In cooperation with the Coeur d’Alene Tribe

Baseline, Historic and Background Rates of Deposition of Lead-Rich Sediments on the Floodplain of the Coeur d’Alene River, Idaho

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CONVERSION FACTORS, VERTICAL DATUM, AND WATER YEAR DEFINITION

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
inch (in)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929, which is the reference datum for 7.5-minute topographic maps of the study area by U.S. Geological Survey.

Water year: In U.S. Geological Survey reports dealing with surface-water supply, a water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends; thus, the water year ending September 30, 2002, is called the "2002" water year."

Baseline and Historic Depositional Rates and Lead Concentrations, Floodplain Sediments, Lower Coeur d'Alene River, Idaho

Abstract

Lead-rich sediments, containing at least 1000 ppm of lead (Pb), and derived mainly from discarded mill tailings in the Coeur d'Alene mining region, cover about 60 km^2 of the 80-km^2 floor of the main stem of the Coeur d'Alene River valley, in north Idaho. Although mill tailings have not been discarded directly into tributary streams since 1968, frequent floods continue to re-mobilize sediment from large secondary sources, previously deposited on the bed, banks, alluvial terraces, and natural levees of the river. Thus, lead-rich sediments (also enriched in iron, manganese, zinc, copper, arsenic, cadmium, antimony and mercury) continue to be deposited on the floodplain. This is hazardous to the health of resident and visiting human and wildlife populations, attracted by the river and its lateral lakes and wetlands.

This report documents and compares depositional rates and lead concentrations of lead-rich sediments deposited on the bed, banks, natural levees, and flood basins of the main stem of the Coeur d'Alene River during several time-stratigraphic intervals. These intervals are defined by their stratigraphic positions relative to the base of the section of lead-rich sediments, the 1980 Mt. St. Helens volcanic-ash layer, and the sedimentary surface at the time of sampling. Four important intervals represent sediment deposition during the following time spans (younger to older): *1. Baseline,* from 1980 to about 1993 (after tailings disposal to streams ended, but before any major removals of lead-rich sediments); *2. Early post-tailings-release,* from about 1968 to 1980; *3. Historic floodplain-contamination,* from about 1903 to 1968; and *4. Background,* before the 1893 flood (the first major flood after large-scale mining and milling began upstream in 1886).

Medians of baseline depositional rates and lead concentrations in levee sediments vary laterally, from 6.4 cm/10y and 3300 ppm Pb on riverbanks and levee fore-slopes to 2.8 cm/10y and 3800 ppm Pb on levee back-slope uplands. In lateral flood basins, baseline medians increase with water depth, from 2.2 cm/10y and 1900 ppm Pb in lateral marshes, to 2.9 cm/10y and 2100 ppm Pb in littoral margins of lateral lakes, and 4.0 cm/10y and 4400 ppm Pb on limnetic bottoms of lateral lakes.

The median of lead concentrations in baseline sediments is 82 percent of the median for early post-tailings-release sediments, with a 69-percent probability that the two data sets represent statistically different populations. By contrast, the median of lead concentrations in baseline sediments is 57 percent of the corresponding median for historic-interval sediments, and these two data sets definitely represent statistically different populations. The area-weighted average of medians of lead concentrations in baseline sediments of all depositional settings is 2900 ppm Pb, which is 1.6 times the 1800 ppm Pb that can be lethal to waterfowl. It also is 2.9 times the 1000-ppm-Pb threshold for removal of contaminated soil from residential yards in the Coeur d'Alene mining region, and 111 times the 26-ppm median of background lead concentrations in pre-industrial floodplain sediments.

During episodes of high discharge, lead-rich sediments will continue to be mobilized from large secondary sources on the bed, banks, and natural levees of the river, and will continue to be deposited on the floodplain during frequent floods. Floodplain deposition of lead-rich sediments will continue for centuries unless major secondary sources are removed or stabilized. It is therefore important to design, sequence, implement, and maintain remediation in ways that will limit recontamination.

Introduction

Lead-rich sediments, containing at least 1,000 ppm Pb cover about 61 km^2 of the 84-km^2 floor of the main stem of the Coeur d'Alene River valley (Bookstrom and others, 2001). Large-scale mining and milling of veins enriched in silver, lead, zinc, and other metals began in 1886 in the Coeur d'Alene mining region. Beginning in 1886, many mills discarded metallic sulfide-bearing tailings directly into streams in the upper drainage basin of the Coeur d'Alene River, and some mills continued discarding tailings directly into streams until 1968. The discarded tailings washed down-stream, mixed with other sediments in transport, and were re-deposited down-valley.

Frequent floods continue to transport metal-enriched sediment down-valley and onto the floodplain. Thick deposits of lead-rich sediments are present in the low-gradient river channel west of Cataldo Landing. These river-channel deposits of lead-rich sediments are an important secondary source of lead-rich sediments, vulnerable to transport during floods. Floodwaters continue to mobilize and re-deposit lead-rich sediments from this large secondary source, even though tailings have not been discarded into tributary streams since 1968, and large volumes of lead-rich sediments were removed from tributary streams and floodplains during the late 1990's. Floodwaters will continue to remobilize lead-rich sediments from the river channel, as well as from smaller secondary sources along its banks and levees, and will continue to deposit lead-rich sediments in lateral flood basins, where waterfowl commonly feed, until predominant secondary sources are removed, covered and stabilized, or effectively separated from depositional areas on the floodplain.

Most of the lead in lead-rich sediments on the floodplain of the Coeur d'Alene River is in forms that are potentially bioavailable and toxic to animals (including humans) that might ingest or inhale them in sufficient quantities (Krieger, 1990). The biologically based Probable Effect Level for lead in soils or surface sediments is 122 ppm, and the Apparent Effects Threshold is 450 ppm, as reported by the U.S. Environmental Protection Agency (USEPA, 1997). The threshold concentration of lead in soil to be removed from residential sites in the Bunker Hill Superfund site is 1000 ppm (Richard Martindale, written communication, 1999). The USEPA Early Action Level for remediation of sediments and soils in common public-use areas is 2000 ppm Pb (USEPA, 1999). Neufeld (1987), and Audet and others (1999) documented patterns of waterfowl deaths from lead poisoning in the Coeur d'Alene River valley. In waterfowl feeding experiments, Beyer and others (2000) recognized the onset of health injury by lead poisoning from ingestion of 22 percent of sediment, containing 530 ppm Pb, in a diet of rice. At 1800 ppm Pb, feeding experiments by Beyer and others (2000) caused waterfowl to die from lead poisoning.

Purpose

The first purpose of this study is to provide a quantitative estimate of post-tailings-release, pre-remedial baseline depositional rates and lead concentrations in sediments above the 1980 Mt. St. Helens volcanic-ash layer in various depositional settings on the floodplain of the main stem of the Coeur d'Alene River. A second purpose is to compare depositional rates and lead concentrations of floodplain sediments deposited before, during, and after large-scale mining, milling, and tailings disposal into streams of the Coeur d'Alene mining region. A third purpose is to define spatial and temporal patterns of depositional rates in terms of fluvial processes acting on secondary sources of lead-rich sediments, previously deposited along floodwater flow paths. A fourth purpose is to predict how estimated rates of fluvial processes, acting on large secondary sources of lead-rich sediments along floodwater flow paths, are likely to affect the long-term effectiveness of remediation by various possible methods, applied in different depositional settings.

We present this information, and our interpretations, for the consideration of anyone involved in ongoing efforts to plan, apply, and test alternative methods for remediation of environmental hazards, posed by past and continuing deposition of lead-rich sediments on the floodplain of the main stem of the Coeur d'Alene River. Such efforts involve workers affiliated with multiple federal, tribal, state, and local governmental agencies, mining companies, environmental organizations, and engineering firms.

Overview

We begin with a description the geography of drainage basins involved in the transport and deposition of lead-rich sediments. We summarize the history of mining, milling, and tailings management in the Coeur d'Alene mining region. We describe the character of lead-rich sediments stored in different depositional settings on the floodplain of the main stem of the Coeur d'Alene River. We identify time-stratigraphic markers in the section of lead-rich sediments, and define time-stratigraphic intervals between them. We describe our data sets and methods of sample collection and analysis. We present summary statistics for sediment-deposition rates and lead concentrations in floodplain sediments, grouped by time-stratigraphic interval and depositional setting. We compare summary statistics on rates of deposition and lead concentrations for sediments of baseline, historic, and background intervals. We describe processes by which lead-rich sediments, stored in secondary sources along floodwater flow paths, are mobilized, transported, and re-deposited during floods. Finally, we summarize our conclusions and describe their implications for environmental monitoring, remediation, and restoration.

Description of Study Area and Surroundings

The Coeur d'Alene River drains a large part of northern Idaho, from the Idaho-Montana border, to Coeur d'Alene Lake, near the border between Idaho and Washington (figure 1). The floodplain of the main stem of the Coeur d'Alene River extends from the confluence of the North and South Forks of the Coeur d'Alene River (near Enaville, Idaho) to Coeur d'Alene Lake (near Harrison, Idaho, plate 1). The channel of the main stem of the Coeur d'Alene River begins about 3 km (2 mi) downstream from the western margin of the Coeur d'Alene mining region (figure 2) and meanders west-southwest to its delta in Coeur d'Alene Lake, a river distance of about 56 km (36 mi).

Figure 1. Location map showing the Coeur d'Alene River system, CdA Lake, and the Spokane River.

Figure 2. Index and location maps showing the Coeur d'Alene mining region, upstream from the main stem of the Coeur d'Alene River and Coeur d'Alene Lake.

The floodplain of the main stem of the Coeur d'Alene River is about 44 km (27 mi) long, and it averages about 1.9 km (1.2 mi) wide. Its surface area is approximately 84 km^2 (32-mi^2). We divide the floodplain longitudinally into upper (eastern), middle, and lower (western) parts (figure 2). The larger-scale maps in figures 3, 4 and 5 show the boundaries of these floodplain segments, and the locations and names of lateral lakes and marshes, tributary streams, towns and settlements. Plates 1 and 2 are 1:50,000-scale maps of surficial geologic environments on the floodplain of the main stem of the Coeur d'Alene River, with colored dots to symbolize baseline rates of sediment deposition, and lead concentrations in sediments deposited on the floodplain from 1980 to about 1993.

Water Levels and Topography

During summer, the Post Falls dam holds Coeur d'Alene Lake at a nearly constant elevation of 648 m (2125 ft), according to the U.S. Geological Survey datum at Harrison, or 649 m (2128 ft), according to the older datum at Post Falls. At summer water level (SWL), the pool of the reservoir controlled by the Post Falls dam extends up the Coeur d'Alene River to Cataldo Landing, where summer water level in the river also is about 649 m (2125 ft). Natural levees and lateral marshes and lakes flank the river (plates 1 and 2).

Heights of crests of natural levees at 13 surveyed sites vary from a maximum of 4.3 m at Rose Lake to 0.9 m at Harrison, with a mean and standard deviation of 2.2 +/-1.0 m (according to spot elevations, surveyed to 0.3 m accuracy by Washington Water Power Co., 1980). Levee-crest heights tend to decrease down-valley, but also tend to be relatively high in narrow valley segments and on outside margins of meanders.

Elevations of standing water on the floodplain tend to approach river water level, but may be higher where isolated and held, or lower where isolated and pumped. Summer water depths range from 0 to 2 m deep in lateral marshes and littoral zones of lateral lakes, and from 2 to about 8 m deep in lateral lakes. Lateral lakes in the mouths of tributary valleys commonly have steep sides and flat bottoms at depths between about 4 and 8 m (unpub. data, 2000).

U.S. Geological Survey topographic maps indicate about 914 to 1070 m (3000 to 3500 ft) of vertical relief in the hills north and south of the Coeur d'Alene River valley. Elevations of the valley floor rise from about 649 m (2125 ft) at the mouth of the Coeur d'Alene River to 655 m (2150 ft) at the confluence of the North and South Forks, 670 m (2200 ft) at Smelterville, 914 m (3000 ft) at Wallace, and 1040 m (3400 ft) at Mullan. The elevation at Lookout Pass, on the Idaho-Montana border, is about 1460 m (4800 ft), which is about 610 m (2000 ft) below the elevation of the highest nearby peak.

Valley glaciers occupied small cirques and flowed down U-shaped valleys to about the Star-Morning millsite, just west of Mullan. West of there, valley cross-sections generally are V-shaped, except where alluvial and lacustrine sediments fill the bedrock valley bottom, forming relatively wide and flat alluvial plains.

About 15,500 to 13,500 years ago, Glacial Lake Coeur d'Alene rose to about the elevation of Kellogg (Dort, 1960). Since then, the Spokane River has eroded down through outburst flood gravels from Glacial Lake Missoula that dammed Glacial Lake Coeur d'Alene, and the river is incising into bedrock at Post Falls (Alt and Hyndman, 1995).

The bedrock elevation in the river channel at Post Falls is about 2 m below SWL, which is held constant by the Post Falls Dam. During episodes of high discharge, water enters Coeur d'Alene Lake faster than it can exit, even though the gates of Post Falls Dam are wide open. Coeur d'Alene Lake therefore overfills to elevations as high as about 652 m (2140 ft), which is about 4.5 m (15 ft) above SWL.

Precipitation and Vegetation

The drainage basin of the Coeur d'Alene River is in a unique inland-forest wet belt on the western slope of the Northern Rocky Mountains, with very high average annual precipitation, about 75 to 80% of which is in the form of snow (Alan Isaacson, forest hydrologist, oral commun., 2004). Prevailing winds are from the southwest, so that air masses from the Pacific Ocean pass northeastward over Coeur d'Alene Lake, rise up the western slopes of the Northern Rocky Mountains, and cool adiabatically. As average annual temperatures decrease with increasing altitude, average annual precipitation increases sharply from about 41 cm/y (16 in/y) in the valleys and plateaus of eastern Washington to over 122 cm/y (48 in/y) in the Coeur d'Alene Mountains (Jackson, 1993).

On the floodplain of the main stem of the Coeur d'Alene River, riverbanks and levees support redtop grass, alders and other shrubs, and trees such as cottonwoods and pines. Seasonal lateral marshes support emergent vegetation, such as grass, sedges, common reed, and horsetail reed. Margins of perennial marshes support emergent vegetation, such as cattails, while floating plants, such as lily pads are commonly visible in open water. Since the 1968 cessation of tailings disposal into streams, lake water has clarified, and plant life, including planktonic diatoms and submergent bottom-rooted plants, such as pondweed, have flourished in the shallow open waters of perennial marshes and lateral lakes.

Lower hillsides are in the Ponderosa Pine Zone, but the hills west of Coeur d'Alene Lake are in the Grand Fir and Douglas Fir Zones, where lodgepole pines also are common. Hillsides at moderate elevations are in the Western Redcedar Zone, where dominant trees include western redcedar, western hemlock and western white pine, as well as grand fir and western larch. Englemann Spruce and Subalpine Fir zones are confined to relatively high elevations along the border between northeastern Idaho and northwestern Montana (Frenkel, 1993).

Deforestation, Runoff and Floods

Clear-cut logging, road building, forest fires, and surface disturbances resulting from mining, milling, smelting, and human habitation in the Coeur d'Alene mining district have resulted in deforestation of many areas in the upper riverine subsystem of the Coeur d'Alene-River drainage basin. As a result, the ratio of runoff to precipitation has increased, especially since the early 1960's. Some tributary streams that once ran bank-full or more about twice in 3 years now run bank-full 5 or 6 times a year. As a result, rates of erosion, sediment-transport, and deposition also have increased, especially along streams in the upper part of the Coeur d'Alene drainage basin (Alan Isaacson, oral commun., 2004).

Flooding is frequent on the floodplain of the Coeur d'Alene River. The first major floods after the onset of mining and milling in 1886 were in 1893-94. Between 1893 and 2004, at least 40 discharge episodes peaked at 17,000 f^3/s or more. Discharge rates of that magnitude or more cause most of the valley floor to be flooded (S.E. Box, unpub. compilation of data from U.S. Geological Survey records, 2000). On average, therefore, much of the valley floor was flooded about every 2.5 y. Furthermore, floods with peak discharge of about 70,000 ft^3/s or more have occurred three times in the last 70 years, and twice in the last 30 years (in 1933, 1974 and 1996).

Berenbrock (2002) estimated peak flows at the Cataldo gage at selected recurrence intervals as 18,800 ft^3/s at the 2-y frequency interval, 29,400 ft^3/s at the 5-y interval, 37,800 ft^3/s at the 10-y interval, 50,000 ft^3/s at the 25-y interval, 60,300 ft^3/s at the 50-y interval, 71,800 ft^3/s at the 100-y interval, 84,500 ft^3/s at the 200-y interval, and 104,000 ft^3/s at the 500-y interval. The U.S. Army Corps of Engineers (USACE, 2001) estimated somewhat higher peak flows at the Cataldo gage at selected recurrence intervals: 41,400 ft^3/s at the 10-y frequency interval, 73,500 ft^3/s at the 50-y interval, 90,000 ft^3/s at the 100-y interval, and 136,000 ft^3/s at the 500-y interval.

Upper Perennial Riverine Subsystem

Classified according to the Wetlands Classification scheme of Cowardin and others (1979), the upper perennial riverine subsystem of the Coeur d'Alene River drainage basin includes all streams of the North- and South-Fork drainage basins, and extends down-gradient from the confluence of the North and South Forks to Cataldo Landing (figure 3). The upper perennial riverine subsystem has a relatively steep gradient, swift currents, a cobble-gravel bottom, and a braided channel, with cobble-gravel bars, gravely riverbanks, and alluvial terraces, topped by sandy to silty floodplain sediments. Downstream from mining and milling operations in the Coeur d'Alene mining area, fine-grained sediment in the matrix of the gravel, and sandy to silty over-bank sediments generally are enriched in metals derived from mining.

Although tailings-contaminated sediments were deposited on wide alluvial terraces along the South Fork during the early history of mining and milling, the South Fork has since incised enough that it generally did not overflow its banks during the major flood of February, 1996, except near Osburn and west of Smelterville (figure 2). Downstream from the lower end of Smelterville Flats, however, the South Fork overflowed onto its floodplain where it is joined by Pine Creek. The Lower North Fork, and the upper main stem of the Coeur d'Alene River completely inundated their floodplains during the major flood of 1996 (figure 3 and plates 1, and 2).

Figure 3. Map showing the upper (eastern) part, main stem of the Coeur d'Alene River valley.

Figure 4. Map showing the middle part, main stem of the Coeur d'Alene River valley.

Figure 5. Map showing the lower (western) part, main stem of the Coeur d'Alene River valley.

Lower Perennial Riverine Subsystem

The lower perennial riverine subsystem of the main stem of the Coeur d'Alene River extends from Cataldo Landing to Coeur d'Alene Lake (figures 3, 4 and 5). At Cataldo Mission Terraces, the floodplain widens, and the river gradient flattens, approaching zero from Cataldo Landing to Coeur d'Alene Lake. Water levels in the lower perennial riverine system and Coeur d'Alene Lake are therefore interdependent, and tend to equalize during and after episodes of imbalance between rates of inflow and outflow from Coeur d'Alene Lake.

At Cataldo Landing (figure 3) the upstream gravel bottom gives way to a large friction-dominated central sand bar. From Cataldo Landing to Coeur d'Alene Lake, the river occupies a single meandering, sand-bottomed channel, generally about 60 to 100 m wide and 5 to 15 m deep. Sandy lead-rich sediments, averaging about 3 m thick, cover most of the river bottom, especially along relatively straight reaches and in point bars along inside margins of meanders (Figure 6, and Bookstrom and others, 2001; Box and others, 2001).

Figure 6. Block diagram showing features typical of the floodplain of the lower perennial subsystem of the Coeur d'Alene River system, west of Cataldo Landing.

Natural levees flank the river channel, and lateral flood basins flank the levees (figure 6, and plates 1 and 2). From the levee crest to the lateral margin of the valley floor, the floodplain surface generally slopes away from levee crests. Therefore, most of the valley bottom west of Cataldo Landing is flooded during frequent episodes of high flow, during which water flows from the rising river to the floodplain through low passes in levees, inundating the floodplain as Coeur d'Alene Lake levels rise. Levee fore-slopes face and slope toward the river. Riverbank deposits of lead-rich sediment cover levee fore-slopes, forming wedge-shaped deposits that thicken toward the river. Steep riverbanks commonly form by lateral erosion of riverbank-wedge deposits of iron-oxide-cemented lead-rich sediment (figure 6). Levee back-slopes face and slope away from the river, and toward lateral flood basins.

According to the wetlands classification system of Cowardin and others, 1979, lateral wetlands that are seasonally to perennially water-saturated, but are less than 2 m deep at summer water level are classified as palustrine. Larger water bodies (at least 8 ha or 20 acres) that are more than 2 m deep are classified as lacustrine. The shallow *littoral zone* extends from the lakeshore to the 2-m depth contour (at summer water level). The deeper *limnetic zone* includes areas with lake-bottom depths greater than 2 m at summer water level. On the floodplain of the Coeur d'Alene River, 11 lateral lakes occupy relatively low parts of lateral flood basins, which commonly are at the mouths of tributary side-valleys. Bookstrom and others (1999) mapped littoral and limnetic zones in lateral lakes. The lateral lakes generally have relatively flat bottoms at maximum depths of less than about 8 m (unpub. data, 1999).

Distributary channels connect the river with most lateral lakes and some lateral marshes. Natural levees generally flank distributary channels, forming riparian levee-uplands (figure 6). Tributary streams commonly flow into the distal margins of lateral lakes and marshes (plates 1 and 2).

Near the mouth of the Coeur d'Alene River, low natural levees flank the river where it traverses the Harrison Arm of Coeur d'Alene Lake, and flows into the St. Joe Arm of Coeur d'Alene Lake (figure 5). From the crest of the river-mouth bar, the Coeur d'Alene River delta-front slopes to the bottom of the deeper St. Joe Arm of Coeur d'Alene Lake. From the base of the delta-front slope, the proximal toe of the delta flattens, thins, and merges with the distal floor of Coeur d'Alene Lake.

Coeur d'Alene Mining Region

The western edge of the Coeur d'Alene mining region lies about 3 km (2 mi) upstream from the study area. From there, it extends about 50 km (3 to 30 mi) eastward, within the upper perennial subsystem of the Coeur d'Alene River drainage basin. Most of the significant mines and mill-sites of the Coeur d'Alene mining region are within the South Fork drainage basin, but several are in the southeastern part of the North Fork drainage basin. One mine and mill were in the French Creek drainage basin, which joins the main stem of the Coeur d'Alene River near Kingston (figure 3).

History of Production of Ore, Lead, Zinc, and Silver

The Coeur d'Alene mining region has produced about 7 million metric tons (Mt) of lead, 3 Mt of zinc, and 30 thousand tons (kt) of silver (Long, 1998a). According to criteria by Singer (1995), this places the Coeur d'Alene mining region among the top 1 percent of Ag producers, the top two percent of lead producers, and the top five percent of zinc producers in the world (Long and others, 2000). Thirty mines in the Coeur d'Alene region each produced at least 30 kt of lead, 50 kt of zinc, or 85 kt of silver (Bookstrom and others, 1996; Long and others, 2000). Those mines are considered significant producers, according to the criteria of Singer (1995), who showed that over 99 percent of world production comes from deposits with metal resources at least this large. In addition to large mine-mill complexes associated with these 30 significant deposits, over 100 smaller mines are widely scattered in the Coeur d'Alene mining region.

Ore deposits in the Coeur d'Alene mining region typically consist of steeply plunging ore shoots within steeply dipping veins, which commonly extend to great depths of 2 km or more below the surface. The veins contain quartz and siderite (iron carbonate) with varying amounts of galena (silver-bearing lead sulfide), sphalerite (cadmium-mercury-bearing zinc sulfide), and tetrahedrite (silver-bearing copper-antimony sulfide), as well as other, less economically important but environmentally significant minerals, such as pyrite (iron sulfide), chalcopyrite (copper-iron sulfide), and arsenopyrite (iron-arsenic sulfide). Fryklund (1964) noted that the sphalerite and tetrahedrite of the Coeur d'Alene mining district also contain traces of mercury.

Large-scale mining and milling began in 1886, and increased to its first peak during World War I, at 3.2 Mt/y in 1917 (figure 7a). After the war, ore production decreased to about 1.3 Mt/y in 1923, and then rose to about 2 Mt/y in 1929. After the stock market crashed in 1929, ore production decreased to 1 Mt/y during the Great Depression, from 1933 to 1935. Ore production increased during the build-up toward World War II, and by the end of the war, ore production had reached 2.75 Mt/y. After the war, production continued to increase, peaking at 3.2 Mt/y in 1948. During the cold war, ore production fluctuated mostly in the range 1.5 +/- 0.3 Mt/y, after which it has generally declined to between 0.4 and 0.7 Mt/y during the era of relatively free world trade.

