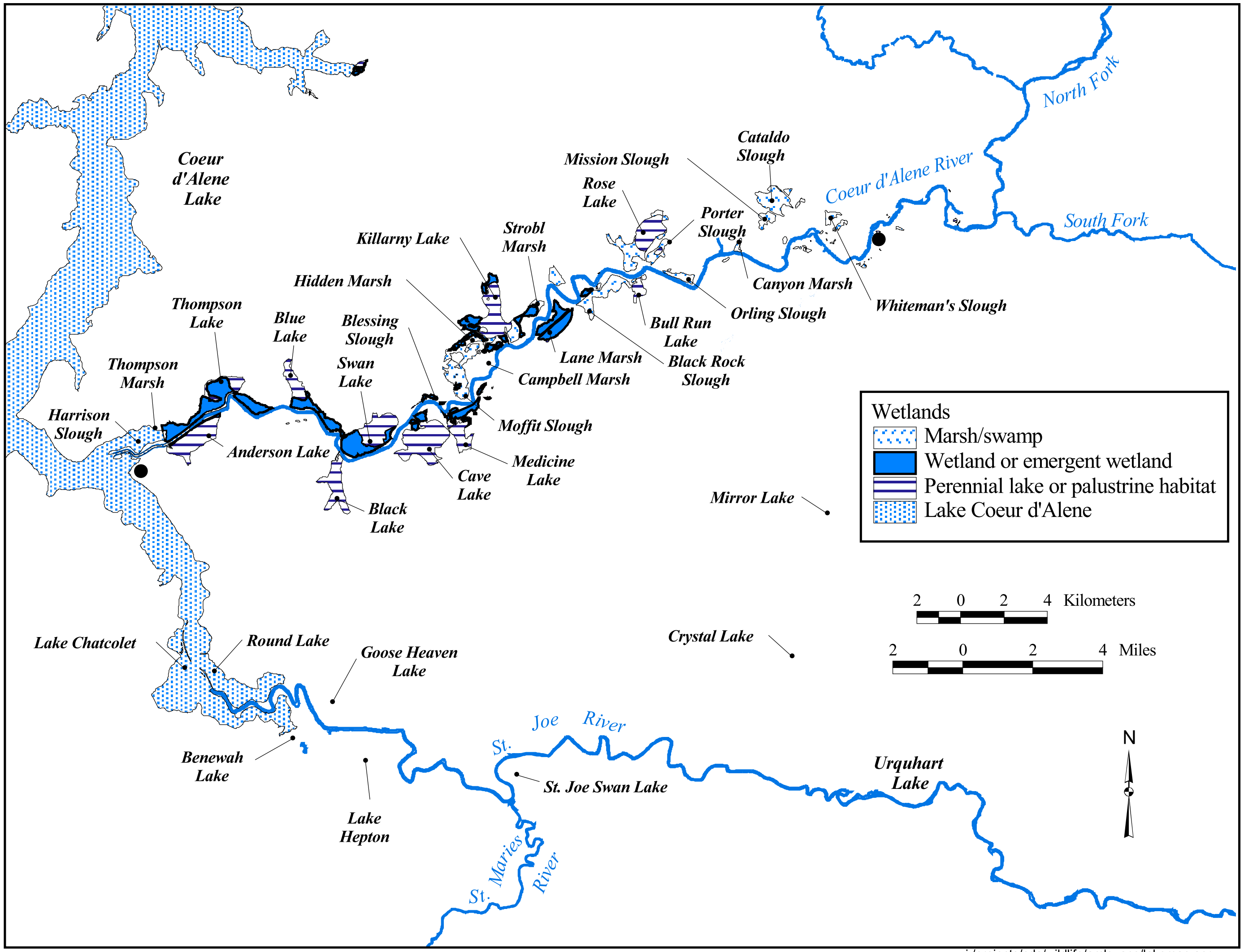

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Figure 5-1. Geographic areas used to describe sources of hazardous substances in the mainstem Coeur d'Alene River and the lateral lakes area.

Bookstrom et al. (1999) mapped and described surficial hydrologic and sedimentary features of the lower Coeur d'Alene River valley. An abbreviated summary of their description, with particular reference to descriptions of the distribution of metal-enriched sediments, follows.

From the confluence of the North and South Forks of the Coeur d'Alene River to Cataldo, the channel is composite and braided. Upstream of Cataldo Flats, the channel is bordered by erosional remnants of up to four alluvial terraces, all of which are in the floodplain. High-water overflow channels and channel scars braid some of the alluvial terraces. These lead to lateral marshes and oxbow ponds, which slowly drain back to the river. The lower terraces are flooded more frequently than the upper ones and have received more metal-rich sediment; metal-enriched sediments are thickest in overflow channels and partly filled channel scars. Accumulations of metal-enriched sediments along channel scars active during the mining era are locally more than 2 m thick.

Downstream of Cataldo Flats, the river current decreases, the river bottom is sandy to muddy, and the channel contains thick deposits of metal-enriched sand. At Cataldo Landing, where the river current diminishes, a large metal-enriched sand bar nearly fills the channel. The river channel is bounded by steep banks where the river has cut into bank-wedge deposits of metal-enriched sand and silt previously deposited on the natural, premining levees. Bank wedge deposits are believed to have formed mostly before 1968. Since then, they have eroded laterally while continuing to thicken vertically. Since 1980, an estimated average of 8 cm of metal-enriched sediment has been deposited. Bank thickness of metal-enriched sediments typically ranges from 2 to 0.4 m; on levee tops, thicknesses range from about 1.4 to 0.3 m. Over-bank deposits of metal-enriched sediment extend over the tops of natural levees toward lateral flood basins. On the levees that are only flooded occasionally, metal-enriched sediments oxidize and become iron-stained. In saturated environments, the metal-enriched sediments are often in transitional to reducing conditions and are generally dark gray to black. Distributary streams and human-made canals allow transport of contaminated sediments across the floodplain.

Along straighter reaches, the river channel is partly filled with metal-enriched sediments that form a relatively flat, sandy bottom. The average thickness of metal-enriched sediments in the river channel decreases with distance downstream, from 3.5 m between Cataldo Landing and Rose Lake to 2.7 m from Rose Lake to Medicine Lake, to 2.2 m from Medicine Lake to Harrison. Point-bar deposits of metal-enriched sand are present on the inside margins of meander bends, and lateral bar deposits extend downstream from many point bars. Premining sediments are exposed only along nondepositional river bends. The palustrine wetlands of the lower basin are shallow (less than 2 m at low water) and support emergent wetland vegetation (Cowardin et al., 1979). Some are seasonally flooded, some infrequently flooded, and others perennially or persistently flooded. Where palustrine wetlands are farmed, they are artificially drained and seasonally flooded.

The palustrine wetlands of the lateral lakes include meadows, marshes, and sloughs. The metal-enriched sediments of the lateral lakes marshes are silty, muddy, and organic rich. Metal-enriched sediments in seasonally palustrine wetlands cycle between reducing and oxidizing conditions, which increases the geochemical mobility of metals in the sediments.

Lacustrine habitats of the lower basin are inland bodies of standing water that are larger than 20 acres and have maximum depths of more than 2 m at low water (Cowardin et al., 1979). Lacustrine habitats include littoral zones, where the water is less than 2 m deep at low water, and deep lake environments. The lateral lakes receive suspended metal-enriched sediments from river floodwaters that wash over levees, or via distributaries and canals. Many lateral lakes also receive nonmining sediments from tributaries to the lower river. In deep lake environments, contaminated sediments are in transitional to reducing conditions. In littoral zones, sediments may cycle between reducing and oxidizing conditions as water levels fluctuate seasonally.

Small deltaic deposits of metal-enriched sediments have formed at the mouths of distributary streams in lateral lakes. Larger deposits are present at the mouth of the Coeur d’Alene River where it enters Coeur d’Alene Lake. The deltaic deposits at the mouth of the river are moved by the river current into the lake, where they settle on the lake bed. Horowitz et al. (1995) found that eighty-five percent of Coeur d’Alene Lake contained metals-enriched lakebed sediments. They estimated that 75 million metric tons of trace-element enriched sediment have been deposited in Coeur d’Alene Lake in the last 100 to 110 years.

Anthropogenically influenced sedimentary features include metal-enriched dredge spoils at the Cataldo Mission Flats, road and railroad beds, road, railroad, and other types of cuts and embankments, ditches, canals, filled areas, dikes, levees, piers, riprap, bank liner pilings, and canals, and artificial nesting mounds created from dredged metal-contaminated sediments. The discontinued Union Pacific Railroad follows the river through the lower basin, modifying the natural flow of water to and from the river in places. Water control structures, including artificial levees, dikes, canals, ditches, ponds, and drainage pumps, influence the hydrology of the basin.

5.3 DATA SOURCES

Data from samples collected previously in the basin, from samples collected as part of the injury assessment for the NRDA, and from samples collected recently by the USGS and by the U.S. EPA for the Coeur d’Alene Basinwide RI/FS were used in the evaluation of sediment conditions. Samples collected previously in the basin include tailings core samples collected from the Cataldo Mission Flats (Galbraith, 1971; Galbraith et al., 1972; Ridolfi, 1991); sediments collected in lateral lake bed sediments and wetlands (Bauer, 1974; Funk et al., 1975; Rabe and Bauer, 1977; Neufeld, 1987; Hornig et al., 1988; Krieger, 1990; Bender, 1991); sediments collected from Coeur d’Alene Lake bed and banks (Winner, 1972; Keely, 1979; Hornig et al., 1988; Horowitz et al., 1992, 1993, 1995); and sediments collected from the river, banks, and delta (Maxfield et al., 1974; Reece et al., 1978; Roy F. Weston, 1989; USGS, 1991).

Data from the Bunker Hill Basinwide RI/FS that were used in the evaluation include data from sediment cores from the river channel, wetlands, and lake beds (URSG and CH2M Hill, 1998). Data from the USGS that were used in the evaluation include sediment core data from the bed of Coeur d'Alene Lake (Horowitz et al., 1992, 1993) and sediment transport data collected during the February 1996 flood in the Coeur d'Alene River basin (Beckwith, 1996).

Samples collected by the Trustees for the NRDA include soil and sediment samples from the floodplain (Hagler Bailly Consulting, 1995; Horowitz, 1995; see Chapter 9 of this document); sediment samples from floodplain palustrine and lacustrine wildlife habitats (Campbell et al., 1999; see Chapter 6 of this document); sediment samples from the littoral zone of the northwest shore of Coeur d'Alene Lake (Cernera et al., 1998); and sediment samples from river and creek beds (Woodward, 1997; Farag et al., 1998).

Table 5-1 (reprinted from Chapter 2, Table 2-11) summarizes concentrations of hazardous substances in sediments collected by the investigators identified above. The data presented in Table 5-1 illustrate that floodplain sediments throughout the lower Coeur d'Alene River basin contain substantially elevated concentrations of the hazardous substances cadmium, lead, and zinc.

The recent sediment sampling studies, including studies conducted as part of the NRDA, are described in more detail in the following paragraphs.

NRDA Studies

In 1993, the USGS collected sediment samples from approximately 150 sites between Smelterville and the mouth of the mainstem Coeur d'Alene River at Harrison (Horowitz, 1995). Samples were collected on a 1 km grid, with random location within each 1 km grid cell (Horowitz, 1993[2]). Samples were collected from the 0 to 2 in. and 2 to 6 in. depths. Samples were sieved to retain the <180 µm fraction, and analyzed using a complete-acid digest. Concentrations of cadmium ranged from 0.5 to 202 mg/kg; concentrations of lead ranged from 32 to 11,000 mg/kg, and concentrations of zinc ranged from 80 to 7,300 mg/kg. Mean concentrations and ranges by area are summarized in Table 5-1. Sample site locations are shown in Figure 5-2.

As part of the riparian resources injury assessment (Hagler Bailly Consulting, 1995; LeJeune and Cacela, 1999; see Chapter 9), soil samples were collected near a subset of Horowitz (1995) sampling locations. The Horowitz data were stratified by measured lead concentration level as 0-100 mg/kg lead, 100-500 mg/kg lead, 500-1,000 mg/kg lead, and >1,000 mg/kg lead.

2. Unpublished summary of field sampling procedures used by USGS in Coeur d'Alene, Idaho, Summer 1993. Provided by A.J. Horowitz, USGS, Doraville, GA.

Table 5-1
Mean (minimum-maximum) Metal Concentrations in Tailings, Sediments, and Soils in Lower Coeur d'Alene River Basin

Site	Type	Sample Size	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
Anderson Lake	Sediment	24[a]	11.6 (0.3-53.9)	1,105 (20-3,860)	1,244 (73-6,520)
		3[b]	48 (42-56)	2,650 (1,750-3,350)	2,983 (2,150-3,550)
		1[c]	9.7	2,492	2,180
Bare Marsh	Sediment	25[a]	10.0 (0.8-46.0)	1,433 (71-7,020)	1,166 (64-6,180)
	Soil	1[d]	13.0	2,100	—
Black Lake	Soil	39[e]	11.5 (0.5-48.0)	2,280 (32-11,000)	1,463 (80-7,300)
	Sediment	24[a]	10.2 (1.5-33.0)	1,075 (174-4,720)	935 (185-2,760)
		4[b]	21.8 (11-29)	1,935 (490-4,700)	2,250 (1,750-2,600)
Black Rock Slough	Sediment	24[a]	17.9 (0.3-39.3)	3,447 (63-7,630)	2,272 (49-6,620)
Blessing Slough	Sediment	24[a]	19.7 (0.1-46.9)	3,801 (36-9,190)	1,584 (49-3,530)
		3[f]	—	3,499 (3,223-3,996)	—
	Soil	2[d]	7.8 (4.5-11.0)	720 (560-880)	—
Blue Lake	Sediment	24[a]	24.0 (1.5-56.5)	3,445 (31-7,860)	2,435 (97-4,460)
		4[b]	45.5 (25-83)	2,988 (950-4,200)	3,788 (2,000-6,800)
		3[f]	—	2,576 (2,447-2,688)	—
Bull Run Lake	Sediment	24[a]	21.3 (9.0-46.1)	5,060 (1,070-15,400)	2,834 (1,260-5,720)
Campbell Marsh	Sediment	25[a]	21.9 (2.7-37.4)	4,674 (312-8,890)	2,381 (239-4,330)
	Soil	13[d]	16.2 (3.2-29.0)	2,582 (26-7,500)	—
Cataldo	Soil	32[e]	8.6 (0.5-21.0)	1,817 (54-4,900)	1,189 (80-6,200)
		9[g]	22.2 (4.8-33.1)	3,742 (182-5,720)	2,361 (370-4,270)
		26[h]	18.0 (0.1-158)	3,204 (15-9,600)	2,037 (22-6,830)
	Sediment	4[i]	14.5 (2.4)	2,390 (138)	2,543 (108)
		12[j]	16.7 (7.4-22.6)	3,352 (2,610-4,180)	3,069 (1,960-3,860)
		1[c]	4.8	2,310	1,350
		4[k]	10.5 (8.4-12.9)	2,800 (2,000-3,800)	10,075 (6,500-19,000)
		33[h]	16.9 (0.02-75.3)	1,942 (12-4,640)	1,755 (44-3,780)
Cataldo Boat Ramp	Soil	1[l]	18.5	6,030	5,510
	Sediment	1[l]	3.5	1,380	13,700
Cataldo Mission	Soil	1[l]	6.9	1,110	1,580
	Tailings (0-1 feet)	6[m]	—	4,217 (2,800-5,500)	3,183 (2,400-4,000)
Cataldo Mission	Tailings (2-3.5 feet)	42[m]	—	5,069 (300-13,100)	4,229 (400-16,000)
	Tailings (4-6.5 feet)	17[m]	—	626 (50-4,300)	741 (200-3,100)
	Tailings (7-11.5 feet)	10[m]	—	128 (50-500)	380 (300-600)
Cataldo Slough	Sediment	18[a]	25.5 (0.7-67.8)	2,365 (83-5,650)	2,797 (132-11,700)

Table 5-1 (cont.)
Mean (minimum-maximum) Metal Concentrations
in Tailings, Sediments, and Soils in Lower Coeur d'Alene River Basin