Large-scale lead production peaked at a rate of185 kt Pb/y in 1917, as World War I ended (figure 7a). Since 1917, lead production has generally declined in a descending pattern of short-term fluctuations with peaks at 140 kt Pb/y in 1929, 100 kt Pb/y in 1943, and 80 kt Pb/y in 1965. Since 1980, lead production has fluctuated between about five and 50 kt Pb/y.

Zinc was not recovered until 1905, so tailings produced before 1905 generally contained high concentrations of sphalerite. Zinc production rose to about 40 kt Zn/y in 1917, decreased in the early 1920s, and then increased to a maximum of 80 kt Zn/y during World War II, when pre-1905 tailings at several locations were re-processed to recover zinc.

Silver in galena was recovered from the start, and silver production briefly reached 370 t Ag/y in 1914. Silver-rich tetrahedrite veins of the "Silver Belt" portion of the region went into production during the 1920's and 1930's. As indicated in figure 7a, silver production exceeded 340 t Ag/y from 1936 to 1942, from 1950 to 1976, and in 1989-90. Since about 1980, world production of silver as a byproduct of open-pit gold and copper mines has held silver prices down, and has rendered economically marginal the relatively high-cost recovery of silver from deep underground mines of the Coeur d'Alene region.

Figures 7a and 7b. Graphs showing annual production of ore, lead and zinc, and production-related events (7a) tailings-related events 7b).

History of Tailings Production

To recover silver, lead and zinc, mills in the Coeur d'Alene mining region produced about 109 Mt of crushed and pulverized mill tailings, containing over 1 Mt of lead and 1 Mt of zinc. Prior to 1968, approximately 56 Mt of tailings containing an estimated 800 kt of lead were discarded directly into streams that are tributary to the main stem of the Coeur d'Alene River (Long, 1998b).

Large-scale milling began in 1886 at the Bunker Hill mine. Early milling of high-grade ores, using gravity jigs, recovered only 50 to 85 percent of the lead in ores, losing the rest to tailings, which were "flumed" into adjacent streams. Jigs are essentially mechanical panning devices, which depend on gravity to separate relatively high-density ore minerals from relatively low-density gangue (waste) minerals in agitated water. Settling velocities depend not only on particle density, but also on particle size, and jaw crushers and crushing rolls, which were used to crush the ore, produced a wide range of particle sizes. The majority of particles were coarse to middling, but the rest were fine- to very fine-grained. The powdered particles formed slimes in water, and would not settle. Jig slimes with very high concentrations of ore minerals were discarded directly into streams, while coarser jig tailings accumulated along the streamside near the mills, to be washed down-valley during spring runoff episodes. Ores of the Bunker Hill deposit near Kellogg (the largest producer of the region) were relatively coarse-grained, and by 1937 the Bunker mill was achieving better than 85-percent recovery of galena by sorting crushed ore by grain-size, and using jigs, vibrating tables and related devices (Long, personal communication, 2002).

Ores of the Morning mine near Mullan (the second-largest producer) were fine-grained, so the Morning mill obtained less than 65-percent recovery of lead using jigs and other gravity-separation devices. The slime fraction of jig tailings from the Morning mill (and most other jig mills) was discarded directly into streams, and was rapidly carried away in suspension. However, the coarse fraction tended to collect near the mill, which clogged the stream channel, causing local flooding of alluvial terraces.

The Morning mill installed flotation equipment to recover sphalerite from slimes in 1911-1912 (Long, 2001). Over the next few years other mills installed flotation equipment to recover galena- and sphalerite-bearing slimes from gravity-separator tailings. In the flotation process, frothing agents are added to a highly fluid mixture of water and finely-ground ore particles, and compressed air is forced up through the slurry to form oily bubbles. Metallic sulfide ore minerals cling to rising oily bubbles, but other minerals sink. Rising bubbles carry ore-mineral particles to the surface, where they are collected and dried to produce an ore-mineral concentrate. By the late1920's most mills had abandoned jigs and were fine grinding all the ore to be treated by the flotation process (Earl Bennett, personal communication, 1996). By the late 1930's flotation mills were achieving over 85-percent recovery of ore minerals, and the Bunker mill converted to flotation shortly before World War II (Keith Long, personal communication, 2002).

During World War II, about 5 Mt of jig tailings and tailings-bearing sediments were excavated and reprocessed at several locations, including Osburn Flats, and the Sweeney mill, near Kellogg. About 75 percent of the Zn, 65 percent of the Ag, and 50 percent of the lead in those materials was recovered (Long, 1998b). Tailings from reprocessing were either returned to dumps, or discarded into the South Fork. By the late 1950s, flotation mills were achieving over 95-percent recovery of lead and silver.

History of Tailings-Management Practices

Milling began in 1886, and from the start most tailings were flumed directly to the adjacent streams. Most mills were located in the narrow bottoms of V-shaped valleys, with little space for tailing impoundments. In 1901 a tailings dam was built across the South Fork at the west end of Smelterville Flats to capture slimes discharged from the Bunker Hill milling complex at Kellogg (figure 2). Tailing dams also were built at Osburn Flats on the South Fork, and Canyon Creek. The dams at Osburn and Canyon Creek washed out in 1917 (the year of peak lead production) leaving metal-rich jig tailings perched on alluvial terraces above the active stream channel. The dam at Smelterville Flats washed out in 1933, leaving thick and extensive deposits of metal-rich jig tailings on Smelterville Flats (Long, 1998b).

The Bunker Hill Company built the first large tailing-settling pond at the present site of the Bunker (Central) Impoundment Area near Kellogg in 1928 (Long, 1998b). Subsequent tailings were deposited on older jig tailings, which also were used to build the impoundment dikes. The Page mill also built a tailings-settling pond farther west on Smelterville Flats.

In 1932, M.M. Ellis, of the U.S. Bureau of Fisheries found no live fish, and no phytoplankton or zooplankton in the waters of the South Fork or the main stem of the Coeur d'Alene River, from above Wallace to the mouth of the river near Harrison. He also noted that "The mobility of the mine wastes and mine slimes carried by the Coeur d'Alene River has made possible the pollution of considerable lateral areas, as the flats and low lands adjacent to the river, because large quantities of these wastes are swept out onto the flats during high water, and left there as the river recedes" (Ellis, 1932, p. 23). Ellis also noted that "the small particles of ore together with various other substances in these mine wastes, when exposed to the joint action of air, light and moisture can produce a whole series of new compounds some of which may affect aquatic life quite differently from the mine wastes as originally poured into the stream" (Ellis, 1932, p. 29).

After visiting the Sullivan Mills, in British Columbia, Ellis (1932) wrote that they processed similar tonnages of similar ore, but had perfected a settling basin system that provided a practical solution for waste disposal without stream pollution. Since the many mills of the Coeur d'Alene region were scattered over a wide area, and most were in narrow canyons, many continued to discard mill wastes directly into streams.

Rather than build pipelines to transport tailings to relatively wide, flat areas, the mine owners installed a suction dredge to remove tailings-contaminated sediment from the river at Cataldo Landing. The dredge operated during summers from 1932 to 1967 (Long, 1998b, Grant, 1952). It removed sandy metal-enriched slurry, and pumped it to Cataldo Flats and Mission Flats, where the sediment was deposited to form about 7.5 to 10 Mm^3 of dredge spoils, containing about 44 to 69 kt of lead (Bookstrom and others, 2001).

Each summer the dredge removed from the dredge pond an amount of sediment equivalent to the amount of tailings produced in the preceding year (William C. Rust, oral commun., 2004). However, the lead content of the sediment removed was much less than that of the tailings released. The sediment removed was mixture of tailings-contaminated sediment from the South Fork, and uncontaminated sediment from the North Fork. A large percentage of relatively fine-grained tailings-rich sediment did not settle at the dredge pond, but was transported in suspension, to be deposited farther down-valley. Especially thick and lead-rich deposits of tailings-contaminated sediments formed in the river channel along the Dudley reach, which extends from the downstream margin of the dredge pond to the Town of Rose Lake.

In 1949 the Dayrock mine in Ninemile Creek began using the sand fraction of their tailings as underground backfill, a practice that was adopted by most of the other mines from 1954 to 1961 (Long, 1998b). This halved the amount of finer-grained tailings and slimes to be discarded, so that construction of settling ponds in the relatively narrow valley bottoms of the mining region became feasible. Nevertheless, until 1968, some mills continued to discard tailings and slimes directly into creeks, so that the South Fork continued to run "the color of 'dirty dough'" (Rabe and Flaherty, 1974). Finally, in 1968, the Clean Water Act forced all operating mills to impound their tailings in settling ponds (Long, 1998b).

Data Sets and Methods

Data sets used in this report include those compiled from previous reports by Bender (1991), Rabbi (1994), Hoffmann (1995), Horowitz and others (1995), Fousek (1996), and Box and others (2001). We include additional data on the thickness of sediments above the 1980 volcanic-ash layer from Fousek (unpub. data, 1993), and on thickness of lead-rich sediments above and below the 1980 volcanic-ash layer from Bookstrom (unpub. data, 1994).

We compiled relevant data from a total of 148 sites in spreadsheet CdA_SR_PB.xls (appendix 1). Ideally we would have data on the thickness and concentration of lead in all lead-rich sediments above and below the 1980 Mt. St. Helens volcanic-ash layer at each site. However, not all sites have the 1980 marker layer, and not all sites were exposed, or sampled and analyzed for lead to the bottom of the section of lead-rich sediments. Some sites with the 1980 volcanic-ash layer did not have lead-rich sediments above or below it. A few sites were outside the study area, but were included for comparison of sediment-deposition rates within and outside the study area.

To represent the characteristics of sediments deposited during a particular time-stratigraphic interval, we used all the data available for sediments of that interval. However, to compare sediment-deposition rates or lead concentrations between time-stratigraphic intervals, we used only sites with data for both of the intervals to be compared.

Sampling Strategies

Fousek (1996) applied a combination of random and systematic sampling strategies. He randomly chose one sample location within each systematically defined 1mi^2 Section of land on the floodplain. At each site, he systematically sampled intervals from 0-5 cm, 5-15 cm, and 15-30 cm. At sites where 1980 volcanic-ash layer was present, he divided the sample interval in which it occurred into subintervals above and below the ash layer. He analyzed these sub-samples for lead and zinc, and published the results. He also recorded depth to the 1980 volcanic-ash layer, and thickness of the ash layer, but did not publish the depth and thickness measurements, which are included here, in appendix 1 (Fousek, unpub. data, 1993).

Bender (1991), Rabbi (1994), Hoffmann (1995), and Horowitz and others (1995) applied a combination of stratified and systematic sampling strategies. By sampling only limnetic lake-bottom sediments, near the central axis of the lake sampled, they extracted samples from a relatively homogeneous group (or statistical stratum). From each vertical core, they systematically sampled continuous strings of 2-cm depth intervals, which also are sediment-thickness intervals, since the sediments are layered horizontally.

Box and others (2001) applied a combination of opportunity and stratified sampling strategies. They sampled sites where sections of lead-rich were exposed, or were amenable to sampling by digging, hand coring, or vibro-core drilling. They classified sites by depositional environment, and defined sample intervals on the basis of lithologic and stratigraphic characteristics.

Sampling Methods

Methods of sample-site location, thickness-interval measurement, and sample collection are fully described in reports from which data were derived. In general, thickness of horizontally layered sediments was measured vertically downward from the surface of sediments composed predominantly of mineral grains at the time of sampling. Low-density surface duff, consisting of matted decomposing organic matter, was not included in measurements of thickness of lead-rich sediments, even though lead-rich dust or mud commonly coats the organic debris in duff. Samples collected from measured depth intervals were chemically analyzed for lead, and the results were used to identify the base of the section of lead-rich sediments (defined as sediments containing at least 1,000 ppm Pb).

Robert Fousek (unpub. data, 1993) measured the thickness of the 1980 volcanic ash layer and of sediments above it to the nearest 1/8th in (0.25 cm), and locally to the nearest 1/16th in (0.13 cm). Most of his cores penetrated only 15 cm, and did not reach the bottom of the full section of lead-rich sediments. Below 5 cm his sample interval was 10 cm (from 5 to 15 cm), which generally exceeded the thickness of sediments above the ash layer.

Box and others (2001) and Bookstrom and others (2001) reported thickness of sediments above the 1980 volcanic ash layer to the nearest 0.5 cm, and thickness of the ash layer itself to between 0.1 and 0.5 cm. Below the ash layer, they generally reported thickness of stratigraphically defined sample intervals to the nearest cm. Most of their sample intervals below the ash were thicker than sediments above the ash layer. Many of their measured sections did not reach the bottom of the section of lead-rich sediments, especially where sections of lead-rich sediments extend below the water table.

Bookstrom (unpub. data, 1994) used a field X-Ray fluorescence spectrometer to provide semi-quantitative analyses of samples of wet sediments in the field, in order to identify the base of the section of Pb-rich sediments, and measure the thickness of that sedimentary section.

Chemical Analytical Methods

Methods of sample preparation, digestion, and chemical analysis are fully described in reports from which the data were derived. We accepted published data on the concentration of lead in sediments, even though different methods of sample collection, sample preparation, digestion, and chemical analysis were used. Box and others (2001) tested the accuracy, precision, and inter-laboratory agreement of lead analyses done by 5 laboratories that used a variety of extractions and analytical methods. For standards from the National Institute of Standards and Technology (NIST), the most accurate results were within 1 percent of the mean of NIST values. For repeated analyses at a single laboratory, the most precise laboratories were within 7 percent. For analyses of splits of Coeur d'Alene sediment samples by multiple laboratories, inter-laboratory agreement was within 10 to 25 percent.

Data-Classification and Estimation Methods

We classified the depositional setting of each sample site as riverbank, upland, palustrine, lacustrine-littoral or lacustrine-limnetic. We assigned each sample-depth interval to a time-stratigraphic interval, according to its stratigraphic position relative to one or more time-stratigraphic markers, such as the surface at the time of sampling, the 1980 volcanic-ash layer, and the base of the section of lead-rich sediments.

To estimate the time-averaged sediment-deposition rate for time-stratigraphic interval at a sample site, we measured the thickness of sediment between time-stratigraphic markers, and divided the time-stratigraphic interval thickness (in centimeters, to two significant figures) by the time span between deposition of the lower and upper time-stratigraphic markers (in decimal decades). We express the average rate of sediment-thickness increase during a time-stratigraphic interval, as the average sediment-deposition rate (sdr), in cm per decade (cm/10y, to two significant figures).

For a sample interval that matches a defined time-stratigraphic interval, the lead concentration of the sample interval represents the lead concentration of sediments deposited during the corresponding time-stratigraphic interval. That is the case for sample intervals that extend from the sediment surface at the time of sampling to the top of the 1980 volcanic-ash layer. For any time-stratigraphic interval (tsi) spanning more than one sample interval (si), we calculated thickness-weighted lead concentration for sediments deposited during the time interval as

$$\text{ppm Pb}_{tsi} = si_1(\text{cm} * \text{ppm Pb}) + si_2(\text{cm} * \text{ppm Pb}) + \ldots si_n / \text{total cm}_{ti}.$$

We retained four significant figures to calculate thickness-weighted average lead concentrations, and summary statistics. However, calculation of thickness-weighted average lead concentrations involves multiplication and division of lead concentrations by interval thickness, measured to two significant figures. We therefore rounded summary statistics for thickness-weighted average lead concentrations, and estimated rates of lead deposition to two significant figures.

Descriptive Summary Statistics

We used Microsoft EXCEL® to calculate and tabulate descriptive summary statistics and perform student's t-tests. Statistical measures used to describe and compare the data are listed, defined and described briefly as follows, after Spiegel (1961), Parratt (1971), Gonick and Smith (1993), and Koch and Link (1970).

Statistical Definitions

n = number of sample sites,

Min to max = minimum value to maximum value (defines the limits of the range or spread in the data),

Mode = value of the most frequent occurrence (most probable value),

Mean (experimental arithmetic mean, or average) = sum of values / n,
(The most important indicator of the central tendency of normal distributions, but sensitive to outliers in skewed distributions, and unstable in small populations)

Standard deviation (stdev) = [(sum of deviations from the mean)^2 / (n – 1)]$^{1/2}$,
The standard deviation is the usual estimator of the spread from the mean in normal distributions. The mode, median, and mean are coincident in normal distributions, and the data are distributed symmetrically about the mean. Approximately 68 percent of the values are within +/- one standard deviation of the mean, and 95 percent of the values are within +/- two standard deviations of the mean,

Coefficient of variation (CV) = standard deviation / mean, (ratio of the standard deviation to the mean),

Peakedness (or kurtosis): a measure of peak height versus peak width, (+) indicates relatively peaked, (-) indicates relatively flat,

Skewness: characterizes the degree of symmetry of a distribution around its mean, (+) indicates a distribution with an asymmetric tail extending toward more positive values, (-) indicates a distribution with an asymmetric tail extending toward more negative values,

Geometric mean (geo mean) = antilog of the sum of logs of non-zero values / n, (indicates the central tendency of a lognormal distribution, in which most values are small, but a few are very large, and the logarithms of the values follow a normal distribution),

Median (med) = middle value in an odd number of values (ordered by magnitude), or average of two values closest to the middle in an even number of values),

Student's *t*-test: statistical test used to determine whether the means of relatively small sample sets are significantly different, and represent significantly different populations of data. The probability P(T<=t) depends on the relationship of the spreads of the values in the data sets and on the sizes of the sample sets being compared, as indicated by the degrees of freedom (df). The populations are assumed to have normal distributions, but the test works reasonably well if CV is less than 1.2 (Koch and Link, 1970), and the distribution is approximately mound-shaped (Gonick and Smith, 1993). The test is run with the null hypothesis that the two compared data sets are the same, which implies that P(T<=t) = 0. If the two data sets are not the same, the test results are expressed as a decimal fraction, such as 0.05, which indicates the degree of uncertainty that the two populations represented by the data sets are identical. Subtracting this decimal fraction from 1 and multiplying by 100 gives the percent-probability that the represented populations are different. If P(T<=t) is 0.05 or less, the probabilities are 95% to 100% that the populations are different, so they are classified as significantly different. If P(T<=t) between 0.05 and 0.25, the probabilities are 75% to 95% that the populations are different, so we classify them as probably different. If P(T<=t) is between 0.25 and 0.50, the probabilities are 50% to 75% that the populations are different, so we classify them as possibly different. If P(T<=t) is between 0.50 and 0.75, the probabilities are 25% to 50% that the populations are different, so we classify them as possibly not different. If P(T<=t) is 0.95 or more, the probabilities are 5 percent or less that the populations are different, so we classify them as practically no different.

Statistical Characterizations

Four tables of summary statistics document sedimentation rates, and five tables document lead concentrations in sediments deposited in different depositional settings during different time-stratigraphic intervals. These tables list the summary statistics defined above for each sample set that represents sediments deposited in each depositional setting, during a particular time-stratigraphic interval, or pair of intervals to be compared. We list the arithmetic mean, geometric mean, and median as alternative representations of central tendency. Since most of the data sets have distributions that are intermediate between normal and lognormal, none of these statistical indicators perfectly represents the central tendency of the represented population. To further characterize distributions, we list peakedness and skewness, although these may be poorly defined in small data sets.

The area-weighted average of the medians of sediment-deposition rates or lead concentrations in different depositional settings weights the median for each depositional setting in proportion to the area-fraction of the floodplain that it represents (rather than to the number of sample sites in each setting). Bookstrom and others (2001) estimated areas covered by lead-rich sediments in each of the following depositional settings as: Riverbed, 7.3 km^2; Riverbank, 2.2 km^2; Upland, 14.0 km^2; Palustrine, 19.6 km^2; Lacustrine littoral, 8.3 km^2; and Lacustrine limnetic, 9.6 km^2. Thus, lead-rich sediments cover about 61 km^2 of the 84 km^2 of the floor of the Coeur d'Alene River valley, 57.3 km^2 of the non-riverine floodplain, and 44.1 km^2 of the non-limnetic part of the floodplain.

In tables comparing relatively small data sets with different means, but with standard deviations that overlap, we tested whether the means of the two data sets are significantly different by applying a two-tail Student's t-test, assuming unequal variances in the data sets. We compared data from the same interval in different depositional settings, and data from different intervals in the same depositional setting.

We use cumulative frequency diagrams to show the cumulative probability of values relative to their magnitudes (as in figures 9, 13 and 19). Histograms indicate frequency by class interval (as in figures 11, 12, 15, and 16). Box-and-whisker plots (made with the Statview®) show the median (50^{th} percentile) at the waist of a box, bounded by the 25^{th} and 75^{th} percentiles, with vertical lines extending down to the 10^{th} percentile and up to the 90^{th} percentile, and dots for individual values down to the minimum and up to the maximum (figures 17, 21, and 23).

We cite the mean and standard deviation to characterize the central tendency and the spread, respectively, for most of the determinations. According to Koch and Link (1970), the mean is more than 90-percent efficient if the CV is less than 1.2, as it generally is for our data sets (See tables). If the standard deviation is greater than the mean (and the minimum is not less than zero), we also cite minimum and maximum values to indicate the total range of the spread of values.

Statistically Based Estimates

We use the median as a conservative indicator of the central tendency for purposes of estimating volumes and tonnages of lead-rich sediments deposited, and of tonnages of lead in such sediments. Unlike the arithmetic mean, the median (or 50th percentile) is not much affected by relatively rare and extreme values in small data sets. The median generally is very close to the geometric mean, and is a more commonly used and widely understood indicator of the central tendency than the geometric mean.

The mean may be strongly affected by relatively rare and extreme values, especially in relatively small data sets. Nevertheless, we use the arithmetic mean of annual rates of bank-retreat to generously estimate the average annual tonnage of bank sediments mobilized by bank erosion.

Stratigraphy of Unconsolidated Sediments

Pre-Industrial Sediments

Pre-industrial sediments in the valley of the main stem of the Coeur d'Alene River are unconsolidated fluvial and lacustrine sediments of Pleistocene to Holocene age that contain less than100 ppm Pb. The thickness of pre-industrial sediments along the deep axis of the bedrock valley increases down-valley. Norbeck (1974) used drill holes and geophysical data to estimate that the maximum thickness of pre-industrial sediments in the Coeur d'Alene River valley increases from about 60 m at a cross-section near Cataldo, to about 130 m at a cross-section between Rose Lake and Killarney Lake. The U.S. Army Corps of Engineers (1952) drilled three holes to investigate a proposed dam site near Springston. The deepest hole penetrated about 120 m of sand, silt and clay, but failed to reach bedrock.

Background Sediment-Deposition Rates (sdrBG)

In the central part of Killarney Lake, 600 cm of pre-industrial organic silt was deposited during about 6700 y at a time-averaged rate of 0.9 cm/decade. A drill core from the central part of Killarney Lake recovered 50 cm of metallic-organic silt (deposited during the mining era) deposited on 600 cm of pre-industrial organic silt, overlying 30 cm of Mazama volcanic ash (Sprenke and others, 2000). Bacon (1983) reported an isotopic age determination of 6730 +/- 40 y for the Mazama volcanic ash. Thus, the average background rate of sediment deposition in Killarney Lake was 0.9 cm/decade from about 6700 years ago to about 100 years ago.

Background sediment-deposition rates in lateral marshes and levee back slopes probably were similar to those in lateral lakes (about 0.9 cm/decade). However, background sediment-deposition rates may have been up to twice as high along riverbanks (about 1.8 cm/decade). Nevertheless, riverbanks comprise only about 4 percent of the total floodplain area, so the area-weighted average of background sediment-deposition rates for the entire floodplain probably was about 1 cm/decade.

Background Lead Concentrations (PbBG)

For a set of 233 samples from 92 samples taken from below the section of lead-rich sediments, and containing less than 100 ppm Pb, we calculated the following summary statistics for background lead concentrations (PbBG) in sediments deposited before mining-derived sediments from the Coeur d'Alene mining area began to be deposited in the lower Coeur d'Alene River valley.

Minimum of PbBG, 4 ppm Pb,
Maximum of PbBG, 97 ppm Pb,
Mode of PbBG, 17 ppm Pb,
Mean +/- standard deviation of PbBG, 31 +/- 19 ppm Pb,
Median of PbBG, 26 ppm Pb.

According to Krauskopf and Bird (1995) the global-average abundance of lead in shale is 20 ppm, which is close to the mean concentration of lead in sediments of the St. Joe River valley. Abraham (1994) reported lead concentrations ranging from 21 to 23 ppm Pb in six samples of sediments from the St. Joe River valley, which has no known exposures of Coeur d'Alene-type veins, and is unaffected by mining.