Site	Type	Sample Size	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
Cave Lake	Sediment	22[a]	10.2 (0.9-28.1)	1,391 (36-7,490)	1,043 (48-4,450)
		3[b]	36 (29-45)	2,950 (2,300-3,850)	2,950 (2,750-3,300)
		6[h]	16.2 (0.2-39.1)	3,088 (12-9,360)	1,974 (40-5,280)
CdA River	Soil	44[n]	11.3 (0.3-31.8)	2,223 (20-8,030)	1,234 (55-8,850)
		49°	3.7 (0.5-23.8)	241 (18-1,565)	202 (39-865)
	Sediment	10[p]	—	1,997 (587-4,460)	—
		3[f]	—	2,853 (2,447-3,489)	—
		9[d]	—	2,521 (1,775-3,475)	—
CdA River Delta	Sediment	107[q]	43 (16-75)	3,700 (3,000-6,300)	3,800 (3,200-4,700)
		9[j]	33.2 (5.8-50.7)	3,374 (2,460-4,320)	3,007 (2,250-3,480)
		2[c]	25.5 (8-43)	3,929 (3,700-4,158)	3,740 (3,680-3,800)
		7[r]	—	—	3,103 (635-6,760)
CdA River near Black Lake	Sediment	4[i]	27.0 (2.7)	3,850 (442)	4,475 (474)
		4[k]	53.8 (21-145)	6,123 (3,310-12,700)	4,470 (3,070-7,350)
		28[h]	21.3 (0.02-70.6)	5,842 (18-35,600)	3,564 (50-10,700)
	Soil	18[h]	4.6 (0.02-17.3)	1,188 (6-6,530)	628 (31-2,730)
CdA River near Blue Lake	Sediment	7[k]	40 (19-107)	4,420 (2,150-6,870)	4,568 (3,040-5,580)
CdA River near Killarney Lake	Sediment	4[i]	24.8 (4.2)	2,175 (293)	3,290 (333)
	Soil	25[h]	6.7 (0.1-24.0)	1,949 (7-9,910)	1,064 (17-4,590)
CdA River near Rose Lake	Sediment	4[i]	33.0 (2.7)	6,810 (1,469)	6,790 (858)
		1[c]	7.2	3,870	7,300
CdA River near Thompson Lake	Sediment	2[j]	17.4 (16.5-18.0)	3,677 (2,710-4,740)	3,245 (1,730-6,650)
		1[c]	8.3	3,992	4,220
		5[k]	90 (9-208)	14,492 (4,880-28,600)	7,024 (3,400-11,830)
		3[f]	32.2 (19.7-56.6)	3,177 (2,281-4,405)	—
Dudley	Soil	9[g]	32.2 (19.7-56.6)	4,462 (2,010-6,870)	3,038 (1,830-5,430)
		10[h]	4.0 (0.1-9.2)	767 (20-2,810)	491 (86-1,230)
Harrison	Soils	5[e]	5.5 (0.5-18.0)	1,423 (140-3,500)	734 (150-2,200)
		21[h]	16.0 (0.03-72.1)	2,846 (21-17,500)	2,204 (45-10,700)
	Sediment	4[i]	25.5 (1.9)	3,363 (267)	3,895 (276)
		5[k]	4.7 (<0.5-10)	2,016 (42-5,280)	965 (111-2,270)
		28[h]	18.7 (0.03-79.5)	4,544 (11-19,900)	2,938 (48-11,500)
Harrison Marsh	Sediment	13[a]	38.1 (19.7-63.3)	4,129 (1,540-7,000)	3,959 (2,870-5,170)
Harrison Slough	Sediment	24[a]	32.3 (11.6-96.4)	4,515 (3,030-8,660)	3,425 (1,700-7,040)
Hidden Marsh	Sediment	19[a]	20.5 (0.8-77.3)	2,763 (72-6,340)	1,493 (95-2,920)

Table 5-1 (cont.)
Mean (minimum-maximum) Metal Concentrations
in Tailings, Sediments, and Soils in Lower Coeur d'Alene River Basin

Site	Type	Sample Size	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
Killarney Lake	Sediment	23[a]	36.1 (11.1-76.2)	5,002 (1,890-9,680)	3,550 (1,020-5,860)
		3[b]	78.3 (50-130)	3,700 (2,550-4,600)	4,483 (4,000-5,200)
		90[s]	42.5 (<1-146)	4,893 (<2-37,400)	6,587 (100-34,150)
		3[f]	—	4,522 (3,207-5,502)	—
		10[h]	25.0 (0.02-55.8)	3,886 (48-12,800)	3,504 (134-8,710)
	Soil	7[g]	17.8 (0.2-36.3)	4,704 (434-11,600)	2,442 (589-3,980)
CdA Lake	Sediment (surface)	150[t]	62 (<0.5-157)	1,900 (14-7,700)	3,600 (63-9,100)
	Sediment (core)	12[t]	25 (<0.1-137)	3,200 (12-27,500)	2,400 (59-14,000)
CdA Lake Northwest Shore	Sediment (lower)	9[u]	0.7 (0.2-1.8)	34.9 (4-123)	363 (118-756)
	Sediment (upper)	9[u]	0.6 (0.2-1.5)	59.7 (10.2-326)	289 (55-542)
CdA Lake-North	Sediment	5[c]	7.4 (6.6-8.2)	3,315 (1,146-5,732)	4,466 (2,740-5,360)
		15[r]	—	—	3,723 (588-7,320)
CdA Lake-South	Sediment	1[c]	9.9	367	1,310
Lane	Soil	26[e]	16.0 (0.8-34.0)	2,886 (70-5,100)	2,030 (125-5,100)
Lane Marsh	Sediment	24[a]	16.5 (3.0-31.6)	3,442 (338-7,550)	1,821 (374-3,890)
		3[d]	8.5 (6.0-12.0)	2,067 (1,200-3,100)	—
Medicine Lake	Sediment	24[a]	23.8 (3.4-80.6)	3,187 (228-19,900)	2,349 (397-10,400)
		2[b]	37 (30-44)	2,825 (2,650-3,000)	2,750 (2,550-2,950)
		9[h]	27.9 (0.2-83.3)	5,755 (30-25,800)	3,835 (130-12,500)
Medimont	Sediment	28[h]	24.1 (0.1-114.0)	5,507 (17-32,900)	3,885 (45-15,400)
	Soil	30[e]	8.7 (0.5-31.0)	1,641 (29-4,900)	1,342 (75-5,100)
Medimont	Soil	1[l]	105	19,200	7,400
		24[h]	5.8 (0.05-23.8)	2,218 (18-14,500)	1,149 (30-4,510)
Mission Slough	Sediment	13[a]	22.7 (4.0-45.3)	2,928 (501-5,110)	2,258 (456-4,530)
Moffit Slough	Sediment	24[a]	14.9 (0.5-44.1)	2,851 (32-16,200)	1,665 (43-6,030)
	Soil	5[d]	17.0 (6.1-38.0)	3,022 (210-5,400)	—
Orling Slough	Sediment	24[a]	14.2 (4.8-23.1)	4,207 (426-9,680)	1,679 (723-2,410)
Porter Slough	Sediment	24[a]	14.0 (0.6-31.0)	2,621 (88-8,230)	1,526 (63-3,960)
Rose Lake	Soil	37[e]	13.7 (0.5-202.0)	1,624 (47-6,600)	1,294 (93-6,800)
		10[d]	—	2,890 (249-8,655)	—
	Sediment	20[a]	18.6 (1.2-38.6)	3,227 (32-8,870)	2,188 (56-6,090)
		3[b]	10.3 (2-15)	1,817 (100-3,200)	1,413 (240-2,100)
		9[h]	0.4 (0.02-2.4)	120 (17-350)	201 (69-385)
Strobl Marsh	Sediment	24[a]	26.1 (6.8-58.8)	5,826 (3,970-11,100)	3,012 (815-5,520)
		4[d]	11.3 (2.8-22.0)	1,860 (130-4,400)	—
Swan Lake	Sediment	18[a]	32.4 (2.7-72.0)	3,965 (213-8,350)	3,258 (241-5,780)
		4[b]	31.8 (19-57)	3,263 (1,800-3,900)	3,025 (1,900-4,650)
		3[f]	—	3,814 (3,305-4,145)	—

Table 5-1 (cont.)
Mean (minimum-maximum) Metal Concentrations
in Tailings, Sediments, and Soils in Lower Coeur d'Alene River Basin