Results of a Student's t-test indicate that the mean of lead concentrations in Coeur d'Alene-River background sediments is significantly higher than the mean of lead concentrations of sediments in the St. Joe River valley, both of which are underlain by predominantly argillitic rocks (metamorphosed shaly rocks) of the Belt Supergroup. The somewhat higher lead concentrations in background-era sediments of the Coeur d'Alene River valley probably resulted from weathering and erosion of veins exposed in the Coeur d'Alene mining region before mining began. However, the vein-derived component of pre-mining sediments in the Coeur d'Alene River valley was small, because only small volumes of ore minerals were exposed in outcropping veins, exposed locally to weathering and erosion, while very large volumes of surrounding host rocks were exposed to weathering and erosion throughout the drainage basin. That changed rapidly as large-scale mining selectively brought vein material to the surface, to be pulverized, and exposed to oxidation, and down-valley transport.

The Section of Lead-Rich Sediments (PbR)

We define the section of lead-rich sediments (PbR) as the part of the stratigraphic section of surficial sediments that contains at least 1000 ppm Pb. The base of the section of lead-rich sediments is the base of the lowest sample interval containing at least 1000 ppm Pb, and the top of the lead-rich interval is the top of the highest sample interval containing at least 1000 ppm Pb. Rarely, a sample interval containing less than 1000 ppm Pb is included in the section of lead-rich sediments, if it is bracketed above and below by lead-rich sediments, and the thickness-weighted average of the lower-grade interval and the overlying interval exceeds 1000 ppm.

Lead-rich sediments cover about 60 km^2 of the 80 km^2 of the surface of the floor of the main stem of the Coeur d'Alene River valley (Bookstrom and others, 2001). Most lead-rich surface sediments are highly enriched in zinc and silver, and enriched in copper, cadmium, iron, and manganese, relative to median concentrations of those elements in sediments outside the area contaminated by mining wastes, or deposited before mining began. Some lead-rich sediment is also highly enriched in arsenic, antimony, and mercury (Fousek, 1996, Box and others, 2001). Concentrations of lead are commonly highest near the base of the section of lead-rich sediments, and decrease up-section from the basal maximum (figure 8). This reflects the history of lead production and milling practices, as summarized in figures 7a and 7b. Maximum lead concentrations near the base of the section reflect the early peak in lead production, which occurred when jig tailings with very high concentrations of lead (and zinc) were being discarded directly into streams.

Horowitz and others (1995) described a full section of lead-rich sediments, and reported the results of their analyses for lead and Cs isotopes for core H123, which they extracted from the toe of the Coeur d'Alene River delta in Coeur d'Alene Lake (table 1). On the basis of time-stratigraphic markers, cesium isotopic age determinations, and the history of tailings production and disposal, we divide the section of lead-rich sediments into time-stratigraphic units, as shown in figure 8 and table 1, and described below.

Table 1. Stratigraphic Section of Lead-Rich Sediments from Coeur d'Alene Lake (after Horowitz and others, 1995)

Time-Stratigraphic Markers

Time-stratigraphic markers are identifiable stratigraphic beds or layers that were deposited at a known time, or during a relatively short time span that is known exactly, or approximately.

Surface at the Time of Sampling (1991 to 1998)

We define the surface at the time of sampling as the top of the section of mineral-dominated sediments at the time of sampling. To estimate the baseline sediment-deposition rate for a particular site, we measured the thickness of sediment above the 1980 layer at that site, and divided that thickness by decades from May of 1980 to the sampling date (to the nearest year, or tenth of a decade). Duff, consisting primarily of decomposing plant debris with only a small proportion of sediment commonly overlies mineral-dominated sediments, but was not included in measurements of thickness, or in samples of sediments collected for chemical analysis. Most sample sites (111 of 131 sites, or 85 percent) were sampled during the summers of 1991 through 1995, and 71 (or 54 percent) were sampled in 1993. Thus, most sampling was done before South-Fork floodplain remediation projects began in late 1995, and before the major floods of 1996 and 1997. However, 20 sites (or 15 percent) were sampled in 1998 to fill gaps in the spatial distribution of sample sites on the floodplain.

Mt. St. Helens Volcanic-Ash Layer (1980)

On May 18, 1980, the Mt. St. Helens volcano (in western Washington) erupted explosively, blasting volcanic ash high into the atmosphere (Corcoran, 1985). Prevailing southwest winds carried the volcanic-ash plume east, and tuff particles settled to the ground, covering the Coeur d'Alene River valley with a distinctive layer of nearly white ash-fall tuff. Spring runoff had peaked twice before the ash fall, but peaked again on May 27, after the peak of the ash fall. Coeur d'Alene Lake fluctuated between 0 and 0.6 m (0 and 2 ft) above summer water level as the volcanic ash fell during late May and early June (U.S. Geological Survey, 1981). In December of 1980 a significant over-bank flood rose to 3.6 m (12 ft) above summer water level at Dudley (AVISTA - Washington Water Power, unpub. data, 1980), variously eroding, re-distributing, and burying unconsolidated volcanic ash.

Where it is preserved on the floodplain of the Coeur d'Alene River, the 1980 Mt. St. Helens volcanic ash forms a nearly white layer of microscopic shards of volcanic glass (bubble-wall fragments) and crystals, buried beneath subsequently deposited sediments. The 1980 volcanic-ash layer varies in thickness from 0.2 to 4.5 cm, with a mean and standard deviation of 0.8 +/- 0.7 cm thick (based on measurements at 91 sites). The 1980 volcanic-ash layer contains various proportions of admixed metal-enriched floodplain sediment. Thus, lead concentrations in 4 samples from the 1980 layer range from 620 to 1300 ppm, and average 1020 ppm Pb (Fousek, 1996, Horowitz and others, 1995).

Where it was buried and preserved in the stratigraphic section, the 1980 volcanic-ash layer provides a time-stratigraphic marker. Sediments below it were deposited before May 18, 1980, and sediments above it were deposited later. The ash layer is well preserved in the upper part of the section of sediments at a high proportion of sites along riverbanks and levees. However, the 1980 volcanic-ash layer is only locally present in palustrine and littoral settings, and is absent from riverbed sediments, and from sediments on limnetic bottoms of lateral lakes.

A thick layer of duff at many palustrine sites may have inhibited the formation of a distinct ash layer. Where the ash layer is present in palustrine and littoral settings, it tends to be relatively thick and diffuse, and is penetrated by networks of rootlets. Thus it appears that root-growth progressively disrupts the ash, and mixes it with sediments above and below it.

Volcanic ash that fell on the river probably was carried away during a late-May peak in spring runoff, or during a flood the following December. Volcanic ash that settled to the limnetic bottoms of lateral lakes, probably mixed with water-saturated diatomaceous ooze, which has collected on lateral-lake bottoms since the water clarified after cessation of tailings disposal to tributary streams in about 1968-69 (Hoffmann, 1985). Mixing of volcanic ash into such mobile, water-saturated, organic ooze probably prevented the formation and preservation of a distinct layer of 1980 volcanic ash in limnetic zones of lateral lakes.

Horowitz and others (1995) recorded the 1980 volcanic-ash layer in 8 of 12 gravity cores from Coeur d'Alene Lake-bottom sediments, which contained layered sediments both below and above the 1980 layer. Coeur d'Alene Lake is much deeper than the lateral lakes, and its bottom sediments evidently are less organic-rich, less water-saturated, less mobile, and less subject to disruption than the bottom sediments of shallower lateral lakes.

Base of Section of Lead-Rich Sediments (~1903)

Metal-enriched sediments may have begun to be deposited on the floor of the valley of the main stem of the Coeur d'Alene River during the floods of 1893 and 1894. These were the first major floods after large-scale milling began in 1886. Horowitz (1995) estimated that metal-enriched sediments were first deposited in Coeur d'Alene Lake between 1895 and 1911 (~1903 +/- 8 y). The 1895 date was calculated on the basis of the time it would take for the full thickness of lead-rich sediments to be deposited at the post-1951 rate of sediment deposition. That rate was determined on the basis of the thickness of sediments deposited after the 1951 onset of ^{137}Cs fallout from atmospheric nuclear testing, which was detected in drill-core sediments. However, sediment-deposition rates probably varied through time. The 1911 date was based on counts of sedimentary laminations, presumed to represent annual layers. However, it is more likely that each layer represents a significant discharge event. Such events may not have occurred every year, but may have occurred more than once in some years.

In 1903, farmers in the lower valley filed the first of many lawsuits against mining companies, alleging damage from upstream disposal of tailings (Long, 2000). This provided the first well-documented claim of serious damage to the floodplain of the main stem of the Coeur d'Alene River as a result of upstream tailings disposal. We therefore interpret the base of the section of lead-rich sediments in the Coeur d'Alene River valley as an approximate time-stratigraphic horizon, representing the onset of deposition of lead-rich sediments in about 1903. It probably took the farmers some time to organize their lawsuit, but they may have sued before lead concentrations widely exceeded 1,000 ppm. We therefore follow Horowitz (1995) in bracketing the onset of mining-derived metal deposition between 1895 and 1911. Thus, we estimate that the base of the section of lead-rich sediments represents an approximate time-stratigraphic horizon, approximately dated as 1903 +/- 8 y.

Time-Stratigraphic Intervals

We measure and name time-stratigraphic intervals on the basis of their relationship to the sedimentary surface at the time of sampling, the 1980 volcanic-ash layer, and the base of the section of sediments. We start from the top of the section, because the surface at the time of sampling is known for every section, and depth to the 1980 volcanic ash is known for most sections. However, sampling did not reach the base of every section of lead-rich sediments, containing at least 1000 ppm Pb.

Pre-Remedial Baseline Interval, AA (1980 ~1993)

The pre-remedial baseline interval (AA) consists of mineral-dominated sediments above the 1980 volcanic-ash layer at the date of measurement and sampling (54 percent of which was done in 1993, 85 percent of which was done between 1991 and 1995, and 15 percent of which was done in 1998). The baseline interval is considered pre-remedial, because most sampling was done before sediments were removed from large areas in the South Fork drainage basin, beginning in late 1995. Baseline sediment-deposition rates and lead concentrations provide a basis for comparison to previous and subsequent sediment-deposition rates and lead concentrations. To calculate the baseline rate of sediment deposition for each site, we used the time span from May of 1980 to the sampling date, rounded to the nearest year. In text, tables and figures, however, we simplify the composite time span to that represented by 85 percent of the samples, which is from 1980 to 1993 +/- 2 y, or 1980 ~1993.

Historic Floodplain-Contamination Interval, BA, (~1903 to 1980)

The historic floodplain-contamination interval (BA) consists of sediments below (and deposited before) the 1980 volcanic-ash layer. Sediments of the BA stratigraphic interval probably were deposited between about 1903 +/- 8y and 1980. Thus, sediments of the BA interval were deposited during a time span of about 77 +/- 8 y. Average BA-interval sediment-deposition rates, calculated on the basis of a 77-y time span, therefore have a relative error of about +/- 10 percent

Lead concentrations and lithologic characteristics of BA-interval commonly change down-section, so that the BA interval can be divided into subintervals, which can be recognized fairly consistently. Since the 1980 volcanic ash provides a clear, sharp time-stratigraphic marker, and the BA interval lies below it, we number BA subintervals BA1 and BA2 with increasing depth below the 1980 marker layer (which is opposite to the usual geologic practice of numbering stratigraphic units in the historical order of deposition, from the base of the section upward).

Early Post-Tailings-Release Subinterval, BA1 (~1968 to 1980)

In 1968, daily disposal of about 2,200 t of tailings to tributary streams ended (Hoffmann, 1995), and dredging at Cataldo Landing stopped. Thus, the daily supply of fine-grained suspended tailings was greatly reduced, but the supply of sandy sediment increased, because such sediment was no longer being removed from the river at Cataldo Landing. In response to these changes, rates of deposition of sandy sediments nearly doubled at the toe of the Coeur d'Alene River delta in Coeur d'Alene Lake, whereas rates of deposition of fine-grained sediments decreased to about 14 percent of historical BA rates at sites along the central axis of the lake, north of the delta toe (tables 1 and 2). Meanwhile, in bays of Coeur d'Alene Lake with tributaries not connected to the Coeur d'Alene River, rates of deposition of moderately metal-enriched sediment (formed by mixing of clean tributary sediment with metal-enriched lake sediment) continued more-or-less unchanged (table 2).

Table 2. Sediment-Deposition Rates and Lead Concentrations, Coeur d'Alene Lake Sediments below and above the 1980 Volcanic-Ash

We define the early post-tailings-release (BA1) subinterval to include any sample interval that directly underlies the 1980 volcanic-ash layer, and is within 10 percent of the thickness of the overlying the AA time-stratigraphic interval. In oxidizing environments, sediments of the AA and BA1 intervals tend to be relatively sandy and loose, as compared to underlying sediments, which tend to be finer grained, more oxidized, and more consolidated by iron-oxide cementation. However, there is no consistently recognizable marker layer at the base of the BA1 interval. Furthermore, we did not define the BA1 subinterval until after most of sampling had been done, and at most sites the sample interval directly below the 1980 marker layer is more than 10 percent thicker than the overlying AA interval. Therefore, we have lead-concentration data for the BA1 subinterval at only 13 sites, eight of which are in oxidizing environments along riverbanks and levees.

Since the AA and BA intervals both followed cessation of tailings disposal into tributary streams, and both followed cessation of dredging, we suggest that decadal sediment-deposition rates probably were similar for sediments of the AA interval and the underlying BA1 subinterval, unless the histories of flooding for the two intervals were very different. Although the flood histories of the AA and BA1 intervals are not identical, they are roughly similar. The 1974 flood, with a peak discharge of about 72,000 ft^3/s at Cataldo, was the only major flood during the BA1 subinterval, whereas three smaller floods with peak discharges of near 40,000 ft^3/s occurred during the baseline interval (S.E. Box, unpublished compilation of USGS stream-gage data, 1993).

If AA and BA1 sediment-deposition rates were similar, and the assigned thickness of the BA1 interval is within 10 percent of the thickness of the AA interval, then the time span represented by the BA1 interval is within about 10 percent of the time interval represented by the AA interval (13 +/- 2 y). Thus, sediments of the BA1 interval probably were deposited mostly between about 1967 +/- 2.2 y and 1980, and most sediments of the BA1 subinterval probably were deposited after the 1968 cessation of tailings-release into streams.

Tailings-Release Subinterval, BA2 (~1903 to ~1968)

The tailings-release subinterval (BA2) consists of lead-rich sediments that lie below the BA1 interval. The thickness of the BA2 subinterval is defined by the thickness of the BA interval minus that of the BA1 subinterval. There is no time-stratigraphic marker layer between the BA1 and BA2 subintervals, but in the oxidizing environments of riverbanks and levees, sediments of the BA2 interval tend to contain higher proportions of fines, and tend to be more thoroughly cemented by iron-bearing oxides than overlying sediments of the BA1 subinterval and the AA interval.

Sediments of the BA2 subinterval probably were deposited between about 1903 +/- 8 y and 1967 +/- 2 y, when tailings were being released continuously into upstream tributaries in the Coeur d'Alene mining region, and tailings-bearing sediments were being deposited on the floodplain of the main stem of the Coeur d'Alene River. Since the BA1 subinterval was sampled at only 13 sites, and the base of the section of sediments was not exposed at many of those sites, the thickness and thickness-weighted average lead concentration of the BA2 subinterval can only be estimated for a few sites, one of which is summarized in table 1.

Jig Tailings-Release Sub-Subinterval, BA2J (~1903 to ~ 1918)

The jig tailings-release sub-subinterval (BA2J) is defined by a zone of very lead-rich sediments, containing 6000 to 30,000 ppm Pb, which commonly is present at the base of the section of sediments (table 1 and figure 8). The upper boundary of the BA2J sub-subinterval is transitional, and therefore difficult to identify closely or consistently. Nevertheless, we interpret the BA2J sub-subinterval to represent sediments deposited from about 1903 +/- 8y to about 1918 +/- 6y, when lead production was peaking, jig milling was predominant, and most tailings were being discarded directly into streams.

Flotation Tailings-Release Sub-Subinterval, BA2F (~1918 to ~ 1968)

The flotation tailings-release sub-subinterval (BA2F) lies above the jig-tailings-release sub-subinterval (BA2J). The thickness of the flotation-tailings-release sub-subinterval is that of the BA2 subinterval minus that of the BA2J sub-subinterval (table 1 and figure 8). We interpret sediments of the BA2F sub-subinterval to represent sediments deposited from about 1918 +/- 6y to 1968, when flotation milling was predominant, and some tailings were still being discarded directly into streams.

Early Metal-Enrichment Interval, EME (~1893 ~1903)

The early metal-enrichment interval includes discontinuous lenses of metal-enriched sediments that lie beneath the section of lead-rich sediments. Metal-enriched sediment may have begun to be deposited on the floodplain of the main stem of the Coeur d'Alene River during the major floods of 1893 and 1894, about 8 or 9 years after large-scale mining and milling began in the Coeur d'Alene mining region. However, discontinuous lenses of metal-enriched sediments below the section of sediments probably were deposited before the 1903 lawsuit, which we interpret to indicate widespread and significant damages from deposition of tailings-contaminated sediment on the floodplain of the main stem of the Coeur d'Alene River.

Alternatively, some occurrences of metal-enriched sediments below the section of sediments may contain metals that were chemically leached from the overlying section of sediments, and re-deposited beneath it. Other occurrences of metal-enriched sediments below the section of sediments may have resulted from down-hole contamination during sampling. Down-hole contamination is likely at sites where samples were collected by drilling underwater, as at the Dudley drill site (figure 8).

Character of Sediments by Depositional Setting

The thickness, grain size, and thickness-weighted average lead concentrations of sediments generally decrease with increasing distance from the river and its distributary channels. Depositional settings, in which deposited sediments are stored, also change laterally, from predominantly subaqueous in the river channel, to predominantly subaerial along the riverbanks and levees, to seasonally and perennially subaqueous in lateral marshes, and to predominantly subaqueous in lateral lakes. Figure 8 shows lead-concentration profiles for typical sections of sediments in riverbed, riverbank, lateral-marsh, and lateral lake environments.

Figure 8. Lead concentration profiles for stratigraphic sections of sediments in the Coeur d'Alene River and on its floodplain.

Riverbed Sediments

Riverbed sediments contain about 51 percent of the lead in sediments on the floor of the main stem of the Coeur d'Alene River valley (Bookstrom and others, 2001). In the lower perennial riverine subsystem, west of Cataldo Landing, riverbed sections of sediments commonly have a basal jig tailings-release sub-subinterval with very high lead concentrations, between 10,000 and 30,000 ppm Pb. Near Dudley, this basal interval grades upward to a flotation tailings-release sub-subinterval of well-layered olive gray, medium-grained sand and silt containing about 10,000 to 14,000 ppm Pb. About an upper meter of active bed sediment consists of well-mixed, poorly stratified, light olive gray to olive brown sand, with subordinate interstitial silt- and mud-sized particles, and with lead concentrations in the range 3,000 to 6,000 ppm Pb (figure 8).

Riverbed sediments are water-saturated, and are stored in transitional suboxic to anoxic conditions, with pore water pH ranging from 6.3 to 7.0 (Balistrieri and others, 2000). Riverine sediments have Zn/Pb ratios greater than 1 (Box and others, 2001, in press). Detrital sulfides of zinc, iron, and lead (sphalerite, pyrite and galena) are more common in riverine deposits (below the zone of annual water-level fluctuation) than in relatively oxidized subaerial deposits on riverbanks and levees (Rantala and Hooper, 1996).

Riverbank and Levee Sediments

Riverbank-wedge deposits of sediments contain about 4 percent of the lead in sediments on the floor of the Coeur d'Alene River valley, and levee back-slope deposits of sediments contain about 10 percent of that lead (Bookstrom and others, 2001). Lead-rich sediments on riverbanks and natural levees are mostly sand and silt, variably cemented by red, brown, orange, yellow and black iron and manganese oxides hydroxides and oxy-hydrides, formed by subaerial weathering of iron-bearing sulfide ore minerals, and manganese-bearing sulfide and carbonate minerals, derived from mined veins. Rare detrital sulfide grains are severely pitted, indicating that they have been partially dissolved, and "lead occurs in a wide variety of ferro-manganese/oxy-hydroxide phases" that typically form "non-stoichiometric and nano-crystalline grain coatings" (Thornburg and Hooper, 2001). Zinc is a minor component of complex manganese oxy-hydrides and is strongly partitioned into siliceous ferri-hydrite grain coatings. In oxidizing levee sediments, where pore water is weakly acidic due to the oxidation of iron-bearing sulfides, zinc is leached and depleted relative to lead. Therefore, sediments on riverbanks and uplands generally have Zn/Pb ratios less than 1.0 (Box and others, 2001, in press).

On the river-facing fore-slope of the levee crest, a wedge-shaped prism of sediments thickens down-slope from the levee crest toward the riverbank (figure 6). Above the 1980 volcanic-ash layer, loose, sandy, pale-brown sediment, commonly containing 3000 to 5000 ppm Pb tops riverbank sections of blocky, iron-oxide-cemented riverbank sediments. Post-1980 bank sediment resembles active riverbed sediment from the upper part of the section of lead-rich sediments stored in the riverbed. Like the active riverbed sediment, the post-1980 bank sediment contains detrital grains of sphalerite, pyrite, and galena, and it has Zn/Pb ratios of 1 or more, because it has not been long exposed to the oxidizing environment of the riverbank. It represents the fraction of the active riverbed sediment that was fine-grained enough to be transported to the surface of the riverbank, and coarse-grained enough to be deposited there. Its presence indicates that the surface of the riverbank receives vertical deposition of sandy sediment during floods, even as the face of the riverbank is eroded laterally.

The levee back-slope extends from the levee crest to the lateral marshes and lakes. It slopes gently away from the river and the levee crest. Sandy to silty sediment, carried in the lower part of the floodwater column, settles on levee back-slopes in order of decreasing grain-size and density. Relatively thick deposits of levee sand form where sand is washed over the levee on the outer, down-valley margins of meanders. Very thick sand splays form where floodwaters flow through low passes in the levee, and spread onto lateral marshes. During floods, oxidized sediments on levee back-slopes may be vulnerable to mobilization and transport into adjacent lateral marshes and lakes.

Palustrine Sediments

Palustrine (lateral-marsh) sediments contain about 8 percent of the lead in sediments on the floor of the Coeur d'Alene River valley (Bookstrom and others, 2001). Lateral marshes are present along the lower margins of levee back-slopes, and some extend into the mouths of some side valleys. In seasonally flooded parts of lateral marshes, sediments are drained and oxidized during the dry season, but are flooded and reduced during and after winter and spring floods.

In lateral marshes with emergent vegetation, a mat of duff (decaying organic debris) commonly develops above mineral-dominated sediments. Muddy to powdery sediment commonly coats organic debris in the duff, but the percentage of sediment in the duff is low. Below the duff layer, sediments generally consist of silty mud that is poorly stratified. In general, the concentrations of lead in mud or dust from the duff are similar to those in underlying sediment. The 1980 Mt. St. Helens ash layer is recognizable at only a small percentage of palustrine sites, probably because rootlets of abundant surface vegetation tend to disrupt the ash layer.

In perennially water-saturated to subaqueous lateral marshes, sediments are mostly dark gray to black silt and mud, indicative of suboxic to anoxic conditions. Detrital metallic-sulfide mineral grains are rare in lateral-marsh sediments, but Thornburg and Hooper (2001) identified a wide variety of microcrystalline to amorphous sulfidic-metal bio-coatings with various proportions of lead, zinc, copper, and sulfur. They interpreted these as authigenic metallic-sulfidic biochemical sediments. Such sediments may form as follows: 1. Oxidized sediments are winnowed from levees and transported to marshes, where they are deposited and stored under reducing conditions. 2. Fe and Mn oxy-hydrides are reduced, which releases metallic ions. 3. Sulfide ions, produced by sulfate-reducing bacteria, combine with metallic ions to form authigenic biochemical metallic-sulfidic sediments.

Organic peat with very little mineral or metal content commonly underlies the section of sediments in palustrine settings. The underlying peat has background lead concentrations and was deposited before tailings-bearing sediments began to accumulate in lateral marshes.

Lacustrine Sediments

Lateral-lake sediments contain about 10 percent of the lead in sediments on the floor of the Coeur d'Alene River valley (Bookstrom and others, 2001). Lead-rich sediments in lakeshore littoral zones (less than 2 m deep at summer water level) are similar to those in lateral marshes. However, sections of sediments on the relatively flat bottoms of lateral lakes (generally 5 to 6 m deep) are different. Rember and others (1993) used a freeze box to recover non-layered, organic-rich, water-saturated sediment from the top of the stratigraphic section of sediments in the limnetic zone of Medicine Lake. According to Robert Hooper (personal communication, 2003), the non-layered sediment at the top of the lake-bottom section of sediments is diatomaceous. It also is homogeneous with respect to lead concentration, as indicated by assays of similar material from other freeze-box cores. This non-layered sediment is underlain by metal-enriched silty mud that is finely laminated and compact. Drill cores apparently fail to recover the watery diatomaceous ooze at the top of the section, but do recover the compact, laminated silt and mud below it. The section of laminated metal-enriched sediments is underlain by non-layered, organic-rich, metal-poor mud that accumulated before the deposition of overlying tailings-contaminated sediments.

Many lateral lakes fill the mouths of side valleys that are tributary to the main-stem valley. Lake shores adjacent to levees and marshes slope gently, but lakeshores along the sides of tributary valleys in bedrock slope steeply. Sandy deltas form at the mouths of distributary streams, which deliver sediment from the river, and of tributary streams, which deliver clean sediment from tributary valleys. Runoff from nearby levees and marshes also supplies sediment to lateral lakes.

Some lateral lakes, like Bull Run Lake, are close to the river and directly connected to it by one or more short distributary channels. Sections of sediments in such settings tend to have very high maximum lead concentrations near their bases (figure 8, Bull Run Lake section). Others, like Rose Lake, are far from the river, and are not connected to it by an active distributary channel. Sections of sediments in such settings tend to have lower maximum lead concentrations, which commonly peak well above the base of the section of lead-enriched sediments (figure 8, Rose Lake section).

Baseline Depositional Rates and Lead Concentrations

Baseline Sediment-Deposition Rates, Overall Summary Statistics

Baseline sediment-deposition rates measured at 125 sites on the floodplain of the main stem of the Coeur d'Alene River vary from 0 to nearly 29 cm/10y, and have an overall mean and standard deviation of 4.7 +/- 4.3 cm/10y. Table 3 lists summary statistics for baseline sediment-deposition rates on the floodplain, based on data listed in appendix 1, collected from sample sites shown on plate 1. The mean and standard deviation for baseline sediment-deposition rates for riverbanks is 6.9 +/- 5.3 cm/10y, as compared to 3.7 +/- 3.8 cm/10y for levee uplands, 2.5 +/- 1.7 cm/10y for palustrine lateral marshes, 2.4 +/- 1.4 cm/10y for littoral zones of lateral lakes, and 3.8 +/- 0.8 cm/10y for limnetic zones of lateral lakes (table 3).

Table 3. Baseline Sediment-Deposition Rates for Floodplain Sediments of Interval AA (1980 ~1993)

Results of Student's *t*-tests indicate that baseline rates of sediment deposition are significantly higher for the population of sites along riverbanks than for the populations of sites in all other depositional settings on the floodplain. Baseline rates of sediment deposition on upland levee back-slopes are similar to those on limnetic lake bottoms, but baseline sediments on uplands are sandy to silty, whereas those on limnetic lake bottoms consist of organic-rich, and water-saturated slime or slurry. Baseline rates of sediment deposition in lateral marshes and littoral zones of lateral lakes are similar, and are lower than those on levee back-slopes and littoral lake bottoms.

Baseline sediment-deposition rates are greater than 2 cm/10y at 65 percent of 125 measurement sites, greater than 3 cm/10y at 50 percent, greater than 5 cm/10y at 30 percent, and greater than 8 cm/10y at 20 percent of those sites (figure 9). Local maximum sediment-deposition rates (and local ranges of rates) decrease with increasing distance from the river (figure 10). Nearly all of the sites with baseline sediment-deposition rates above about 5 cm/decade are along riverbanks or natural levees. Baseline sediment-deposition rates, which commonly are greater than 10 cm/decade on riverbank and levee-upland sites near the river, generally decrease to less than 5 cm/decade at distances over 500 m from the river. Baseline sediment-deposition rates in palustrine and lacustrine settings generally are less than about 5 cm/decade, but range up to about 8 cm/decade at one palustrine site that is about 450 m from the river (figure 10).

Figure 9. Cumulative frequency diagram showing baseline sediment-deposition rates (sdrAA) for sediments deposited on the floodplain from 1980 to about 1993.

Figure 10. Scatter diagram showing baseline sediment-deposition rates (sdrAA) versus distance (m) from the Coeur d'Alene River.

The frequency distribution of baseline sediment-deposition rates (sdrAA) for the entire floodplain has a positive skewness of 2.28, a mode of 3.9 cm/decade (table 3 and figure 11). The overall distribution of natural logs of sdrAA is roughly symmetrical, which indicates a lognormal distribution (figure 12). Therefore, the geometric mean of 3.4 cm/decade is a better indicator of the central tendency than the arithmetic mean of 4.7 cm/decade. The median of sdrAA is 3.1 cm/decade is close to the geometric mean rate, and is a more commonly used indicator of the central tendency. The median of baseline rates of sediment deposition along riverbanks is 6.4 cm/decade, as compared to 2.8 cm/decade for upland levee back-slopes, 2.2 cm/decade for palustrine lateral marshes, 2.9 cm/decade for littoral shores of lateral lakes, and 4.0 cm/decade for limnetic bottoms of lateral lakes. The area-weighted average of these medians is 2.9 cm/decade for the floodplain as a whole.

Figure 11. Frequency diagram of baseline sediment-deposition rates (sdrAA).

Figure 12. Frequency diagram of natural logs of baseline sediment-deposition rates (ln sdrAA).

Baseline Lead Concentration, Overall Summary Statistics

Baseline lead concentrations in lead-rich sediments of the AA interval (PbAA) at 77 floodplain sites (plate 2) range from 1100 to 7500 ppm Pb, with a mean and standard deviation of 3400 +/- 1500 ppm Pb, and a median of 3300 ppm Pb (table 4). Means and standard deviations of PbAA by depositional setting are: 3400 +/- 990 ppm Pb for 20 riverbank sites, 3600 +/- 1600 ppm Pb for 40 levee upland sites, 2800 +/- 2100 ppm Pb for 9 palustrine sites, 2300 +/- 900 ppm Pb for 5 littoral sites, and 4100 +/- 1200 ppm Pb for 3 limnetic sites (table 4). Results of Student's *t*-tests indicate that the means of PbAA for riverbank and upland sites are significantly higher than for littoral sites, and the mean of PbAA for limnetic sites probably is higher than for palustrine and littoral sites. About 85 percent of floodplain sites have baseline lead concentrations (PbAA) greater than 1000 ppm Pb, about 50 percent have PbAA greater than 2700 ppm Pb, and about 15 percent PbAA greater than 5000 ppm Pb (figure 13). Maximum lead concentrations and ranges of lead concentrations generally decrease with increasing distance from the river, but with high outliers in limnetic settings between 700 and 1700 m from the river (figure 14).

Table 4. Baseline Lead Concentrations in Floodplain Sediments of Interval AA (1980 ~1993)

Figure 13. Cumulative frequency distribution of baseline lead concentrations (PbAA) in floodplain sediments.

Figure 14. Scatter diagram showing ppm Pb in floodplain sediments of the baseline interval (PbAA) versus distance from the Coeur d'Alene River.

The frequency distribution for baseline lead concentrations in lead-rich floodplain sediments is positively skewed, with a mode of 1800 ppm (table 4 and figure 15). The distribution of natural logs of PbAA in floodplain sediments is negatively skewed, which indicates that the distribution is not lognormal (table 4 and figure 16), possibly because the sample set is truncated, and includes no samples with less than 1000 ppm Pb. Inasmuch as the distribution is positively skewed, we favor the median as an indicator of central tendency for baseline lead concentrations in floodplain sediments. Medians of lead concentration in sediments of the baseline interval vary from 3300 ppm Pb on riverbanks to 3800 ppm Pb on levee uplands, 1900 ppm Pb in lateral marshes, 2100 ppm Pb on littoral margins of lateral lakes, and 4100 ppm Pb on limnetic bottoms of lateral lakes. The area-weighted average of the medians for all depositional settings is 2900 ppm Pb (table 4).

Figure 15. Frequency diagram of baseline lead concentrations (PbAA) in floodplain sediments.

Figure 16. Frequency diagram of natural logs of baseline lead concentrations (PbAA) in floodplain sediments.

Baseline Sediments of Various Depositional Settings and Areas

This section summarizes available data on baseline rates of sediment-deposition, and lead concentrations in sediments of the baseline interval for riparian riverbanks of the Coeur d'Alene River, as compared to nearby rivers, for riparian uplands, and for selected wetlands and lakes. In wetlands where the 1980 volcanic-ash layer was not found, or where it was found at only a single site or a few sites, lead-concentration data for surface sediments, sampled from depth intervals of 0 to 5 cm, or 0 to 10 cm, are included. In limnetic zones of lateral lakes, where the 1980 volcanic-ash layer was not found, lead concentrations from non-layered sediment above laminated lead-rich sediments are interpreted to represent the baseline interval.

Riparian Riverbanks, Baseline Sediments, Main Stem of Coeur d'Alene River

Means and standard deviations of baseline sediment-deposition rates on main-stem riverbanks (from summer water level to levee crest) vary downstream, from 8.5 +/- 6.2 cm/10y for 26 sites along the upper main stem, to 5.3 +/- 3.0 cm/10y for 9 sites along the middle main stem, and 5.5 +/- 4.0 cm/10y for 12 sites along the lower main stem (table 3 and figures 3, 4, and 5). Student's *t*-tests indicate a 90-percent probability that the data set for the upper main stem represents a population that is statistically different from that for the middle main stem, and an 87-percent probability that the data set for the upper main stem represents a population that is statistically different from that for the lower main stem. However there is only a 15 percent probability that data sets for the middle and lower main stem represent statistically different populations. The median of lead concentrations in baseline sediments on riverbanks is 3300 ppm Pb, with a minimum of 1800 ppm Pb, and a maximum of 5400 ppm Pb (table 4).

Baseline sediment deposition rates are relatively high on point-bar banks along inner margins of meanders, intermediate along both banks of relatively straight reaches, and relatively low on cut-banks along outside margins of meanders (as indicated by summary statistics based on data tabulated and classified in appendix 1, and illustrated in plate 1). For 42 sites from Cataldo Landing to Thompson Lake, baseline sediment-deposition rates on riverbanks vary locally as a function of position relative to river-channel meanders. The mean and standard deviation of sediment-deposition rates for 12 sites along inside (point-bar) margins of meanders is 9.5 +/- 7.1 cm/10y, as compared to 7.6 +/- 4.4 cm/10y for 14 sites along relatively straight river reaches, and 5.7 +/- 4.1 cm/10y for 16 sites along the outside (cut-bank) margins of river-channel meanders. Student's *t*-tests indicate an 88-percent probability that the data sets for inside- and outside-margins of meanders represent different populations, and a 76-percent probability that the data for outside margins and straight-reaches represent different populations, but only a 56-percent probability that the data for inside margins and straight reaches represent different populations.

Comparison to Baseline Sediments on Banks of nearby Rivers

Disturbances related to mining in the Coeur d'Alene mining region contribute to abnormally high rates of sediment deposition in the Coeur d'Alene River valley, but post-1980 sediment-deposition rates are also high in neighboring river valleys where little to no large-scale mining has occurred. We measured a sedimentation rate of 4 cm/10y at a site on a riverbank of the North Fork of the Coeur d'Alene River. Relatively little large-scale mining has occurred in the North Fork drainage basin, which is much larger than the South Fork drainage basin, where most of the large-scale mines of the region were operated. We also measured a sediment-deposition rate of 8 cm/10y at a riverbank site on the lower St. Joe River, at the lower end of a large drainage basin where there has been little or no large-scale mining. Average daily discharge rates of the three rivers in 1999-2000, as reported by Clark (2003) were: 2240 ft^3/s for the North Fork, 2730 ft^3/s for the Coeur d'Alene River, and (about 3000 ft^3/s) for the lower St. Joe River. The ratio of riverbank sediment-deposition rate to discharge rate was therefore 0.0018 for the North Fork site, 0.0023 for the main stem of the Coeur d'Alene River, and 0.0027 for the lower St. Joe site. Since there has been little mining in the St. Joe drainage basin, these comparisons appear to indicate that other disturbances, such as erosion related to logging, road-building and forest fires are at least as important as mining in causing abnormally high post-1980 sedimentation rates along the margins of these three rivers.

Riparian Levee Uplands, Baseline Sediments

For 23 sites from Cataldo Landing to Thompson Lake, baseline sediment-deposition rates on levee uplands (on the flood-basin side of the levee crest) vary locally as a function of position relative to river-channel meanders. The mean and standard deviation of sediment-deposition rates for 10 levee-upland sites lateral to (and down-valley from) outside margins of meanders is 6.5 +/- 6.4 cm/10y, as compared to 3.4 +/- 2.2 cm/10y for 10 sites lateral to inside margins of meanders, and 1.8 +/- 0.3 cm/10y for 3 sites lateral to relatively straight river reaches (as indicated by summary statistics based on data tabulated and classified in appendix 1, and illustrated on plate 1). Student's *t*-tests indicate a 96-percent probability that inside-margin and straight-reach rates of sediment deposition are different, a 94-percent probability that outside-margin and straight-reach rates are different, and an 82-percent probability that outside- and inside-margin rates are different. The median of lead concentrations in baseline sediments of levee uplands is 3800 ppm Pb, with a minimum of 1400 ppm Pb and a maximum of 6600 ppm Pb (table 4).

Riparian Distributary Levees and Sand Splays, Baseline Sediments

Baseline sediment-deposition rates, measured at 6 sites along the levees of distributary streams vary from 0.8 to 3.9 cm/10y, with a mean and standard deviation of 2.1 +/- 1.3 cm/10y. By contrast, baseline sediment-deposition rates near the centers of two sand splays were higher, ranging from 4.6 to 9.2 cm/10y, and averaging 6.9 cm/10y (plate 1 and appendix 1). Lead concentrations in baseline sediments at 8 sites on distributary levees and sand splays generally decrease with distance from the river, from 5300 +/- 1200 ppm Pb at 200 to 300 m from the river, to 4600 +/- 130 ppm Pb at 300 to 350 m, to 4300 +/- 3300 ppm Pb at 400 to 500 m from the river, to 1500 +/- 880 ppm Pb at 600 to 700 m from the river (plate 1 and appendix 1).

Thick sand-splay deposits are common in the middle segment of the floodplain, and probably account for the highly variable thickness of baseline-interval sediments on uplands of the middle segment of the floodplain. The CV for sdrAA on uplands in the middle segment of the floodplain is high (1.04), as compared to corresponding CVs for the upper floodplain segment (0.77) and the lower floodplain segment (0.36). Sand splays form where river water overflows through a low pass in the natural levee, spreads onto the floodplain, and deposits sand as it loses velocity. Sand-splay deposits generally are thickest and coarsest-grained near the river, and thinner and finer-grained towards their outer edges.

Wetlands, Palustrine and Littoral Baseline and Surface Sediments

Table 5 lists overall summary statistics for baseline depositional rates and lead concentrations for sediments from palustrine and littoral wetlands, and summary statistics for available data from each of several palustrine and littoral wetlands under consideration for remediation, including Lane Marsh South, Medicine Lake, Cave Lake, Bare Marsh, Thompson Lake, Thompson Marsh, and Anderson Lake. Summary statistics for individual wetlands include lead-concentration data for surface samples. Fousek (1996) routinely sampled from 0 to 5 cm, but also collected sub-samples above and below the 1980 volcanic ash, if present. Campbell and others (1999) consistently sampled from 0 to 10 cm. Means of baseline rates of sediment-deposition are 2.4 cm/10y for littoral, and 2.5 cm/10 y for palustrine areas. At the mean baseline sediment-deposition rate 2.5 cm/10y for palustrine settings, the 5-cm surface samples, collected by Fousek in 1993 would include sediments deposited during a 20-y interval beginning in about 1975. At the same depositional rate, the 10-cm samples, collected in 1995 by Campbell and others (1999), would include sediments deposited during a 40-y interval, beginning in about 1955.

Lead concentrations commonly increase down-section, especially in the lower part of the section of lead-rich sediments. We therefore expected that 5- to 10-cm samples of surface sediment would have consistently higher lead concentrations than samples of the shallower baseline interval at the same sites. However, the mean and standard deviation for 998 samples of surface sediment from throughout the floodplain is 3400 +/- 3000 ppm Pb (Bookstrom and others, 2001), and the mean and standard deviation for 77 samples of sediments of the baseline interval is 3400 +/- 1500 ppm Pb (table 4). Thus, the means of the surface-sample and baseline-sample sets are equal, but the CV for surface samples is 0.88, whereas the CV for baseline samples is 0.44. This indicates that although the means of the surface-sample and baseline-sample sets are equal, there is more variability in the surface-sample set than in the baseline sample set.

Table 5. Baseline Depositional Rates and Lead Concentrations, and Lead in Surface-Sediments of Selected Wetlands

Lane Marsh South, Palustrine Baseline and Surface Sediments

Lane Marsh South is separated from the river by the railroad embankment, which acts as a setback levee that serves to inhibit floodwater from transporting lead-bearing sediment to the marsh behind it. At 6 widely scattered sites in Lane Marsh South, surface sediments contained an average of about 1600 +/- 1500 ppm Pb (minimum 445 to maximum 4680 ppm Pb), as compared to 2800 +/- 2100 ppm Pb for baseline sediments of palustrine settings throughout the floodplain. The ratio of the mean of lead concentrations in Lane Marsh South to the mean of baseline lead concentrations for palustrine settings throughout the floodplain is 0.57. This indicates that the potential severity of contamination in Lane Marsh South is about 43 percent less than average for palustrine settings on the floodplain. However, the maximum lead concentration was 4680 ppm Pb at a site south of the gap in the railroad embankment.

In Lane Marsh North, between the levee crest and the railroad embankment, surface sediments averaged 4900 +/- 1700 ppm Pb in an area where baseline sediment-deposition rates were relatively high (11 to 21 cm/10y, as compared to 6.9 +/- 5.3 cm/10y for riverbank wedges, and 3.7 +/- 3.8 cm/10y for levee uplands). Thus, while lessening the severity of contamination behind it (in Lane Marsh South) the railroad embankment apparently increased the rate and severity of contamination on its river-facing side (in Lane Marsh North).

Medicine Lake, Littoral Baseline and Surface Sediments

At Medicine Lake, the palustrine to littoral wetland being considered for remediation includes two sites where post-1968 rates of sediment deposition range from 0.5 to 2.9 cm/10y. The mean and standard deviation of lead concentrations in surface sediments at seven palustrine and littoral sites around Medicine Lake is 2200 +/- 1200 ppm Pb (minimum 362 to maximum 5620 ppm Pb), as compared 2800 +/- 2100 ppm for palustrine sites, and 2300 +/- 900 ppm for littoral sites throughout the floodplain). This indicates that baseline sediment-deposition rates and lead concentrations in palustrine and littoral areas around Medicine Lake are similar to those in most palustrine and littoral areas on the floodplain.

Cave Lake, Littoral Baseline and Surface Sediments

We have no data for baseline sediment-deposition rates in the palustrine and littoral zones of Cave Lake, but mean and standard deviation of lead concentrations in eight samples of littoral surface sediments is 440 +/- 560 ppm Pb (minimum 36 to maximum 1590 ppm Pb). Although Cave Lake is connected to Medicine Lake by a narrow passage, it is partly isolated from the river by a bedrock hill, and is not directly connected to the river by any distributary that is not blocked by the railroad levee.

Baseline sediment-deposition rates and lead concentrations in surface sediments are therefore low in palustrine and littoral zones marginal to Cave Lake.

Bare Marsh, Palustrine Baseline and Surface Sediments

Bare Marsh is on the inside (northern) margin of an obtuse 120-degree bend in the river channel, and its upstream end is somewhat protected by the nose of a bedrock ridge that reaches the north bank of the river. Nevertheless, the sediment-deposition rate was 3.1 cm/10y at a site near the upstream end of the marsh, in the transition zone between levee-back-slope and palustrine settings. That is similar to the mean rate of 2.5 +/- 1.7 cm/10y for palustrine sites throughout the floodplain (table 5).

The mean and standard deviation of lead concentrations in surface sediments at 26 scattered sites in Bare Marsh was 1500 +/- 1600 ppm Pb (minimum 71 to maximum 5870 ppm Pb, with CV = 1.1) as compared to 2800 +/- 2100 ppm Pb for baseline sediments of palustrine sites throughout the floodplain. The ratio of the mean of lead concentrations in surface-sediment samples from Bare Marsh to the mean of lead concentrations in palustrine settings is 0.54, but the high maximum concentration (5870 ppm Pb), and the large CV (1.1) indicate extreme spatial variation in lead concentrations. Inasmuch as the variation of lead concentrations in our baseline sample set is about half of that in the surface-sample set, we expect that baseline and future contamination may be less variable than indicated by the surface-sample set. We therefore expect that the area selected for cleanup may receive contaminated sediment at about the average rate for palustrine settings, but with lead concentrations that average about 54 percent of the mean for palustrine-settings throughout the floodplain, but might range up to about the average for levee uplands (3600 +/- 1600 ppm Pb) in the transitional zone from levee back-slope to lateral marsh.

Thompson Lake, Littoral Baseline and Surface Sediments

Thompson Lake lies on the northern, outside margin of an acute 65-degree bend in the river. A short distributary channel connects the lacustrine part of the Thompson Lake area directly to the river. Most of the palustrine and littoral wetlands around Thompson Lake lie north and west of the river, and are vulnerable to floodwater flow, outward and down-valley from the western margin of this acute meander bend. By contrast, a relatively small northeastern part of the marsh receives mostly uncontaminated sediment from a lateral tributary.

The only data on baseline sediment-deposition rates in wetlands around Thompson Lake is from a distal littoral site, where the baseline rate of sediment deposition was 2.5 cm/10y, which is very similar to the 2.4-cm/10y mean of baseline sediment-deposition rates for littoral settings throughout the floodplain. The mean and standard deviation of lead concentrations in surface sediments from 20 sites in palustrine and littoral settings of the Thompson Lake area is 4000 +/- 2200 ppm Pb. That is 1.4 times the 2800 +/- 2100 ppm Pb mean for palustrine sites, and 1.7 times the 2300 +/- 900 ppm Pb mean for littoral sites throughout the floodplain.

Thompson Marsh, Littoral Baseline and Surface Sediments

Thompson Marsh lies beside a straight reach of the river, and is separated from the river by a road embankment, built along the levee crest. A dike at the east end of Thompson Marsh separates it from Thompson Lake and its surrounding marshes. The mean of lead concentrations in surface sediments from 19 palustrine sites in Thompson Marsh is 1400 +/- 1600 ppm Pb, as compared to 2800 +/- 2100 ppm Pb for baseline sediments of palustrine settings throughout the floodplain. Thus the mean of lead concentrations in surface sediments is 50 percent of the mean for palustrine settings throughout the floodplain. Nevertheless, Thompson Marsh is frequently flooded, and lead-rich sediment continues to be deposited there.

Anderson Lake, Littoral Baseline and Surface Sediments

Except for a bridged distributary channel at its western end, Anderson Lake is separated from the river by the railroad embankment, which is built along the crest of the natural levee, which is relatively narrow. The mean and standard deviation of lead concentrations in surface sediments at six littoral sites in Anderson Lake is 600 +/ 980 ppm Pb, as compared to 2300 +/- 900 ppm Pb for baseline sediments of littoral settings throughout the floodplain. However, the moderately high maximum, large standard deviation, and high CV (1.63) for lead concentrations in surface-samples indicate a high degree of spatial variability within the area being considered for remediation. Three areas with relatively high lead concentrations are near the northeastern margin of the lake, near a small distributary at the northwestern (down-valley) end of the lake, and near the margins of the limnetic lake bottom.

Limnetic Post-Tailings-Release Sediments

Because the 1980 volcanic-ash layer is not present in most sections of lead-rich sediments deposited on limnetic lateral lake bottoms, alternate approaches were required to estimate the baseline depositional rates or to define the baseline time interval. These approaches are described for data from three lateral lakes below.

Medicine-Lake, Limnetic Post-Tailings-Release Sediments

Rember and others (1993) dated sediments in freeze-box core M92CS (from Medicine Lake) on the basis of cesium-isotopic activities, measured with a gamma-ray spectrometer. Radioactive ^{137}Cs accumulated in the environment from 1951 to 1963-1964 as a result of fallout from atmospheric testing of nuclear weapons. After 1963-1964, atmospheric testing of nuclear weapons ended, and ^{137}Cs activity in the environment decreased as a result of radioactive decay.