Site	Type	Sample Size	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
Thompson Lake	Sediment	24[a]	27.2 (1.7-85.2)	3,723 (324-8,880)	3,009 (163-7,330)
		2[b]	27 (23-31)	3,150 (2,600-3,700)	2,950 (2,900-3,000)
		1[c]	8.9	3,386	2,560
	Soil	1[g]	8.5	2,730	1,075
		8[d]	—	3,133 (34-6,570)	—
		3[d]	12.3 (9.8-14.0)	1,863 (990-2,300)	—
Thompson Marsh	Sediment	24[a]	7.6 (0.3-19.9)	1,812 (99-12,200)	878 (83-2,450)

a. Sediments collected from lacustrine and palustrine areas (Campbell et al., 1999).
b. Sediments collected from 1 to 9 m in lake inlets and open water (Bauer, 1974; Funk et al., 1975; data also presented in Rabe and Bauer, 1977).
c. Hornig et al., 1988 (wet weight measurement).
d. Neufeld, 1987.
e. Soils collected from river bank and floodplain areas (Horowitz, 1995).
f. Krieger, 1990.
g. Soil samples collected from islands and river bank (Roy F. Weston, 1989).
h. Soils collected from floodplains and sediments collected from CdA River and lateral lakes (URSG and CH2M Hill, 1998).
i. Sediments collected from the CdA River. Values in parentheses are standard error of the mean; minimum and maximum values were not provided (Farag et al., 1998).
j. Sediments collected from the CdA river (Reece et al., 1978).
k. Sediment samples collected from river bank (USGS, 1991).
l. Sediments collected from stream channel; soils collected from floodplain banks (Ridolfi, 1991).
m. Tailings core samples collected from Cataldo Mission Flats area (Galbraith, 1971; Galbraith et al., 1972).
n. Soils collected from floodplain areas (Hagler Bailly Consulting, 1995).
o. Soils collected at 0-5 cm in Kootenai County (Keely, 1979).
p. Audet, 1997.
q. Sediments collected from the river delta area (Maxfield et al., 1974).
r. Sediments collected from CdA Lake between 2 and >20 m (Winner, 1972).
s. Sediments collected from three locations in Killarney Lake (Bender, 1991).
t. Horowitz et al., 1992, 1993, 1995.
u. Sediments collected from littoral/water interface and 1 m above the water level (Cernera et al., 1998).

Approximately 15 sites per stratum were randomly selected and sampled in an attempt to collect samples representing a wide range of metal concentrations. Complete sampling and analysis methods are described in Chapter 9. Cadmium concentrations averaged 11.3 mg/kg and ranged from below the detection limit to 31.8 mg/kg. Lead concentrations averaged 2,222 mg/kg and ranged from 19.8 to 8,030 mg/kg, and zinc concentrations averaged 1,234 mg/kg and ranged from 55 to 8,850 mg/kg. Concentrations are summarized by area in Table 5-1. Sample site locations are shown in Figure 5-2.

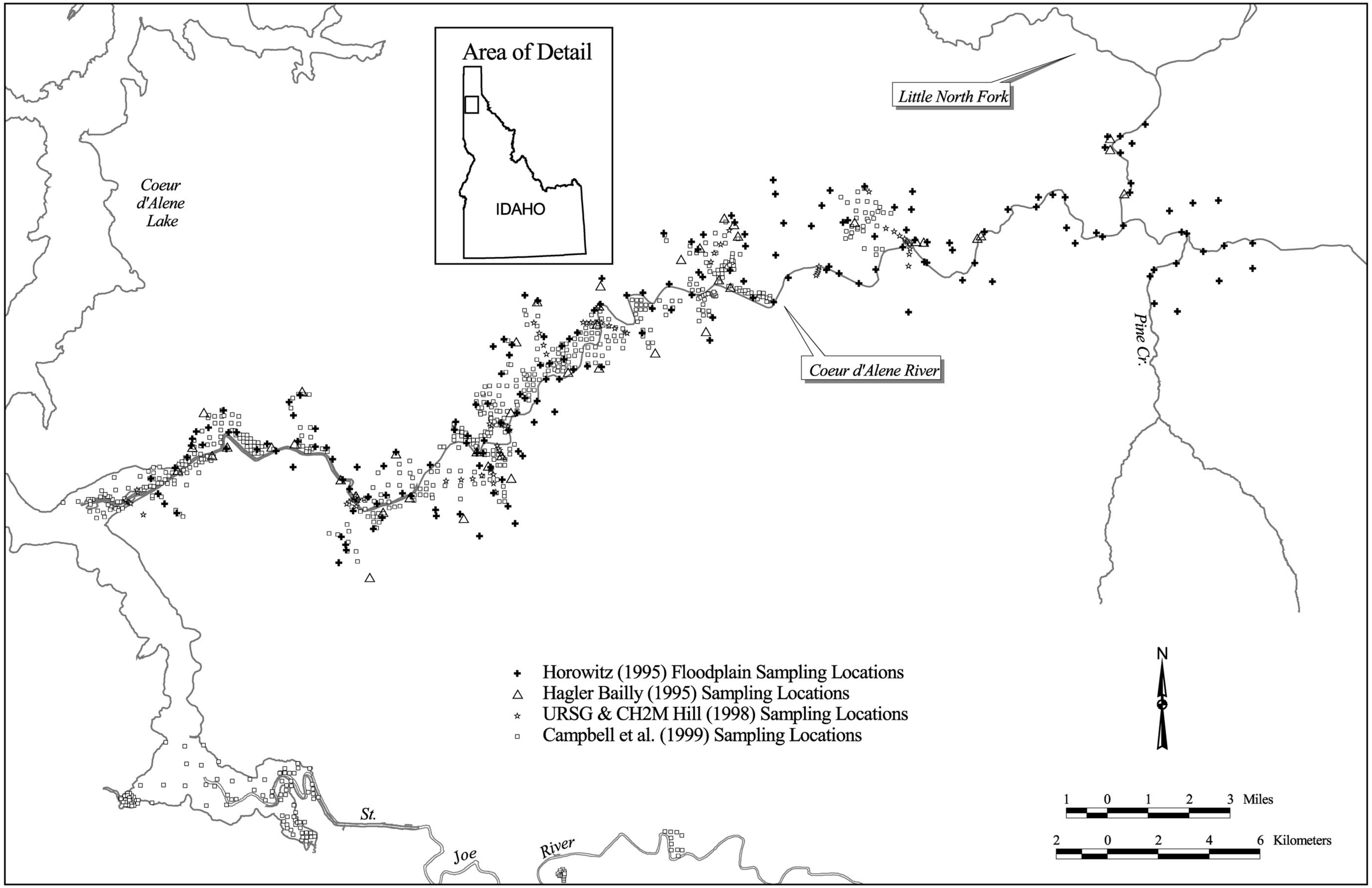

Figure 5-2. Bed, bank, and floodplain sediment sampling locations in the lower Coeur d'Alene River basin.

As part of pathway determination, sediment samples were collected from geographically and hydrologically discrete palustrine and lacustrine wildlife habitats to determine if Coeur d'Alene River basin sediment serves as a pathway of waterfowl exposure to hazardous substances. Concentrations of hazardous substances in Coeur d'Alene River basin sediments ($n = 555$) were compared to concentrations in sediments from the St. Joe River basin ($n = 126$), and concentrations of all analytes (arsenic, cadmium, iron, manganese, lead, and zinc) were greater in Coeur d'Alene River basin samples than in St. Joe River basin samples ($p < 0.0001$; Campbell et al., 1999). The data were also analyzed by comparing mean values from discrete 25 wetland units sampled in the Coeur d'Alene River basin to mean values from each of 6 discrete wetland units in the St. Joe River basin. Mean lead concentrations in all Coeur d'Alene wetland units exceeded 1,000 mg/kg; mean lead concentrations in St. Joe wetland units were all below 20 mg/kg. Mean lead concentrations in sediments from each of the Coeur d'Alene wetland units (range of 1,075 to 5,826 mg/kg) were significantly greater than mean lead concentrations in St. Joe River basin wetland units ($p < 0.0001$). Mean concentrations of cadmium, zinc, arsenic, and manganese were also significantly greater in Coeur d'Alene River basin wetland units than in St. Joe River basin units ($p < 0.0001$). Concentrations are summarized by area in Table 5-1. Sample site locations are shown in Figure 5-2.

Audet et al. (1999), examining the data in Campbell et al. (1999) and waterfowl habitat use data, found that mean concentrations of lead in sediments in waterfowl feeding areas within the wetland units sampled by Campbell et al. (1999) occasionally differed substantially from the overall mean for the wetland area. For 10 of the 25 wetland units sampled, the mean sediment lead concentration for the whole wetland unit and the mean lead concentration for the feeding area within the unit differed by more than 500 mg/kg. Examples include Stroble Marsh and Bull Run Lake, where mean lead concentrations in the feeding area exceeded mean lead concentrations in the whole wetland by 670 mg/kg and 1,662 mg/kg, respectively, and Cave Lake and Cataldo Slough, where mean lead concentrations in the whole wetland exceeded mean lead concentrations in the feeding area by 853 mg/kg and 1,068 mg/kg, respectively. Audet et al. (1999) concluded that feeding area mean concentrations are more appropriate for evaluating lead exposure than whole wetland mean concentrations. Feeding area mean concentrations are presented in Table 5-2.

As part of the characterization of the pathway of metals in water, sediments, and aquatic biota, bed sediments were collected from the Coeur d'Alene River and its tributaries, including the North Fork Coeur d'Alene River, Canyon Creek, Ninemile Creek, and Pine Creek, and the St. Joe and Spokane rivers (Farag et al., 1998). Sediment samples were collected from the South Fork Coeur d'Alene River near Mullan and Pinehurst, and from five sites along the lower Coeur d'Alene River between Cataldo and Harrison. Table 5-1 presents metals concentrations in the sediments from the lower Coeur d'Alene River sites. Concentrations of cadmium, lead, and zinc in sediments and biofilm were as much as 50 to 100 times greater in samples from assessment area sites than in samples from the North Fork and upstream South Coeur d'Alene rivers and the St. Joe River.

Table 5-2
Mean Lead Concentration in Sediment from Wetland Units and from Wildlife Feeding Areas within Each Wetland Unit of the Coeur d'Alene River Basin

Wetland Unit	Whole Wetland Unit		Feeding Area	
	n	Lead (mg/kg)	n	Lead (mg/kg)
Harrison Slough	24	4,515	14	4,597
Harrison Marsh	13	4,129	8	4,815
Thompson Marsh	24	1,812	15	1,836
Thompson Lake	24	3,723	14	4,281
Anderson Lake	24	1,105	7	408
Bare Marsh	25	1,433	16	682
Blue Lake	24	3,445	3	3,830
Black Lake	24	1,075	11	611
Swan Lake	18	3,965	7	4,003
Cave Lake	22	1,391	9	539
Medicine Lake	24	3,187	9	3,443
Blessing Slough	24	3,801	3	4,406
Moffit Slough	24	2,851	11	2,520
Campbell Marsh	25	4,674	9	4,712
Hidden Marsh	19	2,763	3	2,843
Killarney Lake	23	5,002	9	4,793
Strobl Marsh	24	5,826	7	6,497
Lane Marsh	24	3,442	15	3,077
Black Rock Slough	24	3,447	5	1,309
Bull Run Lake	24	5,060	7	6,721
Rose Lake	37	3,227	2	4,095
Porter Slough	24	2,621	11	2,596
Orling Slough	24	4,207	16	4,194
Cataldo Slough	18	2,365	6	1,297
Mission Slough	13	2,928	6	3,065

Data Sources: Audet et al., 1999; Campbell et al., 1999.

Mean concentrations of lead in samples collected near Cataldo, Rose Lake, Killarney, Black Lake, and Harrison ranged from 2,175 to 6,810 mg/kg. Mean concentrations of lead in samples collected in the North Fork Coeur d'Alene River, the St. Joe River, and in the South Fork Coeur d'Alene River near Mullan ranged from 10 to 203 mg/kg. Mean concentrations of cadmium and zinc from the same lower basin samples ranged from 14.5 to 33 mg Cd/kg and 2,543 to 6,790 mg Zn/kg. Mean concentrations of cadmium and zinc in the North Fork, St. Joe, and upper South Fork Coeur d'Alene river samples ranged from 0.2 to 1.4 mg Cd/kg and 61 to 827 mg Zn/kg. Concentrations of hazardous substances in sediments collected from Canyon and Ninemile creeks, and from the South Fork Coeur d'Alene River near Pinehurst, were greatly elevated. Cadmium concentrations at these three sites ranged from 49.3 to 106 mg/kg, lead from 4,503 to 9,187 mg/kg, and zinc from 8,130 to 19,700 mg/kg.

Sediments from the northwestern shore of Coeur d'Alene Lake were sampled to determine concentrations of hazardous substances in sediments at water level and at a location 3 feet above the water level (Cernera et al., 1998).Concentrations of cadmium ranged from below the detection limit to 1.8 mg/kg, concentrations of lead ranged from 4.1 to 326 mg/kg, and concentrations of zinc ranged from 54.5 to 756 mg/kg (Table 5-1). Concentrations of cadmium, lead, and zinc collected at the different heights above water level did not differ significantly.

USGS Studies

Data from samples collected by the USGS during the February 1996 flood indicated that the Coeur d'Alene River transported an estimated 69,000 metric tons of sediment, 720 metric tons of lead, and 180 metric tons of zinc, and 111 kg of cadmium to Coeur d'Alene Lake on a single day (February 10), the day after the peak flow (Beckwith, 1996, 1997). Concentrations of hazardous substances in the South Fork and mainstem Coeur d'Alene rivers were substantially greater than concentrations in the North Fork Coeur d'Alene River, and concentrations of hazardous substances and suspended sediment generally increased with distance downstream (Table 5-3). Comparison of concentrations in unfiltered and filtered samples collected at Cataldo, Rose Lake, and Harrison showed that during the flood, hazardous substances, including cadmium, lead, and zinc, were transported primarily as suspended sediment (>0.45 µm diameter) rather than as dissolved (<0.45 µm diameter) in the water (Beckwith, 1996). The study confirmed that contaminated sediments are mobile in the basin, and that during floods, large volumes of sediments and hazardous substances are transported through the lower Coeur d'Alene River basin.

In addition, the USGS collected surface and subsurface samples from the bed of Coeur d'Alene Lake (Horowitz et al., 1992, 1993). Surface samples (upper 2 cm) were collected at 150 locations (Figure 5-3), and subsurface samples at 12 locations. Subsurface core lengths ranged from 97.5 to 140.5 cm. The data were used to assess patterns in the spatial distribution of metals concentrations and to estimate volumes of contaminated sediments in the lake.

In surface samples, cadmium concentrations averaged 62 mg/kg and ranged from below the detection limit to 157 mg/kg. Lead concentrations averaged 1,900 mg/kg and ranged from 14 to 7,700 mg/kg, and zinc concentrations averaged 3,600 mg/kg and ranged from 63 to 9,100 mg/kg.

Table 5-3
Concentrations of Trace Metals and Suspended Sediment in Unfiltered Samples, Coeur d'Alene River Basin, February 8-10, 1996

Sample Location	Date/Time	Cd (µg/L)	Pb (µg/L)	Zn (µg/L)	Suspended Sediment (mg/L)
North Fork CDA at Enaville	Feb 8, 1300	<1	10	30	68
South Fork CdA at Elizabeth Park	Feb 8, 1130	5	410	820	180
	Feb 9, 1210	13	3,500	2,000	1,900
South Fork CdA near Pinehurst	Feb 8, 1330	7	420	780	410
CdA River at Cataldo	Feb 8, 0910	2	66	190	76
	Feb 9, 1600	9	840	690	890
	Feb 10, 1000	3	340	330	290
CdA River at Rose Lake	Feb 8, 1430	3	500	390	96
	Feb 9, 0915	11	4,500	1,700	980
	Feb 10, 1040	6	3,700	850	440
CdA River at Harrison	Feb 8, 1400	6	3,100	890	260
	Feb 10, 0730	11	6,500	1,600	620

Source: Beckwith, 1996.

In subsurface samples, cadmium concentrations averaged 25 mg/kg and ranged from below the detection limit to 137 mg/kg. Lead concentrations averaged 3,200 mg/kg and ranged from 12 to 27,500 mg/kg, and zinc concentrations averaged 2,400 mg/kg and ranged from 59 to 14,000 mg/kg. The cores all had generally similar features, including an upper, heavily banded (striated) section ranging in thickness from 17 to 119 cm and a lower homogeneous section.

In several of the cores, as many as 80 individual layers were identified. In most cores, a distinct metal enrichment maxima was detected at or near the base of the banded zone. Based on age-estimation of the layers, Horowitz et al. (1995) concluded that metal enrichment of lakebed sediments began between 1895 and 1910, concurrent with the onset of mining and ore-processing in the Coeur d'Alene River basin. In the underlying homogeneous zone only, structures believed to be infilled burrows and worm tubes indicated historical biological activity in the lake bed sediments.