In freeze-box core M92CS (from Medicine Lake) non-layered, water-saturated, organic-rich sediment above the 10-cm depth is underlain silty laminated sediment. Rember and others (1993) identified the 1951 onset of ^{137}Cs accumulation in the 30-32 cm depth interval, and the 1963-1964-peak in ^{137}Cs activity in the 16-18 cm depth interval. This indicates that 14 cm thickness of sediment was deposited in 12.5 y, at an average rate of 1.1 cm/y (or 11 cm/decade). Extrapolation of that depositional rate to the 10-cm depth, where laminated sediments are overlain by non-layered sediment, indicates that the change from layered silty sediment to non-layered organic-rich sediment occurred in about 1969. Thus, the upper 10 cm of non-layered sediment accumulated in about 23 y (from 1969 to 1992) at an average rate of 4.3 cm/decade, as compared to the pre-1969 rate of 11 cm/decade (table 6).

Rember and others (1993) credited the cessation of tailings-disposal into streams (beginning in 1968) for the reduction in sediment-deposition rate, and the change from laminated silty sediments (deposited before about 1969) to non-layered, water-saturated, organic-rich sediments (deposited after about 1969). As the proportion of silty suspended tailings decreased, lake water clarified, and sunlight penetrated the relatively shallow waters of lateral lakes, allowing diatoms and other aquatic organisms to flourish, and increasing the proportion of organic sediment deposited on lake bottoms. The resulting non-layered, water-saturated, organic-rich sediment was too soft and mobile to preserve the 1980 volcanic-ash layer (and too mobile to be recovered by conventional core drilling). Nevertheless, the change from layered to non-layered sediment provides a 1969 time-stratigraphic marker that can be recognized in other freeze-box cores. If the post-tailings-release rate of sediment deposition is assumed constant, the 1.2-decade AA interval occupies the upper 5.2 cm of non-layered sediment, and the baseline rate of sediment deposition at site was about 4.3 cm/decade at site M92CS on the bottom of Medicine Lake (table 6).

Table 6. Sediment-Deposition Rates, Medicine Lake Site M92CS

Hoffmann (1995) reported lead concentrations for 2-cm sample intervals from freeze-box site M91A, on the distributary inlet delta in Medicine Lake, about 300 m northwest of M92CS. In the deltaic setting of site M91A, the upper 8 cm of the section was sandy silt, rather than organic-rich sediment. By analogy with the post-1968 increase in sand in core 123, on the toe of the Coeur d'Alene River delta in Coeur d'Alene Lake, we interpret the up-section change from silt to sandy silt on the distributary delta in Medicine Lake as a time-stratigraphic marker, indicating the ending of sand-dredging at Caltaldo Flats and the cessation of tailings disposal into tributary streams, in 1968-1969.

Assuming relatively consistent rates of sediment deposition after 1968-1969, sediments of the baseline interval occupy the top 4 cm of the M91A section, and baseline (AA) and post-tailings (BA1) intervals were deposited at a rate of about 3.6 cm/decade. The lead concentration in 4 cm of baseline (AA) sediments averages 5200 +/- 1200 ppm, as compared to 5900 +/- 1200 ppm in the underlying 4 cm of post-tailings-release, pre baseline sediments of the BA1-subinterval. From 4 cm to the bottom of the hole at 52 cm, sediments of the BA interval contain an average of 5000 +/- 2000 ppm Pb. The hole bottomed in sediments containing 3900 ppm Pb, and did not reach the basal spike in lead concentration (table 7).

Table 7. Lead in Lateral-Lake Sediments of Baseline (AA), Post-Tailings-Release (BA1) and Historic (BA) Intervals

Killarney Lake, Limnetic Post-Tailings-Release Sediments

Bender (1991) reported lead concentrations for 2-cm increments of freeze-box section KF (or 91SBKF2) near the middle, deepest part of Killarney Lake, where a full section of sediments was 50 cm thick. No description of the sediments in this particular section was published. Nevertheless, we suggest that the 1969 time-stratigraphic horizon can be recognized on the basis of a change from sediments at the top of the section, in which lead concentration is consistent, to underlying sediments in which lead concentrations fluctuate, and generally increase down-section. Sediments in the upper five 2-cm sample intervals, which represent the top 10 cm of the section, contain an average of 4200 +/- 220 ppm Pb. The relatively small standard deviation (220 ppm) and low coefficient of variation (0.05) indicate that the upper 10 cm of sediment is nearly homogeneous with respect to lead concentration. We interpret this to indicate that the upper 10 cm of sediment was deposited after 1969, when earlier deposition of layered sediments changed to deposition of homogeneous, non-layered sediments, in response to cessation of tailings disposal into tributary streams in 1968. Below the 10-cm depth, lead concentrations fluctuate and increase progressively down-section, to a maximum of 37,400 ppm at a depth of 42 to 44 cm. This indicates that sediments below the 10 cm depth are layered, and can thus be correlated with layered sediments of the BA interval, deposited before about 1969 in the dated M92CS section.

If the upper 10-cm interval of homogeneous sediment was deposited at the KF site after about 1969, and rates of sediment deposition were relatively consistent from 1969 to 1991, then about 5 cm of homogeneous sediment was deposited during the baseline (AA) interval, from 1980 to 1991. Therefore, the post-1980 baseline rate of sediment deposition (sdrAA) was 5 cm in 11 y, or 4.5 cm/decade. Before 1980, about 45 cm of sediment was deposited at the KF site during the approximately 77-y historic baseline (BA) interval, at an average rate of 5.8 cm/decade (table 7). Thus, the ratio of sdrAA to sdrBA at the KF site is 0.78.

From 0 to 5 cm of depth, sediments interpreted to represent the baseline (AA) interval contain an average of 4400 +/- 170 ppm Pb, as compared to an average of 4100 +/- 150 ppm Pb in sediments of the BA1 interval, at 5 to 10 cm of depth (table 7). Sediments interpreted to represent the entire BA interval extend from 5 to 50 cm deep, and contain an average of 12000 +/- 9600 ppm Pb. The freeze box sampled to 50 cm deep, and bottomed in sediments containing 600 ppm Pb.

Thompson Lake, Limnetic Post-Tailings-Release Sediments

Hoffmann (1995) reported lead concentrations for 2-cm increments of freeze-box section T91A, near the middle and deepest part of Thompson Lake, where he sampled a nearly full section of sediments. He published no description of these sediments. The upper three 2-cm sample intervals, are nearly homogeneous with respect to lead concentration, and contain an average of 2800 +/- 85 ppm Pb, with a very low coefficient of variation (0.03). Below 6 cm, lead concentrations fluctuate and increase progressively down-section, indicating layered sediments, with a mean of 7800 +/- 4500 ppm Pb (table 7), and a maximum of about 17,000 ppm at the bottom of the 48-cm hole.

By analogy with the dated section M92CS, we suggest that homogeneous sediments above the 4-cm depth were deposited after 1969, and layered sediments below that were deposited before 1969. If sediment-deposition rates were relatively consistent from about 1969 to 1991, about 3 cm of homogeneous sediment would have accumulated during the 11-y baseline (AA) interval, at an average rate of 2.7 cm/10y from 1980 to 1991 (table 7) Before that, the historic (BA) rate of deposition, during the 77 y from about 1903 to 1980, was 5.5 cm/decade (or more, depending on how much of the BA interval lies below the 48-cm depth reached by the freeze box).

Depositional Rates and Lead Concentrations through Time

By comparing depositional rates and lead concentrations of baseline-interval sediments with those of previous time-stratigraphic intervals, we can outline trends in sediment-deposition rates and lead concentrations in sediments deposited through time, from about 1893 to about 1993.

Historic and Baseline Depositional Rates

The historic rate of sediment deposition (sdrBA) is calculated as the thickness (cm) of sediment below the 1980 volcanic-ash layer, divided by the approximately 7.7-decade duration of the of the BA time-stratigraphic interval, which began in 1903 +/- 8 y, and ended in 1980. Historic rates of deposition of sediment on the floodplain average 7.8 +/- 7.3 cm/decade, with a geometric mean of 5.2 cm/decade, and a median of 4.7 cm/decade (table 8, middle part).

Medians of sdrBA by depositional setting are 10 cm/decade for riverbanks, 3.6 cm/decade for levee uplands, 4.0 cm/decade for palustrine lateral marshes, 3.2 cm/decade for littoral margins of lateral lakes, and 5.8 cm/decade for limnetic lateral lake bottoms. The area-weighted average of the medians for all depositional settings is 4.3 cm/decade. Student's t-tests indicate that the mean of sdrBA for riverbank sites is significantly higher than the mean for limnetic sites, and probably is higher than the means for upland and palustrine sites (table 8, middle part).

Summary statistics for sediment-deposition rates for the baseline interval (table 8, upper part) can be compared to sedimentation rates for the historic interval (table 8, middle part). The data represent baseline and historic sediment-deposition rates for 46 sites where we were able to determine both sdrAA and sdrBA. All indicators of central tendency are lower for sdrAA than for sdrBA in all floodplain depositional settings. A series of t-tests indicates that the mean of sdrAA is significantly lower than sdrBA for limnetic sites, and also is probably lower for upland settings (table 8). For the floodplain as a whole, there is an 87-percent probability that sdrAA is lower than sdrBA.

Table 8. Sediment-Deposition Rates for Paired Baseline and Historic Intervals (sdrAA and sdrBA)

Box-and-whisker plots compare distributions of baseline (right) and historic (left) sediment-deposition rates at 46 floodplain sites (figure 17). Baseline sediment-deposition rates (sdrAA) were lower than historic rates (sdrBA) at the maximum, 90th-, 75th-, and 50th- and 25th-percentile levels of the two populations. For example, the ratio of sdrAA to sdrBA was about 0.77 at the maximum level, about 0.75 at the 90th and 75th percentiles, 0.77 at the 50th percentile, and 0.67 at the 25th percentile.

Figure 17. Box-and-whisker plots comparing sediment-deposition rates for sediments of the historic (BA) and baseline (AA) time-stratigraphic intervals.

Figure 18. Scatter diagram showing sediment-deposition rates (sdrAA and sdrBA) versus distance from the river.

Table 9. Sediment-Deposition-Rate Ratios for Paired Baseline and Historic Intervals (sdrAA/sdrBA)

A scatter diagram (figure 18) shows rates of sediment deposition for paired sdrAA and sdrBA intervals at 46 sites, plotted as a function of distance from the river. Maximum values and ranges of sdrAA and sdrBA are highest along riverbanks, and decrease sharply with increasing distance from the river. However, maximum values of both sdrAA and sdrBA increase slightly on limnetic lateral-lake bottoms between 500 and 2000 m from the river. At most distances from the river, the highest sdrAA values (colored symbols) are lower than the highest sdrBA values (open symbols). At the outermost margin of the floodplain, however, lead-rich sediments of the baseline (AA) interval overlap sediments of the historic interval that contain less than 1000 ppm Pb, and therefore represent 0 cm of lead-rich sediment.

Summary statistics indicate that baseline sediment-deposition rates on most of the floodplain generally decreased relative to historic rates, but the opposite occurred at about 50 percent of riverbank sites. Summary statistics for the ratio of sdrAA to sdrBA at individual sites indicate a median of 1.05, a mean of 1.72 +/- 2.33, and a range of 0.1 to 10.3 (table 9). At 11 of 22 sites, the ratio of sdrAA to sdrBA was1.05 or more, at one site it was between 0.95 and 1.05, and at 10 sites it was 0.95 or less. Reasons for this may include the following: 1. Although cessation of tailings disposal in 1968 reduced the supply of fine-grained sediment, it did not significantly affect the supply of sandy sediment to be deposited on riverbanks, 2. Deposition of sandy sediment at riverbank sites is dependent on local and temporary variations in flow velocities, which vary according to flood histories and changing local channel morphologies, 3. Cessation of dredging at Cataldo Landing allowed increased transport of sandy sediment, some of which was suspended and lofted onto riverbanks, but much of which was transported down-river, and deposited on the Coeur d'Alene River delta, where baseline depositional rates increased relative to historic rates by a factor of 1.86 (table 2).

Historic and Baseline Lead Concentrations

The mean concentration of lead in sediments of the historic interval (PbBA) at 28 sites is 5900 +/- 3200 ppm Pb, the geometric mean is 4900 ppm Pb, the median is 5400 ppm Pb, and the area-weighted average of medians for all floodplain depositional settings is 5800 ppm Pb (table 10, middle part). As indicated by Student's *t*-tests, the mean of PbBA for sandy riverbank sites near the river may be less than the mean for silty upland sites, and probably is less than the mean for silty mud in limnetic sites (table 10, lower part). Thus, the tendency for lead concentrations to decrease with increasing distance from the river is countered by a tendency for lead concentrations to increase with increasing proportions of finer-grained sediment deposited on levee back-slopes, and especially at relatively distal limnetic sites.

A cumulative-frequency diagram shows thickness-weighted concentrations of lead (PbBA) in sections of the historic time-stratigraphic interval at 28 floodplain sites (figure 19). The thickness-weighted average of lead concentrations in sediments of the historic interval (PbBA) is greater than 3300 ppm Pb at 80 percent of sites, greater than 5400 ppm Pb at 50 percent, and greater than 8500 ppm Pb at 20 percent. The sites are coded to indicate depositional setting. At most riverbank sites, the historic interval has PbBA between about 3300 and 5500 ppm, and the sediments are sandy to silty. At most levee upland (back-slope) sites PbBA is between 5200 and 8400 ppm, and the sediments are relatively silty. Three limnetic sites have PbBA between 5000 and 12,000 ppm, and most lead-rich sediments are silty to muddy. A scatter diagram of PbBA as a function of distance from the river displays widely scattered data points, showing no clear and consistent relationship between thickness-weighted average lead concentrations for sediments of the BA interval versus distance from the river (figure 20).

Table 10 lists summary statistics for concentrations of lead in sediments of the baseline and historic intervals at 28 sites where both complete intervals have been analyzed for lead. All indicators of the central tendency of PbAA are lower than corresponding indicators for PbBA. The mean of PbAA for the 28 sites is 3100 +/- 1700 ppm, as compared to the 5900 +/- 3200-ppm mean of PbBA. Thus, the ratio of the means of PbAA to PbBA is 0.53. A Student's *t*-test confirms that the mean of PbAA is significantly lower than the mean of PbBA for the floodplain as a whole (table 10, bottom). The box-and-whisker plots in figure 21 show that baseline lead concentrations (PbAA) are clearly lower than historic PbBA at a range of percentile levels. The ratio of the median of PbAA to the median of PbBA is 0.57, and the average of the ratios of PbAA to PbBA at the maximum, 90th, 75th, 50th, and 25th –percentile levels is 0.52.

The mean of baseline to historic lead-concentration ratios (PbAA/PbBA) for 28 floodplain sites is 0.71 +/- 0.38, and the median is 0.72 (table 11). The area-weighted average of medians of PbAA/PbBA by depositional setting is 0.61. As indicated by Student's *t*-tests, the mean of PbAA/PbBA ratios for riverbanks (0.84 +/- 0.26) probably is greater than the corresponding mean for levee-uplands (0.66 +/- 0.39), and may be greater than the mean for limnetic deposits (0.59 +/- 0.39). This indicates that baseline lead concentrations decreased less (relative to historic concentrations) at sandy riverbank sites than at silty levee upland sites, and less at riverbank and upland sites than at limnetic sites, typified by a change from historic laminated silt and mud to baseline organic-rich, water-saturated ooze.

Table 10. Lead Concentrations in Sediments of Paired Baseline and Historic Intervals (PbAA and PbBA)

Figure 19. Cumulative frequency diagram of thickness-weighted average lead concentration in sediments of the historic (BA) time-stratigraphic interval.

Figure 20. Scatter diagram showing thickness-weighted average ppm Pb in sediments of the historic (BA) interval versus distance from the Coeur d'Alene River.

Figure 21. Box-and-whisker plots, comparing interval-weighted average lead (ppm Pb) in sediments of the historic (BA) and baseline (AA) time-stratigraphic intervals.

Table 11. Lead-Concentration Ratios of Paired Baseline and Historic Intervals (PbAA / PbBA)

Although tailings disposal to tributary streams stopped in 1968, secondary sources of lead-rich sediments, previously deposited along floodwater flow paths continue to be mobilized during floods, and mixed with relatively uncontaminated sediments from tributaries largely unaffected by mining. Inasmuch as PbAA is lower than PbBA at 71 percent of 28 sites, and the ratio of the medians of PbAA and PbBA is about 0.52, the proportion of contaminated to uncontaminated sediments in the overall mix has tended to decrease since about 1968.

Early Post-Tailings-Release Depositional Rates (sdrBA1)

We defined the early post-tailings-release (BA1) subinterval as the uppermost subinterval of the historic BA interval, with thickness within 10 percent of the thickness of the overlying AA interval. Only 13 sample sites had a sample interval that fit this definition. We make the simplifying assumption that at any particular site, the time-averaged rates of sediment-deposition for the two post-tailings-release intervals (sdrAA and sdrBA1) were similar enough to be considered sub-equal. If sediments of the successive BA1 and AA intervals were deposited at sub-equal rates, they also were deposited during time spans of sub-equal duration. Since sediments of the AA interval were deposited during a time interval of about 13 +/- 2 y after 1980, we assume that sediments of the BA1 interval were deposited during a time interval of about 13 +/- 2 y before 1980 (or between about 1967 +/- 2 y and 1980).

Cessation of direct disposal of tailings into upstream tributaries, and cessation of dredging at Cataldo Landing occurred in about 1968, and presumably would have affected both post-1967 intervals more-or-less equally. However, since sediment transport increases geometrically with increasing discharge, the major flood of 1974 probably caused an episode of very high rates of sediment-transport and deposition during the BA1 time interval. That deposition may not have been fully compensated by deposition caused by three smaller floods during the AA interval. Thus, sediment in the BA1 interval may have been deposited in a somewhat shorter time interval than the sub-equal thickness of sediment in the AA interval. Thus, the time interval represented by the BA1 interval is likely to be shorter, rather than longer than 13 y, and deposition of the BA1 interval is more likely to have begun after than before 1967, possibly in about 1968.

Tailings-Release Depositional Rates (sdrBA2)

Sediments of the tailings-release (BA2) subinterval probably were deposited between about 1903 +/- 8 y and about 1968. If it took about 7.7-decades for deposition of BA-interval sediments, and about 1.2-decades for deposition of BA1-interval sediments, then sediment-deposition for the BA2 interval can be approximated according to the equation:

$$\text{sdrBA2} = (\text{sdrBA}*7.7 \text{ decades}) - (\text{sdrBA1}*1.2 \text{ decades}) / 6.5 \text{ decades}.$$

Substituting summary statistics for BA and BA1 intervals into this equation yields the following estimated summary statistics for BA2 sediment-deposition rates: sdrBA2 ranges from 0 to 36 cm/decade, with a mode of 3.5 cm/decade, a mean and standard deviation of 8.2 +/- 7.6 cm/decade, a geometric mean of 5.4 cm/decade, a median of 4.9 cm/decade, and an area-weighted average of medians for depositional settings of 4.3-cm/decade.

Figure 22 shows summary statistics for floodplain sediment-deposition rates during successive time-stratigraphic intervals. Before large-scale mining began in 1886, the background rate of sediment deposition on the floodplain of the main stem of the Coeur d'Alene River probably was about 1 cm/decade. From 1886 to 1968, mill tailings were discarded into the South Fork of the Coeur d'Alene River and some of its tributaries. Tailings-bearing sediments probably began to be deposited on the floodplain of the main stem of the Coeur d'Alene River during the major floods of 1893 and 1894.

From about 1903 to about 1968, tailings-bearing sediments of the BA2 time-stratigraphic interval were deposited on the floodplain of the main stem of the Coeur d'Alene River. The median of time-interval-averaged sediment-deposition rates for the BA2 interval is 4.9 cm/decade, which is nearly almost five times the background rate.

Sediment-deposition rates probably peaked during the winter flood of 1933. From about 1932 to 1967 a dredge removed sand from the river channel at Cataldo Landing every summer. River dredging after 1932, decreasing production after 1945, and increasing underground placement of sandy tailings after 1950 combined to decrease the supply of tailings-bearing sediment.

Nevertheless, about 2,200 t of tailings were still being discarded daily into the South Fork and some of its tributaries until 1968, when tailings disposal into streams was disallowed. After 1968, the median of floodplain sediment-deposition rates decreased to the baseline rate of 3.6 cm/decade, which is about 73 percent the median of rates during the preceding BA2 (tailings-disposal) interval, but is about 3.6 times the background rate.

Figure 22. Summary plot showing sediment-deposition rates for sediments of BG (background), BA2 (tailings-release), BA1 (post-tailings-release), and AA (baseline) intervals

Lead in Baseline versus Early Post-Tailings-Release Sediments

Table 12 compares lead concentrations in sediments of the baseline interval (PbAA) with those in sediments of the early post-tailings-release interval at 13 sites. Baseline lead concentrations at these sites have a mean of 3400 +/- 1500 ppm Pb, and a median of 3300 ppm Pb. The area-weighted average of medians of PbAA for sites in all depositional settings is 2500 ppm Pb (table 12). By comparison, lead concentrations in sediments of the early post-tailings-release subinterval (PbBA1) at these sites have a mean of 4000 +/- 1500 ppm Pb, and a median of 4000 ppm Pb. The area-weighted average of medians of PbBA1 for all depositional settings is 3800 ppm Pb. A Student's *t*-test indicates a 69-percent probability that the populations represented by these two small data sets differ significantly (table 12).

Box-and-whisker plots for the two data sets show that for the floodplain as a whole, baseline PbAA decreased relative to PbBA1 at the maximum, 90^{th}, 75^{th}, 50^{th}, 25^{th}, and 10^{th}-percentile levels (figure 23). Furthermore, the area-weighted average of medians of PbAA/PbBA1 ratios for the floodplain as a whole is 0.83, which suggests an overall 17-percent decrease in PbAA relative to PbBA1 (table 12).

The mean and standard deviation of PbAA/PbBA1 ratios is 0.87 +/- 0.28, which indicates a 13-percent decrease from PbBA1 to PbAA, but with a 28-percent spread at one standard deviation (table 13). While PbAA/PbBA1 ratios for levee upland settings decreased by about 16 to 30 percent, PbAA was unchanged relative to PbBA1 in limnetic settings, and PbAA increased by 14 to 18 percent relative to PbBA1 on riverbanks (as represented by three sites).

Table 12. Lead Concentrations in Sediments of Paired Baseline and Early Post-Tailings-Release Intervals (PbAA and PbBA1)

Figure 23.. Box-and-whisker plots, comparing interval-weighted average lead (ppm Pb) in sediments of the early post-tailings-release (BA1) and baseline (AA) intervals

Table 13. Lead-Concentration Ratios of Paired Baseline- and Early Post-Tailings-Release Intervals (PbAA / PbBA1)

Lead in Tailings-Release Sediments (PbBA2)

Sediments of the tailings-release (BA2) subinterval probably were deposited between about 1903 +/- 8 y and about 1968. If it took about 7.7-decades for deposition of BA-interval sediments, and 1.2-decades for deposition of BA2-subinterval sediments, the thickness-weighted average of lead concentrations in sediments of the BA2 interval can be approximated according to the equation:

$$PbBA2 = (PbBA*7.7 \text{ decades}) - (PbBA1*1.2 \text{ decades}) / 6.5 \text{ decades}.$$

Substituting summary statistics for PbBA and PbBA1 into this equation yields the following estimated summary statistics for lead concentrations in sediments of the BA2 subinterval: PbBA2 ranges from 570 to 15,000 ppm Pb, with a mean and standard deviation of 6300 +/- 3500 ppm Pb, a geometric mean of 5100 ppm Pb, and a median of 5800 ppm Pb. The area-weighted average of medians for all depositional settings is 6400 ppm Pb.

Lead in Sediments Deposited through Time

In sediments deposited before 1886, when large-scale mining began in the Coeur d'Alene mining region, the mean of background lead concentrations is 31 +/- 19 ppm, and the median is 26 ppm. Metal-enriched sediments may have begun to be deposited on the floodplain of the main stem of the Coeur d'Alene River during the floods of 1893 and 1894. Lead-rich sediments of the BA2 subinterval probably were deposited between about 1903 and 1968, and the mean and standard deviation of thickness-weighted lead concentration in sediments of the BA2 interval is 6300 +/- 3500 ppm, with a median of 5800 ppm. The BA2 (tailings-release) subinterval includes basal sediments of the jig-tailings-release subinterval, and overlying sediments of the flotation-tailings-release subinterval (figure 24).