Bunker Hill Basinwide RI/FS Study

Sediments of the lower Coeur d'Alene River basin between Cataldo and Harrison were sampled in 1997 as part of the Bunker Hill Basinwide Remedial Investigation/Feasibility Study (URSG and CH2M Hill, 1998). Cores ranging in depth up to 25 feet were collected along transects crossing the river and floodplain of the lower basin. Samples were taken from both floodplain soils and submerged sediments in the main river channel and in lateral lakes (Figure 5-2). The cores were divided into a series of samples for analysis of hazardous substances and other constituents. The data show clear evidence of a horizon of elevated concentrations of hazardous substances in the upper portion of most cores, and a lower horizon of low concentrations of

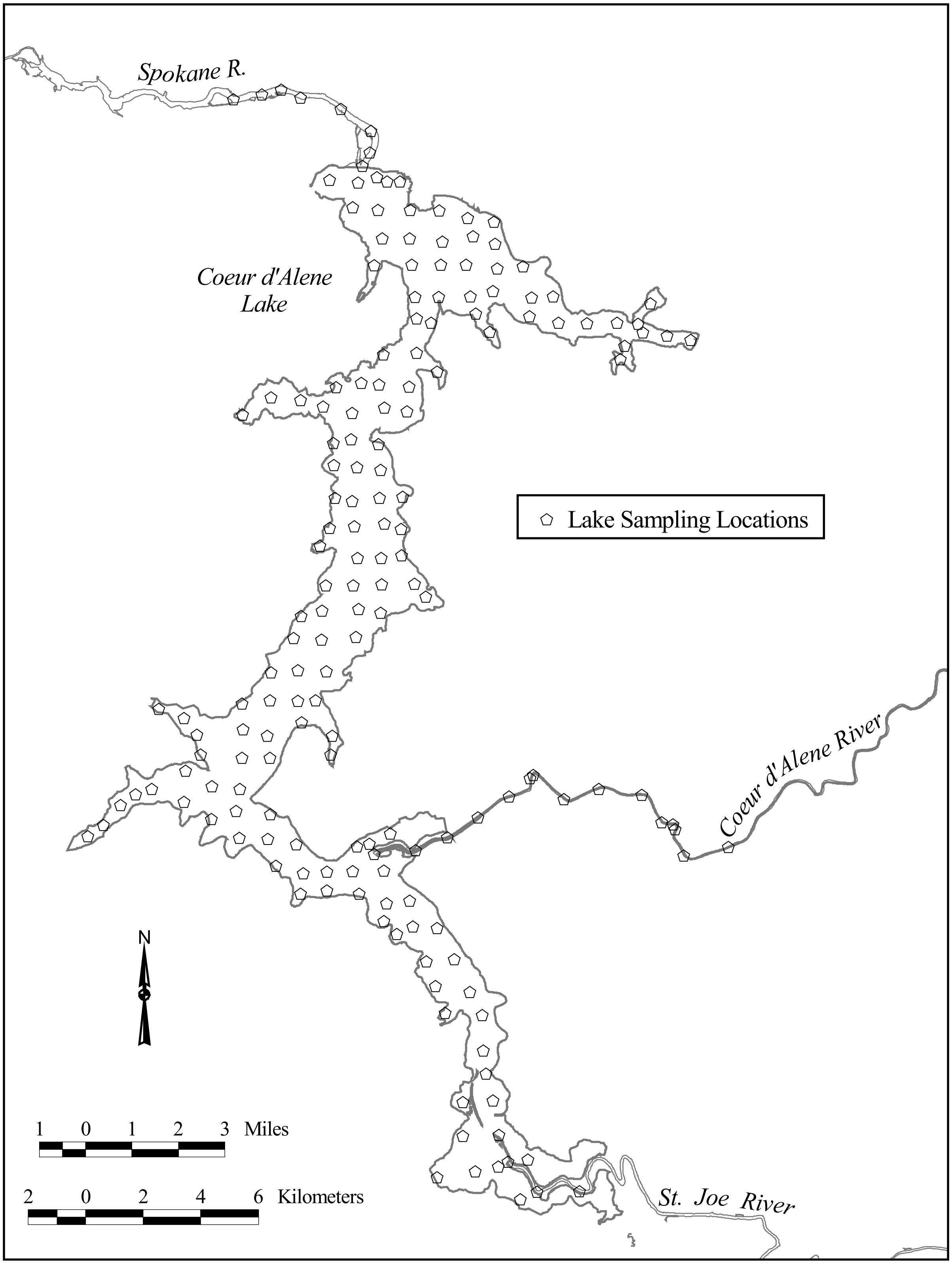

Figure 5-3. Sediment sampling locations in Coeur d'Alene Lake (Horowitz et al., 1992).

hazardous substances. Previous studies (Horowitz et al., 1993, 1995; S. Box, USGS, Spokane, WA, unpublished data) and historical accounts of tailings releases from mills, transport of tailings downstream, and deposition on floodplains, beds and banks of the lower river (Ellis, 1940; Casner, 1991; Long, 1998) indicate that the upper sediments containing elevated concentrations of hazardous substances were deposited after mining began in the basin, and that the lower sediments were deposited before mining began in the basin. An analysis of concentrations in lower pre-mining sediments is presented in Chapter 10.

5.4 DISTRIBUTION OF HAZARDOUS SUBSTANCES IN SEDIMENTS

5.4.1 Lower Basin Sediments

The distribution of hazardous substances in sediments of the lower Coeur d'Alene River basin was assessed using data from samples collected in the 1900's (Hagler Bailly Consulting, 1995; Horowitz, 1995; URSG and CH2M Hill, 1998; Campbell et al., 1999; Chapter 9). Together, these studies provide data from approximately 789 sites in the lower basin (Figure 5-4). The data in Figure 5-4 are from the sources identified in Figure 5-2. Concentrations at the majority of the sites sampled in the lateral lakes area exceed 1,000 mg/kg lead, whereas concentrations in samples from the southern end of Coeur d'Alene Lake are predominantly less than 30 mg/kg. Sediments with concentrations exceeding 1,000 mg/kg are distributed throughout the wetlands, lakes, and river channel of the lower basin (Figures 5-1 and 5-4).

5.4.2 Coeur d'Alene Lake Sediments

Horowitz et al. (1992, 1993, 1995) collected 150 surface and 12 subsurface samples from the bed of Coeur d'Alene Lake. The distribution patterns of metals in the surface sediments are consistent with the Coeur d'Alene River as the main source of contaminated sediments (Horowitz et al., 1992, 1995). Localized areas of peak concentrations reflect water velocity and movement from south to north in the lake. Some of the highest concentrations occur in and around Harrison Slough, where the velocity of the Coeur d'Alene River would be expected to decrease substantially as it enters the lake. Other sites with particularly elevated concentrations are found where the geomorphology of the lake causes changes in the current direction or velocity and where a loss of suspended sediment is likely to occur (Horowitz et al., 1992).

Figure 5-5 shows lead concentrations in surface sediments of Coeur d'Alene Lake, and the majority exceed 1,000 mg/kg. Only the southern end of the lake, which is primarily influenced by sediment inputs from the St. Joe River basin, has lead sediment concentrations below 175 mg/kg.