Lead concentrations in sediments deposited on the floodplain of the main stem of the Coeur d'Alene River probably peaked during the jig-tailings-release sub-subinterval (BA2J, 1903 +/- 8y to 1918 +/- 5y). Jigs achieved poor recovery of ore minerals, and both coarse and slime fractions of very metal-rich tailings were discarded into streams. Lead production in the Coeur d'Alene region peaked in about 1917, in response to World War I. Concentrations of lead in sediment deposited on the floodplain may also have peaked in about 1917, when a flood washed-out tailings dams at Canyon Creek and Osburn Flats, transporting much of the accumulated tailings down-valley. During the BAJ sub-subinterval, lead concentrations in sediments deposited in Killarney Lake reached 37,000 ppm (Bender, 1991).

Figure 24 . Summary plot of lead concentrations (ppm Pb) in sediments of the background (BG) , BAJ (jig), BA2 (tailings-release), BA1 (early post-tailings-release) and AA (baseline) intervals.

Flotation milling achieved improved metal recoveries, so lead concentrations of tailings decreased during the flotation sub-subinterval (BA2F, 1918 +/- 5 to 1968). A major flood in 1933 brought a large pulse of sediment to the floodplain. After the 1933 flood, sands were dredged from the river at Cataldo Landing every summer until 1967. Production of ore (and probably of tailings) peaked in the late 1940s, and then declined. Beginning in the early 1950s, the sand fraction of tailings was increasingly used as underground backfill, and only the fine fraction was discarded into streams. Thus, the amounts and grain-sizes of tailings released to streams probably decreased during the late 1950s and early1960s. Finally, disposal of tailings to streams ended in 1968.

The mean concentration of lead in sediments of the post-tailings-release interval, deposited between 1968 and 1980, and sampled at 13 sites is 4000 +/- 1500 ppm, and the median is 4000 ppm. By comparison, the mean lead concentration of baseline-interval sediments, deposited from 1980 to about 1993 at the same sites is 3400 +/- 1500 ppm Pb, and the median is 3300 ppm Pb. Although the mean of lead concentrations in baseline-interval sediments is 15 percent lower than that for early post-tailings-release sediments, the standard deviations of the two relatively small datasets overlap, and a Student's *t*-test indicates that there is just a 69-percent probability that the populations represented by these two small data sets are statistically different.

The median of lead concentrations in sediments of the baseline interval (2900 ppm Pb) is 46 percent less than the median of lead concentrations in sediments of the historic interval (5400 ppm Pb), and the populations are significantly different. However, the 2900-ppm-Pb median of baseline PbAA is nearly 1.5 times the 2000-ppm-Pb USEPA threshold for early remedial action on public-use sites (USEPA, 1999), 1.6 times the 1800 ppm Pb shown to cause waterfowl deaths (Beyer and others, 2000), and 2.9 times the 1000-ppm-Pb threshold for removal and replacement of residential yards in the Bunker Hill Superfund site (Richard Martindale, written communication, 1999). Furthermore, the median of baseline PbAA is 5.5 times the 530-ppm-Pb threshold for onset of apparent effects to humans (USEPA, 1997), and 6.4 times the 450-ppm-Pb threshold for onset of health effects in waterfowl (Beyer and others, 2000). Also, the 2900-ppm-Pb median of PbAA is about 111 times the 26-ppm-Pb median of background lead concentrations in sediments deposited on the floodplain of the main stem of the Coeur d'Alene River valley before mining began in the Coeur d'Alene mining region.

Tonnage-Accumulation Rates for Sediments and Lead

Table 14 shows how we calculated rates of accumulation of sediments and of lead in sediments deposited in 5 depositional settings on the floodplain of the main stem of the Coeur d'Alene River during the background (BG), historic (BA) and baseline (AA) intervals, as summarized below.

Table 14. Estimated Amounts of Lead-Rich Sediments, and Tonnages of Lead Deposited per Decade during Baseline (AA), Historic (BA) and Background (BG) Intervals, Coeur d'Alene River Floodplain

The area-weighted average of medians for decadal-average thickness-increases in floodplain sediments is 3.2 cm/decade for the baseline interval, 4.3 cm/decade for the historic interval (table 8), and about 1.0 cm/decade for the pre-industrial background interval. Multiplying sediment-thickness accumulation rates by the areas of depositional settings covered by lead-rich sediments (from Bookstrom and others, 2001), indicates decadal average rates of sediment-volume increase during each interval. We calculate the rate of increase in the volume of sediments as 1.72 Mm^3/10y during the baseline interval, 2.20 Mm^3/10y during the historic interval, and 0.53 Mm^3/10y during the pre-industrial background interval. Multiplying rates of sediment-volume increase by medians of densities of sediments (from Balistrieri and others, 2000) indicates decadal average rates of sediment tonnage added to the part of the floodplain covered by sediments during each interval. We calculate the rate of increase in the tonnage of sediments as 1.94 Mt/10y during the baseline interval, 2.49 Mt/10y during the historic interval, and 0.6 Mt/10y during the pre-industrial background interval. Multiplying rates of sediment-tonnage increase by medians of lead concentrations indicates tonnages of lead deposited on the floodplain per decade.

Thus, we estimate rates of increase in the tonnage of lead on the floodplain as 5000 t Pb/10y during the baseline interval, as compared to 16,000 t Pb/10y during the historic floodplain-contamination interval, and 16 t Pb/10y during the pre-industrial background interval. The baseline rate of lead deposition is therefore about 31 percent of the historic rate, which indicates that rates of lead deposition have decreased significantly since the historic interval. However, the baseline rate of deposition of lead on the floodplain is still about 310 times the pre-industrial rate.

Total Tonnage of Lead in Floodplain Sediments

Multiplying median-based estimates of decadal lead-deposition rates by decades of deposition of sediments, we estimate that about 117 kt of lead were deposited on the floodplain from about 1903 to 1993 (table 15). This is between the minimum median-based estimate of 79 +/- 24 kt Pb, and the maximum mean-based estimate of 131 +/- 39 kt Pb by Bookstrom and others (2001), who estimated an analytical uncertainty range of +/- 30 percent. Rounding our current estimate to two significant figures, and applying a 30-percent range of uncertainty, our current estimate, based on medians of rates of lead deposition during the baseline and historic intervals is 120 +/- 40 kt Pb on the floodplain of the main stem of the Coeur d'Alene River (table 15). This is higher than the previous median-based estimate, because it is based only on full or nearly full sections of sediments, whereas Bookstrom and others (2001) included both full and partial sections in order to increase representation of sparsely sampled areas. Nevertheless, the uncertainty range of the present estimate overlaps with the uncertainty ranges of the previous median- and mean-based estimates by Bookstrom and others (2001).

Table 15. Estimated Tonnage of Lead in Sediments on the Floor of the Coeur d'Alene River Valley in about 1993

In table 15, we add our current depositional rate-based estimate of 120 +/- 40 kt Pb in sediments on the floodplain to previous median-based estimates of 129 +/- 39 kt Pb in the river channel, and 44 +/- 13 kt Pb in dredge spoils. Rounded to two significant figures, this yields a new median-based estimate of 290 +/- 90 kt Pb on the valley floor of the main stem of the Coeur d'Alene River valley. This median-rate-based estimate of 290 +/- 90 kt is between the median-based estimate (252 +/- 76 kt Pb) and the mean-based estimate (320 +/- 96 kt Pb) on the valley floor by Bookstrom and others (2001). Our median-rate-based estimate is 15 percent higher than our previous median-based estimate, probably because it is based entirely on full sections of lead-rich sediments, and excludes data from partial sections that were included in the previous data set to improve sample-site spacing.

Sources and Transport of Lead-Rich Sediments

Tailings from mills in the Coeur d'Alene mining area were the dominant primary source of lead-rich sediment in the drainage basin of the Coeur d'Alene River. Until 1968, mill tailings were discarded directly into tributary streams, where they mixed with other sediment in transport. The mixed lead-rich sediment was transported downstream, and deposited down-valley to form secondary sources of lead-rich sediment, which are variously vulnerable to mobilization and transport.

Secondary Sources of Lead-Rich Sediments Deposited on the Floodplain

Box and others (in press) used the geochemical character of sediments transported and deposited by a series of floods between 1995 and 1997 to identify the sources of those sediments. They concluded that sediment deposited on the riverbanks and levees close to the river's edge is derived from riverbed sediment remobilized from channel immediately upstream of the depositional site. The finer sediment deposited on the floodplain farther from the river during flood events is mobilized from a more complex combination of sources, including all upstream streambed sediments and, in higher energy flood events, the surface of the thinly vegetated portions of the floodplain (Box and others, in press).

Although lead-rich sediments have recently been removed from large portions of some floodplains in the South Fork drainage basin, other portions of some floodplains remain covered with lead-rich sediments, and alluvial deposits in stream channels still contain fine-grained interstitial sediments that are lead-rich. During floods, such fine-grained sediments may be mobilized, but after floods, they settle between cobbles and pebbles in the stream bed, and are winnowed away from gravel at the streambed surface.

As measured between 1994 and 1997, the average thickness of lead-rich sediments in the channel of the lower Coeur d'Alene River was 3.6 m between Cataldo Landing and Rose Lake, 2.6 m between Rose Lake and Cave Lake, and 1.8 m between Cave Lake and Harrison. These thick deposits of lead-rich sediment were deposited mostly during the 75-y time interval between the major flood of 1893 (shortly after large-scale milling began) and the cessation of tailings disposal in 1968 (See Time-Stratigraphic Markers, this paper). Thus, time-averaged rates of deposition were about 48 cm/decade for deposits between Cataldo Landing and Rose Lake, 35 cm/decade for deposits between Rose Lake and Cave Lake, and 24 cm/decade for deposits between Cave Lake and Harrison. These were very high rates of sediment deposition, as compared to the probable pre-industrial background rate of about 1 cm/decade (See Background Sediment-Deposition Rates, this paper).

Bookstrom and others (2001) calculated averages of lead concentration in riverbed sediments as 2400 ppm Pb in the sand bar at Cataldo Landing, nearly 10,000 ppm Pb in the Dudley Reach (from the toe of the sandbar at Cataldo Landing to the Rose Lake bridge), 5700 and 10,000 ppm Pb for two reaches of the middle valley, and 7100 and 7400 ppm Pb for two reaches of the lower valley. According to their median-based estimates, secondary sources of lead-rich sediments in the channel of the main stem of the Coeur d'Alene River contain about 129 +/- 39 kt Pb, and riverbank sediments, previously deposited along the upper and outer margins of the channel at flood stage, contain about 9 +/- 3 kt Pb. These secondary sources continue to supply lead-rich sediment to be transported down-valley and onto the floodplain of the main stem of the Coeur d'Alene River during frequent floods.

Transport and Deposition of Lead-Rich Sediment

Fluvial processes act on secondary sources of lead-rich sediments in the river channel to mobilize, transport, and redeposit them along down-valley floodwater flow paths. Lead has minimal chemical mobility in natural surface waters, and is therefore closely associated with particles. Therefore, physical transport of lead-bearing particles by moving water is the predominant mode of transport for lead in the Coeur d'Alene River valley.

Physical Transport of Lead-Bearing Particles

On the basis of periodic measurements at 21 stream gages from Mullan to Long Lake, during the water years 1999-2001, Clark (2003, p. 35) concluded that "In contrast to cadmium and zinc, lead was transported in streams primarily in the particulate form, and total lead concentration at all stations was positively correlated with stream discharge. Transport of lead occurs primarily during elevated stream discharge when lead-rich sediments stored in stream channels and the flood plain of the CDR [Coeur d'Alene River] are eroded and transported downstream." Depending on flow velocity and grain size, density, and shape, lead-bearing particles are mobilized and transported in *washload, suspended bed-material load, or bedload*.

Washload consists of clay, silt and very fine sand (less than 0.0625 mm), sufficiently fine-grained that only low velocity and minor turbulence keep it in suspension (Gordon and others, 1992). Washload is distributed more-or-less evenly throughout the water column, and it travels at the same speed as the water. Streams have very high capacity to transport washload, so the amount of washload carried depends largely on the rate of mobilization. When tailings were being discarded directly into tributary streams, the supply of mobile fine-grained sediments in washload was high year-round. Since 1968 the supply of washload has varied with flow, because very fine-grained sediments in pre-mine sediments along the margins of the main stem are cohesive, and riverbank deposits of sediments are cemented by iron oxides. Nevertheless, very fine-grained particles in loosely packed active riverbed sediment are mobilized at relatively sluggish flow velocities. Once in suspension, particles in washload suspension do not settle until flow velocity and turbulence approach zero, and then they settle gradually.

Bed-material load consists of particles in motion that have about the same size range as particles in the streambed. *Suspended bed material load* is the portion of the bed material that is transported in suspension in the lower part of the water column. It is supported by the water and kept aloft by turbulence, but will settle quickly when flow velocity drops. *Bedload* is the portion of bed material that moves by rolling, sliding, or hopping, and is partly supported by the streambed (Gordon and others, 1992). Sizes and weights of particles transported as suspended bed-material load and bedload vary with flow velocity and turbulence, which vary both temporally and spatially.

According to Leopold (1997, p. 62-63) "Bedload movement begins at discharges just less than bankfull and the bulk of bedload movement occurs at flows ranging from 90 percent of bankfull to twice bankfull discharge." Lead-rich sediments that were previously deposited and stored within and along the river channel are vulnerable to transport during episodes of nearly bankfull or greater discharge. As a result, the river transports large amounts of sediment, and delivers voluminous plumes of suspended sediment to Coeur d'Alene Lake during episodes of bankfull or greater discharge.

When the river overflows onto its floodplain, it transports sediment onto the floodplain in washload suspension throughout the water column, in bed-material suspension in the lower part of the water column, and in bed-load at the base of the water column. As flow velocity decreases with increasing distance from the river, sand is deposited from bedload, fine sand and silt are deposited from suspended bed material load, and silty mud is deposited from washload. Most of the sand is deposited along the bed and banks of the river, but some is deposited on sand splays and distributary deltas. Fine sand and silt are deposited from bed-material load. As flow slackens, fine silt- and clay-sized particles settle gradually from washload, first in flood basins, and then throughout the floodplain and the riverbed.

Since grain-size and weight determine settling velocity in water, and weight is a function of grain size and density, grains of similar size but different density settle at different rates. Lead is a heavy metal (atomic wt 207), so minerals containing high concentrations of lead generally have higher densities than most rock-forming minerals in alluvial sediments. For example, the densities of detrital grains of common lead-bearing minerals are about 7.6 for galena (lead sulfide), 6.5 for cerussite (lead carbonate), and 6.3 for anglesite (lead sulfate), as compared to 2.65 for quartz, 2.6 to 2.8 for feldspars, and 2.0 to 2.7 for clay minerals (Berry and Mason, 1959). Thus, detrital grains of minerals tend to settle much faster, to be deposited much earlier, and to be transported much less far than similar-sized grains of common rock-forming minerals.

Density contrasts are less between grains of rock-forming minerals, and grains of those minerals that are coated or partly coated by lead-bearing hydrous iron- or manganese-oxides. The density of goethite ($HFeO_2$) is 3.3 to 3.5, and that of pyrolusite (MnO_2) varies from 2.8 to 4.4, depending on whether the material is powdery or crystalline (Berry and Mason, 1959). Lead ions adsorbed to such oxides would increase the density of the grain coating, but the effect of lead-bearing metallic-oxide coatings on settling velocities probably depends mostly on the abundance of metallic-oxide coating relative to that of the rock-forming mineral in the settling grain.

Nevertheless, preferential settling of relatively dense mineral particles probably contributes to development of the pattern of decreasing maximum lead concentrations in floodplain sediments of the baseline interval as a function of increasing distance from the river (figure 14). Dilution of sediment by mixing with sediment delivered to the floodplain by lateral tributaries probably also contributes to development of that pattern.

During the falling limb of each flood, flow velocity decreases, and water levels subside. Very fine-grained sediment, transported in washload, settles gradually onto coarser-grained sediment, deposited earlier in the flood cycle. The last sediment deposited is a thin layer of very fine-grained mud that settles from suspension as the floodwater recedes. Where it dries this mud turns to dust, which may the blown away, or washed downward through duff by spring and summer rains.

Transporting, Dispersing, and Depositing Subsystems

Lead-bearing sediments, mobilized from mining wastes in the Coeur d'Alene mining district, are transported to the main stem, where large secondary sources of sediment, previously deposited along the bed and banks of the main-stem channel, are vulnerable to mobilization and down-valley transport during high discharge episodes. When discharge increases on the rising limb of a major flood, the main stem acts primarily as a *transporting subsystem*, which tends to erode where flow velocities are relatively high, and to deposit where flow velocities are relatively low. As the level of Coeur d'Alene Lake rises, the lower valley becomes back-flooded, and the flooded delta plain becomes a predominantly *dispersing subsystem*, in which coarse sediment is deposited on levees and deltas, and fine sediment is dispersed into lateral flood basins, and Coeur d'Alene Lake. During the falling limb of a flood, the river becomes a *depositing subsystem*. Active riverbed sediment stops moving, suspended sediment settles, and the riverbed returns approximately to its pre-flood configuration. As floodwaters recede from the floodplain, very fine-grained sediments settle from washload suspension, coating submerged surfaces with mud.

Seasonal Cycle of Discharge and Sediment Transport

Kjelstrom and others (1994) graphed the minimum, median, and maximum of daily mean discharge for 57 years of record at the Cataldo gage. Medians of daily discharges are lowest from August through October (at about 300 ft^3/s), and peak in April and May (at between 8000 and 9000 ft^3/s). July and August are the driest months over most of the Pacific Northwest. Although median flow is lowest from August through October, occasional thunderstorms may cause brief spikes in maximum daily discharge at Cataldo by about 500 to 1000 ft^3/s (Kjelstrom and others, 1994).

During most of the summer, downstream flow velocity west of Cataldo Landing is nearly imperceptible, because the Post Falls dam holds the water level of Coeur d'Alene Lake reservoir at about the elevation of Cataldo Landing from about late June to late September. As a result, there is almost no downstream flow velocity and almost no downstream transport of sediments west of Cataldo Landing during most of the summer. Nevertheless, riverbank deposits of iron-oxide-cemented sediments are commonly subjected to erosion by motorboat wakes and wind-driven waves. Where and when that occurs, sediment from riverbanks is suspended in river water, to form reddish clouds turbid water. Because of its suspended sediment content, this turbid water has higher density than clear water, so it flows down the side-slope of the river channel. As the turbid water moves down-slope, its suspended sediment settles onto the riverbed en route to and along the deep axis of the river channel. This process is repeated wherever and whenever a wave hits a riverbank deposit of sediment (or a dislodged block of such sediment, lying at the foot of the riverbank) with enough force to mobilize sediment. Little downstream transport of such sediment occurs, however, until the beginning of the next episode of rising discharge and increasing downstream flow velocity.

During autumn the water level in Coeur d'Alene Lake and the main stem of the river west of Cataldo Landing is lowered gradually by as much as about 2 m. Median daily discharge remains low until about mid-November, and then begins to increase. Return-flow of surface water and groundwater from the floodplain to the river transports dissolved metal, including minor dissolved lead, to the river. As mildly acidic groundwater mixes with neutral river water, reddish metal-enriched bio-slime flocculates, and collects locally at the top of the zone of active bed sediment (Balistrieri and others, 2003). This watery floc is the most mobile bed sediment, and is mobilized by very weak currents at the beginning of the next discharge episode. Then bank-derived sediment, deposited on the river-bottom surface during the previous summer, probably is swept down-river and into Coeur d'Alene Lake before the river reaches bank-full flow.

From late November to February, precipitation is frequent and widespread throughout much of the Pacific Northwest. Median flow rises to about 1000 ft^3/s during November, and then rises gradually to about 2000 ft^3/s by mid-February. During most winters, ice forms, snow accumulates, and temperatures remain cold enough to prevent major discharges of liquid water until the annual spring snowmelt runoff begins. However, warm, moist southwest "Pineapple-Express" winds from the Pacific Ocean occasionally bring a winter thaw, accompanied by a major rain-on-snow storm. This can cause daily maximum discharge to peak rapidly at discharge rates up to 79,000 ft^3/s at Cataldo (Kjelstrom and others, 1994), resulting in high flow velocities, bank erosion, channel scour, high sediment loading, and extensive flooding. Winter floods of this type are particularly erosive, because they begin suddenly, when the water level in Coeur d'Alene Lake is at is low, and hydraulic head is high. The winter flood of 1996 had a peak discharge of 70,800 ft^3/s at Cataldo (Beckwith and others, 1996) and flow velocities in the ranged up to 7 ft/s at Rose Lake and Harrison (R.L. Backsen, written commun., 2002). Most of the lead was transported in association with suspended sediment, and only about 3 percent of the transported lead was "dissolved" in water (Beckwith and others, 1996).

Annual spring snowmelt runoff begins in mid-March, and peaks in April and May (Kjelstrom and others, 1994). During most annual spring snow-melt runoff episodes discharge increases gradually. After peaking one or more times, discharge then decreases gradually. A secondary peak in precipitation during May and June may increase and prolong spring runoff (Jackson, 1993). The entire episode tends to be relatively prolonged, and may continue intermittently from about early April to mid-June. While waters of upper tributary streams may be relatively clear during spring runoff, the main stem generally becomes turbid, though flow velocities are relatively sluggish (about 1 to 3 ft/s). Nevertheless, nearly bank-full flow may continue for weeks. As high discharge continues, Coeur d'Alene Lake levels rise, because the St. Joe and Coeur d'Alene Rivers deliver water to the lake faster than it can leave by way of the Spokane River. As the lake level rises, the western part of the Coeur d'Alene River valley is flooded relatively passively by water that backs up-valley from Coeur d'Alene Lake.

Although this can be considered to be lake water, it nevertheless contains suspended sediment, transported to the lake by the river.

Spring and summer thunderstorms occur locally in the drainage basin of the Coeur d'Alene River, and they can cause local episodes of high runoff, local mass wasting, erosion, transport, and deposition, especially in hilly areas of the upper drainage basin, and most especially in areas where vegetation is sparse as a result of past smelter fallout, abandoned tailings impoundments, recent logging, or cuts and fills for roads.

Active versus Stored Riverbed Sediment

The upper meter or so of riverbed sediment at our Dudley drill transect is sandy, poorly layered lead-rich sediment containing about 3000 to 4000 ppm Pb. This overlies a thicker section of well-layered sediments, in which lead concentrations increase down-section, from about 12,000 ppm Pb near the top, to about 27,000 ppm Pb at the base of the section of lead-rich sediments (figure 8). We interpret the upper layer of sandy, poorly layered sediment as active bed sediment, which has been recently mobilized, transported, and re-deposited. We interpret the underlying section of layered lead-rich sediment as stored riverbed sediment, which has not been mobilized since it was deposited in the river channel during the tailings-release time-stratigraphic interval. The upper layer of active bed sediment probably forms by mixing of contaminated sediment from upstream and underlying secondary sources of lead-rich sediment, and uncontaminated sediment from the North Fork and lateral tributaries outside the Coeur d'Alene mining area.

On the riverbed between Cataldo Landing and Rose Lake, sand dunes with amplitudes of about 0.5 to 1 m are common in the sandy layer of active lead-rich bed sediment. Down-river from Rose Lake, the zone of active bed sediment is less distinct from the underlying section of previously deposited sediments stored in the river channel. Nevertheless, grain-size generally decreases and lead concentrations generally increase down-section. At our Killarney drill transect, we drilled a line of holes across a point-bar deposit east of Strobl Marsh (figure 4). At the toe of the point-bar deposit, we drilled through a wedge of sandy, non-layered sediment, containing about 3000 to 4000 ppm Pb, overlying interlayered sand and silt, with lead concentrations increasing down-section from 4000 to 10,000 ppm Pb. The wedge of sandy active sediment thinned upslope, from 3 m thick at the thalweg to zero at about 50 m up the slope of the point bar (figure 6). We interpreted this wedge-shaped deposit of non-layered sandy sediment as active bed sediment. A ground-penetrating-radar survey by Campbell and others (1997) indicated contorted bedding in the layered point-bar sediments, upslope from wedge of active sediment at the toe of the point bar (figure 6). We interpreted this contorted bedding to indicate that layered sediments had slumped toward the toe of the point bar, thus moving layered sediments laterally into the zone of scour. This probably occurred in response to removal of lateral support, caused by scour at the toe of the point bar during episodes of high flow velocity. As flow-velocity decreases at the end of any high-discharge episode, active bed sediment refills the scour zone at the toe of the point bar (figure 6).

Lead concentrations in active riverbed sediment result from a dynamic balance between processes that tend to decrease lead concentrations in active bed sediment versus processes that tend to increase them. Relatively sluggish currents typical of annual spring floods may winnow fines from active bed sediment, thereby removing lead from active bed sediment, moving it downstream, and reducing lead concentrations in the remaining bed sediment. However, low-velocity flows probably do not mobilize much sediment from layered deposits, stored beneath the zone of active bed sediment. Furthermore, lead-rich fines probably are replenished, as flow slackens, and lead-bearing washload settles from suspension.