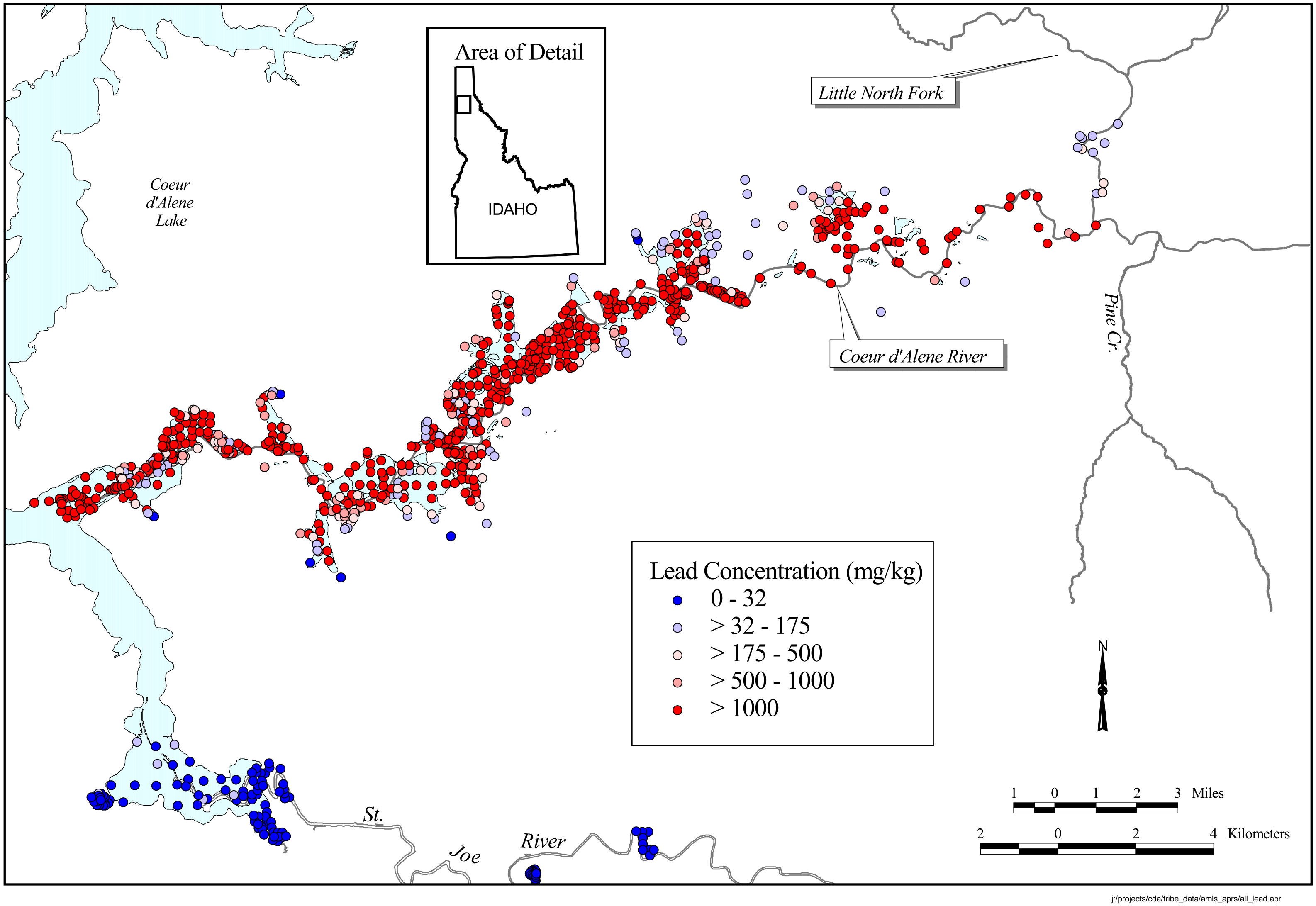

Figure 5-4. Distribution of lead concentrations in surface bed, bank, and floodplain sediments of the lower Coeur d'Alene River basin.

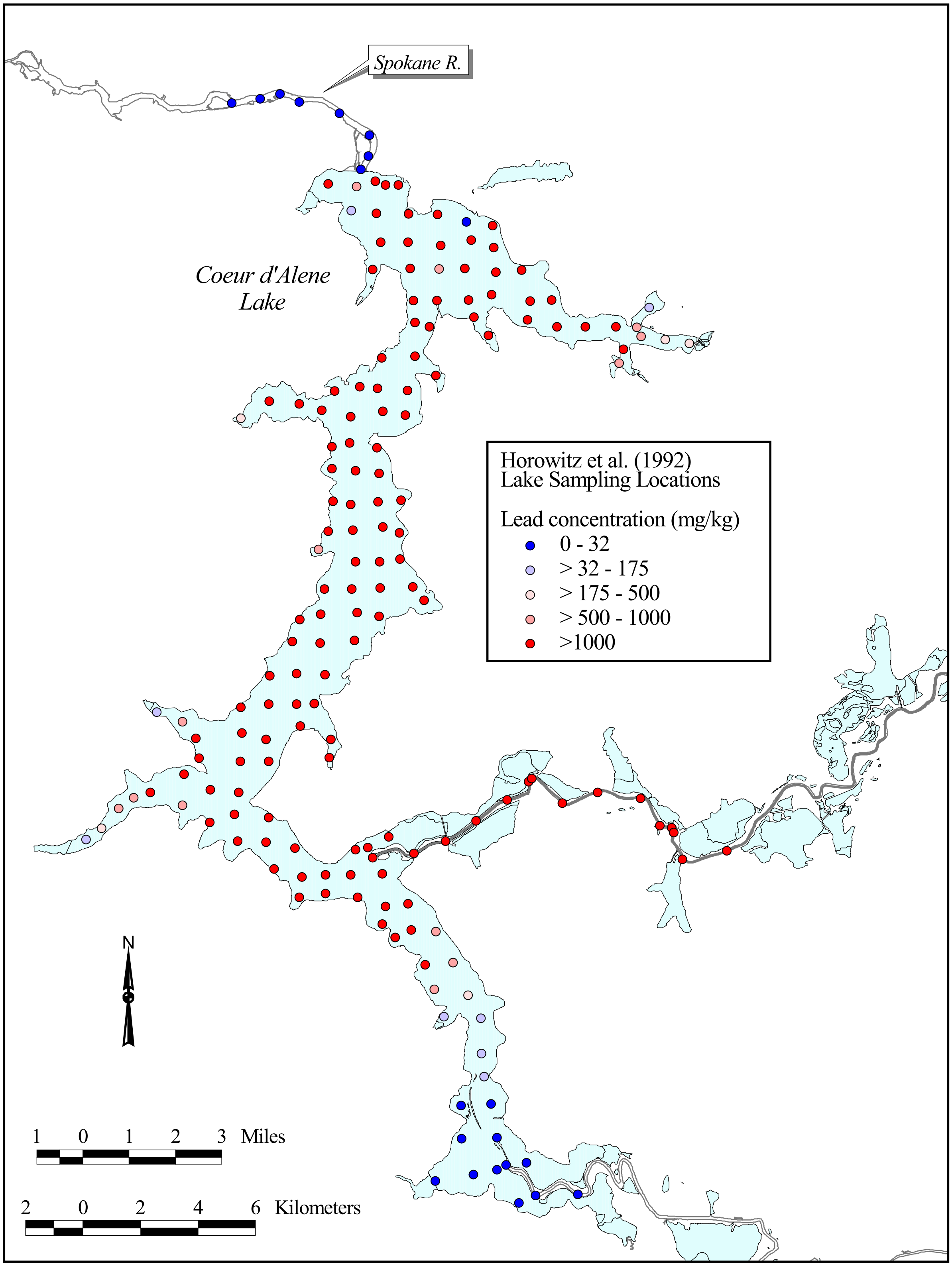

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Figure 5-5. Lead concentrations in Coeur d'Alene Lake surface bed sediments.

The 12 subsurface samples were collected from the Coeur d'Alene River delta, the main stem of the lake, and the backs of several bays perpendicular to the main stem (Horowitz et al., 1993, 1995). Based on metal concentrations in the surface and subsurface sediments and the volume of sediments represented by the cores, the mass of metal-enriched sediment and the mass of each enriched element were calculated. Normal masses of trace elements were calculated by substituting median concentrations data from the lower portion of cores determined to represent premining conditions and a core from the southern end of the lake. An estimated 75 million metric tons of metal-contaminated sediments currently overlie approximately 85% of the bed of Coeur d'Alene Lake (Horowitz et al., 1993, 1995). The contaminated sediments contain an estimated 10,000 metric tons of cadmium, 468,000 metric tons of lead, and 240,000 metric tons of zinc. The mass of metals in background (unenriched) sediments was estimated to comprise less than 2% of the total metal mass for each element (Horowitz et al., 1993, 1995).

5.5 ECOLOGICAL IMPLICATIONS OF SEDIMENT CONTAMINATION

Metals accumulated in sediment can be toxic to aquatic biota, through direct contact with the sediment or through movement of the metals from the sediment into the sediment porewater or water column (Burton, 1992). However, no national sediment quality criteria have been developed to protect aquatic biota or wildlife from toxic sediments. Several groups have developed "sediment effect concentrations" that are intended to estimate sediment concentrations above which adverse effects to benthic macroinvertebrates occur. For freshwater sediments such as those in the Coeur d'Alene River system, sediment effect concentrations have been derived by the Ontario Ministry of the Environment (Persaud et al., 1993) and by researchers who have studied contaminated sediments for the U.S. EPA (Ingersoll et al., 1996). In addition, NOAA has developed sediment effect concentrations using a database that includes information from both freshwater and marine systems (Long and Morgan, 1991). These sediment effect concentrations can be compared to measured metal concentrations in the Coeur d'Alene River basin as an indication of the likelihood that the concentrations are sufficient to cause toxicity.

Sediment effect concentrations were developed by the Ontario Ministry of the Environment (Persaud et al., 1993), U.S. EPA (Ingersol et al., 1996; McDonald et al., 1999), and NOAA (Long and Morgan, 1991) from statistical analyses of datasets on the co-occurrence of sediment contamination and toxicity. Although the underlying databases and statistical analyses used by the different groups differ, the contaminant concentrations predicted to cause toxicity to benthic macroinvertebrates are similar (Table 5-4). For each of the metals shown in Table 5-4, sediment effect concentrations are within a factor of approximately 3 of each other, indicating a general consistency despite differences in underlying databases and methods. Also included in Table 5-4 are "consensus" sediment effect concentrations developed by MacDonald et al. (1999). MacDonald et al. (1999) combined the various individual sediment effect concentrations into single effect concentrations intended to reflect the information from all the separate groups. MacDonald et al. (1999) report that the consensus numbers for cadmium, lead, and zinc correctly predicted sediment toxicity in 93.7%, 89.6%, and 90.0%, respectively, of 347 samples from freshwater systems in the United States.