During sudden-onset winter floods, fast-flowing water locally sweeps away active bed sediment, and erodes into underlying layered deposits of sediment, stored in the river channel. In general, the deeper such scour, the higher the concentration of lead in sediments mobilized from the section of stored sediments. Mobilization of sediment from these higher-grade deposits tends to increase the concentration of lead in suspended sediment, as well as in moving bedload, which is deposited during the falling limb of the high-discharge episode, to form a new blanket of active bed sediment.

According to measurements by Beckwith (1996) concentrations of lead in unfiltered floodwater, sampled during the 1996 flood, increased downstream from 840 μg Pb/L Cataldo, to 4500 μg Pb/L at Rose Lake. This five-fold increase in the concentration of lead in transport indicates that floodwater mobilized major amounts of lead from secondary sources containing very lead-rich sediments that were previously deposited along the river channel between Cataldo and Rose Lake. Downstream from Rose Lake, the concentration of lead in unfiltered floodwater, sampled during the 1996 flood increased by a factor of 1.4, from 4500 μg Pb/L at Rose Lake to 6500 μg Pb/L at Harrison.

Down-Cutting versus Aggradation in the River Channel

In general, scour occurs during the rising limb of a major flood, and deposition occurs during the falling limb. At the end of the flood, scour and fill roughly balance if the river-channel profile is in dynamic equilibrium. Over the long term, however, the Coeur d'Alene River has aggraded, filling the bedrock valley with 60 to 130 m of unconsolidated sediments since the Pleistocene (Norbeck, 1974, and U.S. Army Corps of Engineers, 1952). During the historic interval of mining and release of mill tailings to tributary streams, the rate of aggradation was unnaturally high, as an average of nearly 3 m of lead-rich sediments was deposited in the river channel (Bookstrom and others, 2001). Now that tailings are no longer being discarded into streams, it is not known whether the river channel will restore long-term equilibrium by degrading toward its pre-mining profile, and thereby mobilizing increasingly lead-rich sediments down-section, or by aggrading, and thereby covering stored lead-rich sediments with a thickening blanket of post-tailings sediment.

When the dredge operated at Cataldo Landing, excavation of the dredge pond created a trap for sandy sediment, which the dredge removed annually, and deposited on the floodplain at Cataldo Flats. As the upper end of the trap filled, its lower end was eroded, until a new equilibrium was approached. Depth profiles for the years 1930, 1940 and 1950, measured at a location 1.5 mi downstream from the Cataldo dredge pond indicate that maximum river depth increased by a factor of 1.5, and river width increased by a factor of 1.15 during the time interval from 1930 to 1950, when the dredge was active (Grant, 1952). After the dredge was dismantled in 1968, the dredge pond filled with about 4.5 m of sand containing about 2000 ppm Pb from bottom to top of the section (USEPA, 1998). At our Dudley transect, the 1 m layer of active sand, which overlies layered tailings-rich sediments, probably has formed since the dredge stopped removing medium-grained sand, allowing much more of it to be carried on down the river. Thus, from Cataldo Landing to Dudley, the river probably has undergone net aggradation since dredging at Cataldo Landing stopped.

During the 1996 winter flood, USGS Water Resources personnel measured depth profiles across the river at the Rose Lake Bridge. These profiles indicate on the southern margin of the thalweg, 1.5 m of deposition was followed by 3 m of scour. Meanwhile, on the northern margin of the thalweg, sediment accumulated throughout the flood, to a total thickness of up to 3 m (R.L. Backsen, unpub. data, 1996). After the flood, there was a small net gain in the overall elevation of the river bottom across the Rose Lake transect. By contrast, small net losses were recorded at the Cataldo and Harrison gages.

After the 1996 flood we observed and photographed several locations between Cataldo Landing and Rose Lake where well-layered deposits of sediments had been scoured, so that fresh, steeply eroded exposures of well-layered sediments were visible under water, especially near the margins of the river channel. At the site of our Dudley drill transect a log, which had previously been buried in laminated lead-rich sediments, extended at least 2 m into open water after the flood. Thus, lead-rich sediments, historically deposited in the river channel, continue to be eroded locally during episodes of high discharge and high flow velocity, even though minor net deposition may be recorded at the end of the high-discharge episode.

Deposition and Storage of Lead-Rich Sediment on the Floodplain

When the river overflows its channel, floodwater carries lead-bearing sediment onto the floodplain. That sediment is deposited progressively as floodwater spreads and loses velocity. Levee-sand plumes commonly extend down-valley from the lower outside margins of river-meander bends. This pattern indicates that when the river overflows from meanders, the overflow is directed more-or-less straight down-valley, progressively depositing sand as it moves away from the river, spreads onto the floodplain, and loses velocity. As relatively coarse sediment from the river channel is deposited on levees, currents outside the channel probably winnow fine-grained oxidation products from levee sands, and transport them into flood basins.

In reducing environments of marshes and lakes, metallic oxy-hydrides, transported from oxidizing environments on levee uplands, are reduced. Reduction breaks down metallic oxy-hydrides and releases metallic ions, which combine with sulfide ions (produced by sulfate-reducing bacteria) to form authigenic sulfidic-metallic materials that are non-stoichiometric and amorphous to nano-crystalline (Thornburg and Hooper, 2001). These materials have enormous surface area, and are much more chemically reactive than detrital grains of crystalline metallic sulfide minerals. The lead in these authigenic sulfides is therefore much more bio-reactive and bio-available than the lead in detrital grains of galena.

Fluvial Process Rates

Comparisons of estimated riverbank erosion rates with rates of transport of suspended sediment in the river indicate that riverbanks supply only a minor proportion of the lead-bearing suspended sediment that degrades the quality of water in the river and Coeur d'Alene Lake during high-discharge episodes. Comparisons of riverbank erosion rates with rates of sediment-deposition on the floodplain and in Coeur d'Alene Lake indicate that riverbanks supply only an incidental proportion of the lead-rich sediments deposited on the valley floor.

Annual Rates of Riverbank Erosion

Since about 1968, bank-wedge deposits of sediments have been eroding laterally, while still receiving vertical accumulations of sediment. Stratigraphic sections of bank-wedge deposits are thereby exposed along steep cut-banks, which retreat laterally, toward the levee crest (figure 6). Inasmuch as bank-wedge deposits thin toward the levee crest, progressive lateral erosion of cut-banks exposes progressively thinner remnants of the bank-wedge deposits, at increasingly higher levels in the retreating cut-banks. This is particularly obvious along relatively narrow reaches upstream from the Killarney segment (figure 4). There, levee crests are relatively high and close to the river, and the slope along the base of the riverbank wedge of sediments is relatively steep. Downstream from there, levee crests are progressively lower and farther from the river, so the slope at the base of the section of sediments is relatively gradual.

Wetzel (1994) judged the severity of bank erosion by scoring for bank stability, bank condition, vegetative cover, bank-channel shape, and evidence of in-channel erosion, or deposition. At three sites below Cataldo Landing, she judged bank erosion severe at two sites, and moderate at one site. She applied an empirically calibrated table to convert “severe” to an estimated 9 to 15 cm/y, and “moderate” to an estimated 2 to 6 cm/y of lateral bank recession.

Using the same method, Flagor (2002) judged long-term (about 20-y average) annual rates of lateral bank-recession at 143 selected observation-point sites along the main stem of the Coeur d’Alene River. All of these sites were along very severely eroded segments of riverbank, which he scored as 5.5 to 6 (on a scale of increasing severity from 0.1 to 5 +). To calibrate these scores, Rob Sampson surveyed a limited number of sites where fence-posts, culverts, trees or shrubs could be used to measure the distance of bank retreat during an estimated time interval. Applying this calibration to the rated sites, Flagor (2000) estimated bank retreat rates of about 7 to 8 cm/y for the 143 severely eroded sites that he examined.

At 13 pairs of staked locations on opposite sides of the river, between Cataldo Flats and Harrison, we made a total of 50 measurements of bank retreat rates, by measuring the horizontal distance from a stationary stake, placed a few meters back from the top of the riverbank to the vertical projection of the riverbank face. We did this at 34 sites for the time interval from 1996 to 2000, and Michael Pereira and M.D. McFadden did this for eight sites for time intervals from 1996 to 2002 and 2000 to 2002. No major winter floods occurred during the time intervals of these measurements (late 1996 to late 2002).

The overall mean and standard deviation of bank-recession rates measured in this way was 8.9 +/- 15 cm/y, the minimum was 0 cm/y, the maximum was 96 cm/y, and the median was 5.1 cm/y (S.E. Box, A.A. Bookstrom, Michael Pereira, and M.D. McFaddan, unpublished data, 1996 to 2002). The median of bank-recession rates along the outside margins of meanders was 8.6 cm/y, as compared to 3.8 cm/y along relatively straight reaches, and 3.3 cm/y along inside margins of meanders. On the basis of these measurements, we made median- and mean-based estimates of tonnages of sediments eroded annually from riverbanks, as calculated in table 16. Our median-based estimate is that 6.1 kt/y of sediment is eroded from riverbanks, and our mean-based estimate is that 11.7 kt/y of lead-rich sediment is eroded from riverbanks (table 16).

The overall mean of lead concentrations in riverbank-wedge deposits is about 6300 g/t (Bookstrom and others, 2001). Multiplying this lead concentration by estimated tonnages of lead-rich sediment removed from riverbanks yields a median-based estimate of 38 t/y of lead, and a mean-based estimate of 74 t/y of lead removed from riverbanks by lateral erosion. The mean-based estimate is influenced by a few very high bank-retreat rates, at sites where large blocks collapsed onto the wave-cut bench at the base of the riverbank. Such blocks commonly disaggregate and erode slowly, and gradually release lead-rich sediment to the river for many years. The mean-based estimate is therefore influenced very high bank-retreat rates that are much higher than sediment-mobilization rates. By contrast, the median-based estimate of bank-retreat rates is much less influenced by very high bank-retreat rates, and is therefore a better indicator of sediment-mobilization rates resulting from lateral erosion of riverbanks. We therefore favor the median-based estimate of 38 t/y of lead released by lateral erosion of riverbanks.

Table 16. Estimated Tonnage of Lead-Rich Sediment Released Annually by Riverbank Erosion, Coeur d’Alene River, West of Cataldo Landing

Annual Rates of Deposition from Riverbank to Levee Crest

Annualized baseline rates of deposition of lead on bank-wedge deposits (from the riverbank to levee crest) are similar to annual rates of lead mobilization by lateral erosion of riverbanks from 1996 to 2002, which indicates that vertical deposition of lead in sediments added to riverbank-wedge deposits is nearly in dynamic balance with lead mobilized by lateral erosion of riverbanks. The median of annualized baseline sediment-deposition rates along riverbanks is 0.64 cm/y, and the mean is 0.69 cm/y. The average thickness of sediment deposited on the bank-wedge deposit is about 70 percent of the thickness measured at the bank. Therefore, a median-based estimate of the average thickness of the bank-wedge deposit is 0.0045 m/y, and a mean based estimate is 0.0048 m/y. The total area of bank-wedge deposits along the main stem west of Cataldo Landing is about 2.15 x 10^6 m^2 (Bookstrom and others, 2001). Multiplying thickness by area, a median-based estimate of the baseline volume of sediment deposited annually is 9630 m^3, and a mean-based estimate is 10,400 m^3. We multiply these volumes by the 1.6 t/m^3 dry density of bank sediment (Bookstrom and others, 2001) to estimate that 15,400 t/y to 16,600 t/y of sediment are deposited on riverbank wedges. Multiplying these estimated tonnages of sediment by the concentrations of lead in baseline sediments on riverbanks (median 3300 g/t, mean 3400 g/t) yields a median-based estimate of 51 t Pb/y and a mean-based estimate of 56 t Pb/y deposited on riverbank wedges during the baseline interval. The true central tendency for both populations probably is between the median-based and mean-based estimates. The average of median- and mean-based estimates lead-release by bank erosion rates 56 t Pb/y, and the average of median- and mean-based estimates of lead deposition from summer water level to the levee top is 54 t Pb/y.

Annual Rates of Sediment Transport in the Coeur d’Alene River

Woods (2001) reported discharge and concentration of suspended sediments transported by the river, as measured at the Rose Lake and Harrison gages during March, June, September, and October of 1999. Clark and Woods (2001) graphed relationships between discharge and concentration of suspended-sediment and bedload-sediment discharge for the time period, between February of 1999 and April of 2000. At the Rose Lake and Harrison gages the suspended-sediment load was primarily composed of fine-grained sediment, and bedload transport was either negligible or nonexistent on most of the sampling dates, which all had stream discharge less than 15,000 ft^3/s.

USEPA (2001) estimated average annual sediment transport as a function of discharge for each year from 1992 to 1999 on the basis of periodic stream discharge measurements, and the lognormal relationship between stream discharge and sediment discharge, as graphed by Clark and Woods (2001) for the period from February of 1999 to April of 2000 (during which stream discharge did not exceed 15,000 ft^3/s).

The means and standard deviations of tonnages of suspended sediment transported annually past the Rose Lake and Harrison gages, as estimated by USEPA (2001) were 24 +/- 20 kt/y at the Rose Lake gage, and 73 +/- 110 kt/y at the Harrison gage (table 17). These could be considered as minimum estimates, because they are based on relationships between discharge and sediment transport that were measured at stream discharges of less than 15,000 ft^3/s, which was insufficient to activate bedload transport. Average annual rates of transport, estimated in this way do not adequately represent relatively short episodes of very high discharge, such as the 1996 winter flood.

Annual Rates of Deposition of Floodplain Sediments and Coeur d'Alene Lake Sediments

In table 14 we estimated the decadal average rate of deposition of sediments on the floodplain for the baseline interval as 1.94 Mt of sediment/10y, or about 190 kt of sediment/y (as rounded to two significant figures in table 17). About 37 percent (70 kt of sediment/y) was sandy sediment that was deposited on riverbanks, levees, and sand splays, and about 63 percent (120 kt of sediment/y) was silty to muddy sediment that was deposited in flood basins (table 17).

In table 2 we estimated mean baseline rates of deposition of sediments on the floor of Coeur d'Alene Lake as 11.7 cm/10y on the toe of the Coeur d'Alene River delta, and 0.4 cm/10y on the floor of the distal lakebed. To calculate the decadal increase in volume, we multiplied these rates of increase in thickness by the area of the delta toe and the lake bottom, respectively. To calculate the decadal increase in dry tonnage of sediment, we multiplied by densities of 1.4 t/m^3 of sediment for sandy delta sediments, and 1.07 t/m^3 of sediment for water-saturated distal lake-bottom sediments (from Bookstrom and others, 2001). To convert decadal to annual rates, we divided by 10, and rounded to two significant figures. In table 17, the results of those calculations indicate that during the baseline interval, the delta toe received about 160 t of sandy to silty sediment per year, while the distal lake bottom received about 40 t of silty to muddy sediment per year.

Table 17. Mean Annual Sediment-Transport Rates in the Coeur d'Alene River (1992-1999), and Baseline Sediment-Deposition Rates, Coeur d'Alene River Floodplain, and Coeur d'Alene Lake (1980 ~1993)

Mobilization and Transport of Sediment along the Main Stem

In 1993 and 1994, with mean annual stream flows between 36 and 58 m^3/s, the annual lead load was about 5 times higher at Rose Lake than at Cataldo, and the load at Harrison was 3 to 4 times higher than at Cataldo (as calculated from the data of Beckwith and others, 1997). During the 1996 flood, as measured discharge decreased from 1900 m^3/s at Cataldo, to 1430 m^3/s at Rose Lake and 1350 m^3/s at Harrison, but lead load was about 4 times higher at Rose Lake than at Cataldo, and was about 5 times higher at Harrison than at Cataldo (as calculated from the data of Beckwith and others, 1996, and Beckwith, 1996). These comparisons indicate that during high-discharge episodes, lead mobilization and transport increase by a factor of 4 to 5 along the reach from Cataldo to Rose Lake. We suggest that most of that increase probably occurs downstream from Cataldo Landing, where the river bottom changes from cobble gravel with interstitial fines, to more-easily mobilized and transported sand with a higher proportion of interstitial fines.

Nevertheless, there is much uncertainty in estimating mobilization and transport of lead from different reaches of the South Fork and main stem during episodes of differing discharge and duration, because most of the data are for suspended sediment only, and mobilization is not simply additive down-stream. For example, sediment that is mobilized in any reach is mixed with sediment already in transport from upstream, and some of the sediment that is transported into or mobilized within any reach may be re-deposited before it reaches the next gage. The amount of sediment in suspension and the lead content of that sediment probably vary according to flood stage, source proximity, current direction and velocity, and distance from the river, so sampling at different times, different locations, or by different methods can yield different results, as indicated by the data of Box and others (in press).

Mobilization of Sediment from Main-Stem Riverbanks

In table 17, we compare estimated tonnages of sediment eroded annually from riverbanks versus estimated tonnages of suspended sediment transported annually past the Rose Lake and Harrison river-flow gages. Our median-based estimate of the tonnage of sediment mobilized annually by bank erosion is about 6 kt of sediment/y, and our mean-based estimate is 12 kt of sediment/y. That amounts to about 8 to16 percent of the mean annual tonnage of suspended sediment transported past the Harrison gage. Thus, although bank erosion produces local small-scale plumes of reddish sediment at summer water level, it contributes only about 8 to 16 percent of the suspended lead-bearing suspended sediment that is transported past the Harrison gage and into Coeur d'Alene Lake during high-discharge episodes, which the only time when contamination of surface water by suspended particles of lead-rich sediment becomes pervasive and widespread.

Mobilization and Transport of Sediment from the Main-Stem Riverbed

Inasmuch as lead loads increase by factors of 3 to 5 between Cataldo and Harrison during episodes of high discharge, we estimate that about 1/3 to 1/5 (or 20 to 33 percent) of the lead load measured at Harrison could be derived from sources upstream from Cataldo. If 8 to 16 percent of the lead load measured at Harrison is from riverbank erosion, then the remaining 51 to 72 percent of the lead load measured at Harrison probably is from the main-stem riverbed. Thus, the main-stem riverbed is the dominant source of lead-rich sediment that is mobilized, transported in suspension, and deposited downstream from Cataldo. If we had data on the amount of lead transported in bedload and in bed-material load during major floods, we could increase these estimates of the proportion of lead-rich sediment mobilized from the main-stem riverbed.

River Transport versus Floodplain Deposition Rates

The total of the means of estimated tonnages of suspended sediment transported annually past the Rose Lake and Harrison gages accounts for only about half of our median-based estimate of the tonnage of sediment deposited annually on the floodplain, and only about a quarter of the total tonnage of metal-enriched sediment estimated to be deposited annually on the floodplain and the floor of Coeur d'Alene Lake (table 17). One reason for the apparent mismatch between the means of estimated annual rates of transport and deposition is the high variability of annual flow and transport, as represented by standard deviations that are nearly as large as, or larger than the means. Nevertheless, the mismatch between rates of transport and deposition may be even greater than it appears in this comparison, because transport at the Rose Lake should not be simply added to transport at the Harrison gage. Transport between the gages involves not just additive mobilization, but also input from upstream, and deposition between gages. Furthermore, transport measured at stream gages only spans only the river channel, which is about 100 m wide, whereas data on rates of sediment deposition span the entire floodplain, which is about 2 km wide. Water that leaves the river between gages eventually returns to the river, but much of the sediment that leaves the river between gages is deposited on the floodplain, and therefore may not be recorded at downstream gages.

Another possible reason for the apparent mismatch between rates of sediment transport and deposition is that bed-material load and bedload are not sampled at high discharge. While mud and fine silt are transported in washload suspension throughout the water column, coarser silt is transported in bed-material load in the lower part of the water column, and sand is transported near the base of the water column, in bed-material load and bedload. Thus, the gages do not record sand that is deposited on riverbanks, levees, sand splays, lateral-lake deltas, and the delta of the Coeur d'Alene River in Coeur d'Alene Lake. Furthermore, the Harrison gage does not record sediment that enters Coeur d'Alene Lake from the St. Joe drainage basin, or from smaller tributaries to Coeur d'Alene Lake.

Comparison of our mean-based estimates of the tonnage of sediment mobilized annually by bank erosion (about 6 to 12 kt/y), relative to estimated annual rates of deposition of sediment on the floodplain (about 190 kt/y), indicates than bank erosion could contribute only about 3 to 6 percent of the lead-rich sediment deposited annually on the floodplain. Similarly, even if all of that bank-derived sediment were transported to Coeur d'Alene Lake, we estimate that bank erosion could supply only about 3 to 6 percent of the 200 kt/y of metal-enriched sediment deposited on the floor of Coeur d'Alene Lake. If the bank-derived sediment were divided between the floodplain and the bottom of Coeur d'Alene Lake, we estimate that bank erosion could supply only about 1.5 to 3 percent of the approximately 390 kt of metal-enriched sediment deposited annually on the floodplain and the bottom of Coeur d'Alene Lake (table 17).

Long-Term Contamination in River Systems

Mining-derived metal-enriched sediment that is deposited in transport-dominated river channels generally undergoes a long history of remobilization, dilution during transport, and re-deposition to form and re-form persistent "hot spots," which continue to function as secondary sources of pollution. However, once metal-enriched sediment is deposited in predominantly depositional environments, such as lateral flood basins, it tends to remain, and is buried by a successively younger layers of progressively diluted, and less metal-enriched sediments. For riverbed sediments to become diluted to background concentrations, and for contaminated flood-basin sediments to be buried by uncontaminated sediments takes centuries, depending on the size and metal contents of secondary sources, and the size and discharge of the drainage basin they occupy.

Modeling Studies

Coulthard and Macklin (2003) modeled long-term contamination in river systems from historical metal mining by applying a sediment-catchment model that uses historical mining records to predict present-day and future levels and patterns of contamination. Their results indicate that contaminated sediments collect to form "hot spots," which become secondary sources of pollution, and that more than 70 percent of the deposited contaminants remain within the river system for more than 200 y after mine closure. Thick deposits of highly contaminated sediments along the Dudley reach are a major example of such a “hot-spot” secondary source, which (unless removed by dredging) can be expected to remain within the river for more than 200 years after tailings ceased to be discarded directly into tributary streams.

Stratigraphic Studies

Leblanc and others (2000) studied the stratigraphic section of metal-enriched sediments, deposited in the predominantly depositional estuary of the Rio Tinto River, downstream from a massive-sulfide mining district in Spain, since mining began there about 4,500 years ago. Sediments derived from Copper-Age mining were buried by sediments with progressively lower lead concentrations, which approached the background concentration 450 y after cessation of small-scale Copper-Age mining. An upper interval of metal-enriched sediment extends from 1.3 m deep to the surface. Lead concentrations increase up-section in this interval, from 100 ppm Pb in sediments deposited during pre-Roman mining, about 3,900 years ago, to 5300 ppm Pb in surface sediments, still being deposited in response to present-day mining.

Long-Term Future Contamination in the Coeur d’Alene River Valley

Modern mining has rapidly brought massive amounts of mining waste to the surface in the drainage basin of the Coeur d’Alene River. Large secondary sources of sediment have formed downstream from the mines. Most of the deposited contaminants can be expected to remain within the Coeur d’Alene River system for more than 200 years after the 1968 cessation of tailings disposal into streams. Unless large secondary sources of lead-rich sediments are removed or stabilized, they probably will continue to supply lead-enriched sediment to floodwaters for much longer than the 450 years it took for the Rio Tinto River and its floodplain to fully recover from small-scale releases of Copper-Age mining wastes.

Long-Term Monitoring

Long-term monitoring could provide answers to questions relevant to remedial design. For example, is the river in dynamic equilibrium with its longitudinal profile, or is it down-cutting or aggrading over the long term? An answer to this question would provide a basis for choosing between removal and in-situ stabilization of lead-rich riverbed sediments as the best way to reduce the severity of long-term contamination of the valley floor. The best way to answer this question would be to conduct periodic sonar mapping of the entire river channel (as was recently done by AVISTA, unpub. data, 2004). Short of that cross-sections of channel depth could be made periodically at key locations, either by depth sounding with a weighted cable, or by sonar profiling.

Are rates of riverbank erosion increasing or decreasing through time? An answer to this question could influence the priority given to removal of riverbank deposits of lead-rich sediments. To answer this question, periodic surveys of riverbank retreat could be expanded and continued long-term. At a minimum the 13 sites previously monitored for bank retreat could be re-visited after each high-discharge episode, and at the beginning and end of at least one representative summer season. In addition to measuring the retreat of bank tops, retreat of the entire bank profile could be measured. Monitoring upstream, downstream, and across from bank-stabilization pilot projects would test for indirect changes related to those projects.