Table 5-4
Sediment Effect Concentrations for Freshwater Sediment

Name	Definition	Basis	Concentration (mg/kg dry wt)			Reference
			Cd	Pb	Zn	
Severe Effects Level	"Level at which pronounced disturbance of the sediment-dwelling community can be expected"	Field data on benthic communities	10	250	820	Persaud et al., 1993
Probable Effect Level	"Concentrations that are usually or always associated with adverse biological effects"	Laboratory toxicity tests using field-collected sediment	3.2	82	540	Ingersoll et al., 1996
Effects Range-Median[a]	"Concentration above which effects were frequently or always observed or predicted among most species"	Field data on benthic communities and spiked laboratory toxicity test data	9.0	110	270	Long and Morgan, 1991
Consensus Probable Effect Concentration	"Concentrations above which harmful effects on sediment-dwelling organisms were expected to occur frequently"	Geometric mean of published effect concentrations	4.98	128	459	MacDonald et al., 1999

a. Based on data from both freshwater and marine sites.

Concentrations measured in sediments from the lower Coeur d'Alene River, Coeur d'Alene Lake, and lateral lakes area (see Table 5-1) consistently exceed all sediment effect concentrations presented in Table 5-4. In many areas of the lower Coeur d'Alene River basin, *mean* concentrations of cadmium, lead, and zinc exceed all the effect concentrations by an order of magnitude. Although the sediment effect concentrations listed in Table 5-4 may not be specific to the biotic and abiotic conditions of the Coeur d'Alene River basin, the consistency and degree of exceedence of the effect concentrations indicate a high likelihood of the sediment metal concentrations being sufficient to cause toxicity.

To investigate the site-specific exposure and toxicity of sediments to benthic invertebrates, fish, and wildlife, pathway studies were conducted by the Trustees as part of the NRDA. The pathway studies conducted by the Trustees confirm that biota of the Coeur d'Alene River basin are exposed to hazardous substances in sediments, and that exposure to hazardous substances in sediments causes injury. These pathway studies are described briefly below, and more completely in Chapters 6, 7, and 8.

Contaminated sediments in the Coeur d'Alene River serve as an exposure pathway to waterfowl of the Coeur d'Alene River basin by direct ingestion (Beyer et al., 1994, 1997, 1998). Concentrations in ingested floodplain sediments are sufficient to cause injury to wildlife, including death, physiological malfunctions, and physical deformations (Chapter 6). Contaminated sediments in the Coeur d'Alene River also serve as an exposure pathway to biofilm, benthic invertebrates, and fish of the Coeur d'Alene River basin (Woodward et al., 1997; Farag et al., 1998), and to riparian vegetation (Chapter 9). Concentrations of hazardous substances in river bed sediments, in combination with concentrations in surface water, are sufficient to cause death and physiological malfunctions in fish (Chapter 7).

Exposure of waterfowl to lead and other hazardous substances in sediments was confirmed by collection and analysis of digesta (dietary contents of the digestive system) and excreta (excretory products including feces) from wood ducks, tundra swans, Canada geese, and mallards of the lower Coeur d'Alene River basin and reference areas (Beyer et al., 1997, 1998; Audet et al., 1999). The average lead concentration (dry weight) in excreta of tundra swans was 880 mg/kg in the Coeur d'Alene River basin, and 2 mg/kg in reference areas. Lead concentration in tundra swan feces was significantly correlated ($p < 0.05$; Spearman's rho = 0.74) with the amount of sediment ingested, and fecal lead concentrations of all waterfowl were significantly correlated with lead concentrations in Coeur d'Alene River basin sediments ($r^2 = 0.83$, $p < 0.05$) (Beyer et al., 1998). Lead concentrations in the ingesta of swans from the Coeur d'Alene River basin were 140 times greater than lead concentrations in swan ingesta from the St. Joe River basin. The results of these studies (described further in Chapter 6) confirm that direct ingestion of contaminated sediment is the principal exposure pathway of lead and other hazardous substances to waterfowl in the Coeur d'Alene River basin, and that concentrations are sufficient to provide a direct pathway to wildlife resources of the Coeur d'Alene River basin. Moreover, Coeur d'Alene tundra swans, Canada geese, and mallards ingest contaminated sediments in sufficient concentrations to cause injury, including death, physiological malfunctions, and physiological deformations (Chapter 6).

Farag et al. (1998) demonstrated a link between metal concentrations in sediments and metal concentrations in biofilm in the Coeur d'Alene River basin. As concentrations of hazardous substances in sediments and biofilm increased, concentrations of hazardous substances in composite samples of invertebrates increased. In addition, concentrations of cadmium, lead, and zinc in whole perch collected from the Coeur d'Alene River were significantly greater than concentrations in perch collected from the Spokane River, where sediment and biofilm concentrations are much lower, and mean concentrations of cadmium, lead, and zinc in kidneys and gills of trout collected in the South Fork Coeur d'Alene River near Pinehurst were significantly greater than concentrations in brook trout collected from the North Fork Coeur d'Alene River.

Woodward et al. (1997) showed that Coeur d'Alene River basin sites with the highest concentrations of metals in water, sediment, biofilm, and benthic invertebrates were also the sites where fish populations were reduced, mortality was observed, and tissues contained elevated concentrations of metals. The Woodward (1997) and Farag et al. (1998) data confirm that sediments, biofilm, invertebrates, and fish are exposed to hazardous substances, and provide evidence of the sediment-invertebrate dietary exposure pathway to fish (see also Chapter 7).

In summary, contaminated sediments represent an important exposure pathway of hazardous substances to terrestrial and aquatic biota. Moreover, exposure to these contaminated sediments causes injuries to biological resources that rely on sediments as a component of their habitat.

5.6 INJURY DETERMINATION EVALUATION

5.6.1 Injuries Evaluated in the Assessment Area

Injuries to sediments were assessed in accordance with the DOI guidance for determination of injuries to surface water [43 CFR §11.62 (b)(1)] and geologic resources [43 CFR § 11.62 (e)]. Relevant definitions of injury to sediment include:

- Concentrations and duration of substances sufficient to have caused injury (. . . as defined . . .) to groundwater, air, geologic, or biological resources when exposed to . . . suspended sediments, or bed, bank, or shoreline sediments [43 CFR §11.62 (b)(1)(iv)].

- Concentrations of substances sufficient to have caused injury as defined to surface water, groundwater, air or biological resources when exposed to the substances [43 CFR § 11.62 (e)(11)].

These definitions of injury pertain to sediments as an exposure pathway of injury to other resources. To address these injury definitions, the Trustees conducted pathway and injury studies (Chapters 6, 7, and 8) to evaluate exposure and responses of biota to contaminated and reference sediment.

5.6.2 Confirmation of Exposure in Sufficient Concentrations

The data presented in Tables 5-1 and 5-2, plus additional data presented in the following chapters, confirm that sufficient concentrations of hazardous substances are present in floodplain, bed, bank, and suspended sediments to cause injury to wildlife (Chapter 6, Wildlife Resources), fish (Chapter 7, Fish Resources), and benthic invertebrates (Chapter 8, Benthic Macroinvertebrates). Sufficient concentrations are present in floodplain sediments of the upper basin to cause injury to riparian vegetation (Chapter 9, Riparian Resources).

Information presented in Chapter 6 confirms that:

- Sufficient concentrations of lead are present in sediments of the lower Coeur d'Alene River basin to cause death, physiological malfunctions, and physical deformations in waterfowl [43 CFR 11.62 (f)(4)]. Waterfowl consume sediments contaminated with lead and other hazardous substances, the lead in the sediments is bioavailable, and the lead in the sediment causes the injuries listed above.

Information presented in Chapters 7 and 8 confirms that:

- Sufficient concentrations of hazardous substances are present in sediments of the Coeur d'Alene River basin to expose benthic invertebrates and fish. Exposure to hazardous substances causes injury to fish and benthic invertebrates, including death, physiological malfunctions, and physical deformations [43 CFR 11.62 (f)(4)].

Information presented in Chapter 9 confirms that:

- Sufficient concentrations of hazardous substances are present in floodplain soils and sediments of the upper Coeur d'Alene River basin to expose riparian vegetation. Concentrations of hazardous substances are phytotoxic, and cause injury to riparian vegetation [43 CFR 11.62 (e), (f)(2)].

Based on the consistent evidence that sediments serve as a pathway of injury to biological resources of the Coeur d'Alene River basin, sediments throughout the basin are injured [43 CFR §11.62 (b)(1)(iv) and (e)(11)].

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