How and why are concentrations of lead in active bed sediments changing through time? Answers to such questions will promote understanding of how the composition of active bed sediments reacts to discharge episodes of different magnitudes and durations, and how upstream remediation may reduce lead concentrations in mixed active sediment downstream. Stephen Box (unpub. data, 2005) has begun such a program of periodic sampling of riverbed sediment.

How and why are depositional rates and lead concentrations of sediment deposited on the floodplain changing over the long term? Answers to such questions would provide a basis for evaluating the effectiveness of remediation intended to prevent or lessen continuing floodplain contamination. To answer such questions, depositional rates and lead concentrations in sediments deposited on the floodplain could be monitored periodically over the long term. Monitoring future depositional rates would require placing an artificial time-stratigraphic marker, such as a semi-permeable fabric, staked in place on the sediment surface, to collect sediment deposited during the time-stratigraphic interval to be studied. However, since the difference between baseline and historic depositional rates is not statistically significant, it may be sufficient to test only for changes in lead concentrations in surface sediments deposited over time. If sampling was done on 10-year intervals, and samples were taken from within the upper 8 mm of mineral-dominated sediment, most samples would include only sediment deposited within the 10-year sampling interval (even though most depositional rates vary from 6.9 +/-5.3 cm/10y on riverbanks to 2.5 +/- 1.7 cm/10y in palustrine settings (table 3). Given the wide ranges of spatial variations in lead concentrations indicated by our data, a large number of sample sites, distributed in proportion to the areas of representative depositional settings, would be required to test for overall changes in lead concentrations of sediments deposited on the floodplain over time.

Implications for Remediation

The data presented here provide critically important information about the rates of deposition of metal-enriched sediment in the floodplain of the lower Coeur d’Alene River and the sources and processes that result in this distribution. In some cases our present understanding is enough to compel us to provide a note of caution that some remediation approaches will not result in lasting solutions. In other cases our present understanding of processes that control this continued redistribution is fraught with uncertainty, and we believe that further efforts at clarifying these controls should be undertaken before proceeding with other remediation approaches. In this section we discuss the impacts that some of the rates and processes of metal-enriched sediment redistribution could have on various remediation approaches.

The most obvious implication from this study is that metal-enriched sediment continues to be deposited on the floodplain of the lower Coeur d'Alene River at relatively high (but variable) rates and is likely to continue to do so into the foreseeable future. Remedial actions intended to result in soils on the surface of the floodplain with background metal concentrations (for example, removal of historical metal-enriched deposits to expose pre-mining soils, or capping of the surface with clean soil) will be undone within a few years by new deposition of metal-enriched sediments, unless preventative actions are taken. We note that depositional rates are highest closest to the river (6.4 cm or 2.5 inches of sediment containing 3300 ppm Pb per decade), such that capping or excavation of river banks or the adjacent riparian areas of the natural levees of the river are particularly susceptible to (and difficult to protect from) rapid recontamination. However, the depositional rates of metal-enriched flood sediment, even in marshes far from the river, are high enough (averaging 2.5 cm or 1 inch of sediment with 2100 ppm Pb per decade) to effectively re-contaminate the surface within several years. Thus, for remediation to be effective over the long term, the problem of post-remediation recontamination will need to be dealt with successfully in all remediation efforts on the floodplain.

One way to deal with continuing contamination in relatively small but popular public-use sites would be to remediate repeatedly, as needed. Boat launches, parking lots, camp grounds, and picnic areas could be largely paved, so that they could be re-cleaned repeatedly by sweeping, or washing, or both. This would require long-term funding for monitoring and re-cleaning as necessary. Although practical for relatively small sites, this approach would be much less practical for extensive areas, such as riparian riverbanks and levees along both sides of the main stem of the Coeur d'Alene River from the confluence of the North and South Forks to Coeur d'Alene Lake.

Preventing or decreasing the extent or severity of cumulative recontamination of remediated areas of the floodplain of the lower Coeur d'Alene River would require either (1) isolation of the remediated area from future flood waters, (2) reduction of the metal content of future flood-borne sediment to acceptable levels, or some combination of both. Isolation of a remediated area of the floodplain from sediment-laden floodwater might be accomplished by raising physical barriers to encroaching floodwaters. Isolation would be feasible for some lateral wetlands, but probably not along riverbanks, which are within the margins of the high-water channel of the river. Ultimately the severity of recontamination could be decreased by reducing the concentrations of metals transported during future floods. Such reduction could be accomplished by changing the mixture of metal-rich and metal-poor source components mobilized during floods, either by reducing the relative amount of metal-rich component or by increasing the relative amount of metal-poor component mobilized. Reducing mobilization of the metal-rich component could be promoted by removing metal-rich sediment from source areas vulnerable to erosion, or by immobilizing such sediments in place. Dilution could be promoted by increasing mobilization of metal-poor sources relative to mobilization of metal-rich sources. Based on geochemical signatures, the dominant source of sediment deposited during floods in the riparian zone (river bank and natural levee) along the lower Coeur d'Alene River is streambed sediment re-mobilized from the adjacent river reach (Box and others, in press). The finer sediment deposited on the floodplain farther from the river during flood events is mobilized from a more complex combination of sources, including all upstream streambed sediments and, in higher energy flood events, the surface of the thinly vegetated portions of the floodplain (Box and others, in press). Metal-poor source components of this finer suspended sediment consist primarily of fine sediments derived from the North Fork of the Coeur d'Alene River, with lesser contributions from relatively uncontaminated tributaries upstream in the South Fork and main-stem of the Coeur d'Alene River, and from tributaries discharging directly onto the floodplain of the lower Coeur d'Alene River.

Given that most of the floodplain is covered with metal-enriched soils, remediation has been suggested for areas ranging from riparian riverbanks, which serve as recreational areas for humans and feeding areas for song birds, to more distal marshes that serve as recreational areas for humans and feeding areas for waterfowl. Public-use areas, such as boat launches, picnic sites, and the bike trail along the railroad embankment can be paved, and re-cleaned as necessary, as long as there is funding to pay for such care and maintenance. However, paving and re-cleaning probably would not be practical for the entire area of the riverbanks, which is about 2.2 km^2 (from summer water level to the levee top, on each side of the river, and from Cataldo Landing to the river mouth, as estimated by Bookstrom and others, 2001). Stabilizing riverbanks will prevent erosion, but will not stop continuing deposition of lead-rich sediments along the stabilized riverbanks. Isolation of riparian areas along the immediate river banks would also be impractical, because riverbanks are within the high-water channel of the river.

Areas farther from the river could be more-or-less isolated by artificial dikes. For example, the 1889 railroad embankment along the south side of the Coeur d'Alene River valley provides a long-lived example of such a physical barrier, albeit with physical passages through the barrier at numerous bridges. Several floods have overtopped that embankment during its 115 year history, and many sections of that embankment have been eroded through by floodwaters (as occurred extensively during the 1996 flood). Although metal contents are typically lower in soils south of the railroad embankment (for example, Lane Marsh south), soil metal contents in these protected areas are generally still well above background values, and in many cases exceed levels that are considered injurious to human or wildlife health. Thus, any protective flood barrier built to protect a remediated wetland would need to be built higher, and to be constructed of more erosion-resistant materials than those of the historical railroad embankment. At distributary outlets from the main channel, some type of gate would be necessary to block lead-bearing floodwater from entering lateral lakes and marshes fed by distributaries. One disadvantage of building such a barrier is that it would constrict the floodway, resulting in concentration of floodwater flow, and sediment transport and deposition between the river and the dike. This has occurred between the river and the railroad embankment in Lane Marsh north (table 5). Constraining flood waters to a narrower floodway would also increase the load of metal-enriched sediment to Coeur d'Alene Lake.

Reduction of the metal content of future flood-borne sediment is a mixing problem, which could be approached by decreasing mobilization and transport of sediment from metal-rich sources, or increasing mobilization of metal-poor sediment from metal-poor sources, or both. Decreasing mobilization and transport of metal-rich sediment could be accomplished by removing secondary sources of metal-enriched sediments from the channel and banks of the river, or by in-situ stabilization of such sources, so that they would not be mobilized at likely maximum flow velocities (about 7 ft/s). Metal-poor sediment is being mobilized at abnormally high rates as a result of deforestation and surface disturbances caused by human activities that expose unconsolidated soil, colluvium, and alluvium to erosion and transport down-gradient. Additional dilution of metal-enriched sediment in-transport could be achieved locally by artificially placing clean sediment at key locations along a stream, so that it would be mobilized, transported, and deposited onto a chosen target area by predictable currents resulting from a high-discharge episode.

Remediation Options for Reducing Metal contents of Flood-Borne Sediment

A number of remediation options have been suggested that are aimed at reducing the metal content of flood-borne sediment in the lower Coeur d'Alene River valley. Based on our present understanding of the sources of flood-borne sediment and the processes that mobilize it, we briefly discuss several remediation options that have been suggested.

Source Control by Removal or Stabilization of Riverbanks

Removal or stabilization of lead-rich riverbank deposits has been suggested as a method to reduce the lead load in sediment transported and deposited in the lower Coeur d'Alene River valley, Coeur d'Alene Lake, and the Spokane River. Erosion of riverbank deposits by the wakes of passing boats produces turbid water, transferring bank materials to deeper water. Most of the sediment transported in such turbidity plumes is temporarily re-deposited on the riverbed, near its site of mobilization from the riverbank. Oxidized lead-rich sediment eroded from riverbanks by boat wakes probably is mobilized during the rising limb of the next high-discharge episode. Our analysis indicates that the riverbanks supply about 8 to 16 percent of the suspended sediment transported past the Harrison gage during high-discharge episodes, the only time when water-quality is widely and pervasively degraded by lead associated with suspended sediment. Lead/zinc ratios of suspended sediment samples collected during the floods of 1996 and 1997 are interpreted to indicate a relatively small input from eroding riverbanks (Box and others, in press). Therefore, removal or stabilization of riverbank deposits will make only a relatively minor contribution to improvement water quality during high-discharge episodes, when the waters of the Coeur d'Alene River, Coeur d'Alene Lake, and the Spokane River often transport lead-bearing sediment in suspension.

Source control to reduce ongoing contamination of the floodplain and the bed of Coeur d'Alene Lake is another purpose for removal or stabilization of deposits of lead-rich sediments on riverbanks. However, our analysis indicates that riverbank-erosion accounts for only about 3 to 6 percent of the annual tonnage of lead-rich sediment that is deposited on the floodplain, or about 3 to 6 percent of the annual tonnage of lead-rich sediment that is deposited in Coeur d'Alene Lake, or about 1.5 to 3 percent of the combined annual tonnage of lead-rich sediment that is deposited on the floodplain and in Coeur d'Alene Lake (table 17, middle part). Thus, removal or stabilization of riverbank deposits of lead-rich sediment would produce only an incidental reduction in the amount of lead-rich sediment deposited on the floodplain of the lower Coeur d'Alene River or in Coeur d'Alene Lake. Furthermore, remediated riverbanks would be vulnerable to rapid recontamination by continuing deposition of about 6.9 +/- 5.3 cm/10y of sediment containing about 3400 +/- 990 ppm Pb (tables 3 and 4).

Source Control by Periodic Removal of Sand Splays

A sand splay (or crevasse splay) forms where floodwater transports sandy sediment onto the floodplain through a low pass in the levee. As the floodwater spreads onto the floodplain, it loses velocity, and sandy sediment is deposited to form a delta-like sand splay. The section of lead-rich sediments is more than 211 cm thick at sample site 93SBL31 on the large sand-splay in Strobl Marsh (Box and others, 2001). Oblique U.S. Forest Service air photos taken in June of 1933 indicate the splay was not present at that time, so we infer that the levee eroded and the sand splay began to form during the major winter flood of 1933. At site 93SBL31 the depositional rate between 1933 and 1980 was greater than 34 cm/decade containing 4040 ppm Pb. The baseline depositional rate (from 1980 to 1993) was 4.6 cm/decade of sediment containing 4720 ppm Pb.

Sand splays near Blackrock Slough and Strobl Marsh have been identified as sites that could serve as sediment traps, from which lead-rich sediments could be periodically removed following flood deposition events. The rationale for employing sand splays as sediment traps is that sand splays deliver lead-rich sediment from the river channel to the floodplain, where it could be accessed for removal. However, the presumed benefits of such a removal strategy are not clear. Allowing a small fraction of mobilized sandy bedload to more easily escape the channel at a few localities would have an insignificant effect on the downstream bedload budget, neither reducing its volume nor reducing its metal content. Moreover, removing sediment from the existing sand splay will lower the elevation of the splay relative to the flood stage of the river, and allow a return to higher overflow-current velocities, and pre-1980 rates of sediment transport to and deposition on the sand splay. Since each sand splay is fed through a relatively narrow and well-defined low pass in the levee, rates of post-remedial deposition in and around the sand splay could be greatly reduced by blocking the low pass at the head of each splay.

Local Dilution of Suspended Sediment with Low-Metal Sediment

Concentrations of metals in sediment transported to and deposited on the floodplain of the lower Coeur d'Alene River result from the mixture of metal-rich and metal-poor source components. A possible approach to reducing metal concentrations in transported sediment is to increase the contribution of metal-poor source components, thereby diluting the concentration of metals in the mix. Uncontaminated sediment could be obtained locally from the thick section of unconsolidated sediments that underlies the relatively thin surficial section of contaminated sediments. Uncontaminated sediment could be placed in the path of (or injected into) moving water. For example, uncontaminated sediment could be placed at a distributary inlet, where it would tend to be carried into the lake or marsh fed by the distributary. Alternatively, uncontaminated sediment could be placed along the margin of an eddy, or within a deep hole of the type that exists at tight bends in river channel (as indicated by a topographic map of the river bottom by AVISTA, unpublished data, 2004). Turbulent flow in an eddy or a river-bend hole would tend to loft and mix the sediment, while transporting it down-valley and onto the adjacent floodplain. This approach would take advantage of the power of moving water to mobilize, mix, transport, distribute, and deposit diluted sediment without the use of heavy equipment on water-saturated wetlands. The section of lead-rich sediments would be immediately coated with relatively dilute metal-bearing sediment. This could be repeated during successive floods to build a cap of sufficient thickness to prevent ingestion of underlying lead-rich sediments by wildlife or humans. The capped area could then be isolated from the river to prevent recontamination.

Riverbed Dredging as Source Control

In the section on mobilization of sediment from the main stem of the Coeur d'Alene River, we estimated that about 50 to 70 percent of the lead in suspended sediment transported past the Harrison gage is mobilized from the main-stem riverbed west of Cataldo. Bookstrom and others (2001) estimated that lead-rich sediments on the riverbed contain about 129 kt Pb, which is 14 times the 9 kt Pb contained in riverbank-wedge deposits west of Cataldo Landing. The area of sediments that is exposed to moving water on the riverbed is about 3.8 km^2 (Bookstrom and others, 2001), which is about 44 to 48 times the surface area of steep faces of riverbanks that are vulnerable to lateral erosion (0.079 km^2 to 0.087 km^2 as indicated in table 16). Furthermore, riverbed sediments are relatively unconsolidated, whereas riverbank sediments are cemented by iron and manganese oxides. Riverbed deposits of lead-rich sediments therefore are much more vulnerable to mobilization, transport, re-distribution, and re-deposition during episodes of high discharge than riverbank deposits of lead-rich sediments.

Deposits of sediments stored in the river channel are particularly thick and high-grade along the Dudley reach of the river, which extends from the downstream toe of the sand bar at Cataldo Landing to Rose Lake (river segment R2 in figures 3 and 4). The median thickness of sediments along the Dudley Reach is nearly 4 m, and the maximum thickness is over 8 m with a median of thickness-weighted average lead concentrations of nearly 10,000 ppm Pb (Bookstrom and others, 2001). Lead concentrations in sediment suspended during high-flow episodes commonly increase from about 2000 ppm Pb near Cataldo Landing to about 6000 ppm Pb at the lower end of the Dudley Reach (Box and others, in press). After the flood of February 1996, we noted visible evidence of scour into well-layered sediments, previously deposited and stored in the river channel along the Dudley reach.

Removal of the full thickness of metal-enriched sediment in the river channel for a portion of the Dudley Reach by dredging has been suggested as a strategy for reducing lead concentrations in future suspended and over-bank sediments along and downstream from the excavated reach. If dredging were to begin at Cataldo Landing, and progress down-river from there, the dredged river channel probably would re-fill with relatively dilute metal-bearing sediment, transported from the confluence of the North and South Forks, and containing less than 2000 ppm Pb. If the entire Dudley reach, from Cataldo Landing to Rose Lake were dredged in this way, removed sediment in the river channel along this reach, with an average content of about 10,000 ppm Pb, probably would be replaced by thinner deposits containing less than 2000 ppm Pb (a mixture of newly exposed pre-mining bed sediment with the continued inflow of sediment from upstream). Sediment mobilized from the excavated reach would thus be reduced in metal content, as would sediments transported to and deposited on the floodplain along that reach. This lower-metal sediment would also act to dilute the concentrations of metals in active riverbed sediment for some distance downstream of the excavated reach.

Although removal of the full thickness of metal-enriched sediment in the Dudley reach would reduce the metal concentrations of future flood-mobilized sediment in (and downstream of) that reach, the problem of continued inflow of less metal-enriched sediment from upstream must be considered. Would metal concentrations in future riverbank and floodplain sediment deposits after excavation of metal-enriched riverbed sediment become low enough to significantly reduce or eliminate impacts to wildlife and humans in that reach? Would periodic removal of post-excavation riverbed deposits in the excavated reach provide additional benefits? The answers to either of those questions are uncertain, yet they are critical to predicting the effectiveness of either remedial action.

Riverbed Source Control by In-Situ Stabilization

In-situ stabilization of riverbed deposits of lead-rich sediments is another, potentially lower-cost method of riverbed source control. It might be possible to stabilize deposits of lead-rich sediments in the river channel by capping them in-place with gravel too coarse to be mobilized during the highest probable discharges (about 7 ft/s). Cobble gravel could be obtained by surface mining the river channel or valley fill upstream from Cataldo Landing, and could be deposited over the river bottom downstream of Cataldo Landing to form an immobile gravel cap. If the gravel were obtained from the braided channel of the main-stem or the channel of the South Fork, lead-rich fines could be separated and placed in a repository, thus removing an upstream source of lead-rich sediment, while providing cleaned gravel for capping a downstream source of lead-rich sediment. If uncontaminated gravel were obtained from pre-mining valley-fill deposits along the main stem or the lower North Fork, the fines would not have to be removed, but could be deposited as a part of the gravel cap. Mobilization of these fines during high-discharge episodes would then dilute metal-rich sediments in transport.

In-situ stabilization of lead-rich sediments in the river channel by capping with gravel would have two major advantages over removal: (1) Capping would isolate and prevent mobilization of the most highly lead-rich sediments at the base of the section of lead-rich sediments without disturbing them, and (2) capping would leave metal-enriched sediments in a predominantly reducing environment, where metals are geochemically immobile, whereas removal to a subaerial repository would place them in an oxidizing environment, where zinc, cadmium, copper, silver (and to a lesser degree, lead) are more vulnerable to geochemical mobilization.

For capping of lead-rich sediments in the river channel with gravel to be effective, the gravel would have to be sufficiently coarse, thick, continuous, and widespread to protect underlying lead-rich sediments from vertical scour, interstitial plucking, and lateral erosion. The hydrologic effect of raising the channel floor and preventing erosion along the armored reach is uncertain and would require a pilot project or modeling to evaluate. To our knowledge, no studies have been done to evaluate the feasibility, cost, or effectiveness of such an approach.

Conclusions

The median of thickness-weighted average lead concentrations of sediments deposited during the baseline interval is 3100 ppm Pb, as compared to 5400 ppm Pb for sediments of the historic interval (based on data from 28 pairs of full baseline and full historic intervals of lead-rich sediments). The means of these two sample sets are statistically different.

The median of pre-remedial baseline rates of deposition for lead-rich floodplain sediments is 3.6 cm/decade, as compared to 4.7 cm/decade for sediments of the historic floodplain-contamination interval (based on data from 46 pairs of full baseline and full historic time-stratigraphic intervals of lead-rich sediments). The probability that these two data sets represent statistically different populations is 87 percent.

Based on data from 13 pairs of intervals with sub-equal thickness above and below the 1980 Mt St Helens volcanic-ash layer, the median of lead concentrations in sediments deposited during the baseline interval was 3300 ppm Pb, as compared to 4000 ppm Pb in sediments deposited between about 1968 and 1980 (after the 1968 cessation of tailings disposal to streams, but before deposition of the1980 volcanic ash layer). The probability that the means of these two data sets represent statistically different populations is 69 percent.

On average, much of floor of the Coeur d'Alene River valley is flooded about every 2.5 y, and major floods with peak discharge of about 70,000 ft^3/s or more have occurred three times in the last 70 years, and twice in the last 30 years (in 1933, 1974 and 1996).

During floods, lead-rich sediment is deposited on the floodplain of the main stem of the Coeur d'Alene River. This occurs because lead-rich sediment continues to be mobilized and transported from large secondary sources of lead-rich sediments that were previously deposited in the South Fork drainage basin, and along the bed, banks, and levees of the main stem of the Coeur d'Alene River.

The estimated tonnage of sediment mobilized annually from riverbanks along the main-stem west of Cataldo Landing is about 8 to 16 percent of the mean annual tonnage of lead in suspended sediment transported past the Harrison gage. The estimated tonnage of lead that is mobilized annually from large secondary sources of lead-rich sediments in the channel of the main stem of the Coeur d'Alene River is about 50 to 70 percent of the mean annual tonnage of lead in suspended sediment transported past the Harrison gage. An estimated 14 to 42 percent of the suspended sediment transported annually past the Harrison gage is therefore derived and transported from sources upstream from the Cataldo gage.

However, mean annual tonnages of sediment transported past river gages vary widely from year to year, and river gages record the transport of only about half of the lead-rich sediment deposited annually on the floodplain. The gages have not recorded bed-material load or bedload during major floods with flow velocities sufficient to activate bedload transport, and the gages only record sediment transported within the span of the river channel. Therefore, the gages do not record sediment that is mobilized from the riverbed between gages, and deposited on the floodplain before floodwater returns to the river channel.

Our observations and data indicate that riverbanks and adjacent riparian areas will become recontaminated during high-water episodes after cleanup. Baseline rates of deposition on riverbanks average 6.9 +/- 5.3 cm/10y of lead-rich sediment, containing 3400 +/- 990 ppm Pb. This can be expected to continue indefinitely after riverbank cleanup, unless ways can be found to prevent it or cope with it.

Unless removed or stabilized, the dominant secondary source of lead-rich sediments in the channel of the main stem of the Coeur d'Alene River will continue to supply lead-rich sediment, to be transported down-valley, onto the floodplain, and into Coeur d'Alene Lake for centuries to come.

These data and interpretations have important implications for remediation of areas impacted by deposition of metal-enriched sediment in the basin. Remedial design must not only deal with contamination that occurred in the past, but also with ongoing contamination that will continue into the future, unless controlled as a part of the remediation process.

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Appendix 1. Data Table

Appendix 2. Metadata

Appendix 1. Table A. Data

SAMP_NO	DATA_SET	REF	UTM_E	UTM_N	SYS	ENV	SEG	SEC	AAMTD	ASSAY_INT	M_TO_R	FLUV_FTR
91SBKF2	UI/Bender/89	Bender (1991)	532832	5262904	Llm	FB	Mc	fna	correl	2 span	1693	lat lk limetic
M91A	UI/Hoffman/91	Hoffmann (1995)	531167	5257415	Ldd	FB	Mc	pna	correl	2 span	897	lat lk delta
T91A	UI/Hoffmann/91	Hoffmann (1995)	520987	5259526	Llm	FB	Lc	nfna	correl	2 span	603	lat lk limetic
M92CS	UI/Hoffmann/92	Hoffmann (1995)	531355	5257320	Llm	FB	Mc	p	Cs isotp	na	1235	lat lk limetic
93ABM2	USGS/GD/93	Box and others (2001)	529444	5258540	RU	LV	La	f	msr cm	strat span	22	outside bnk
93ABM4	USGS/GD/93	Box and others (2001)	530875	5258592	U	LV	Mc	f	msr cm	strat span	15	inside rlv
93CSC03	USGS/GD/93	Box and others (2001)	547703	5266465	RU	LV	Ub	p	msr cm	strat span	1	outside bnk
93SBB21	USGS/GD/93	Box and others (2001)	520657	5258947	RU	LV	Lc	f	msr cm	strat span	1	outside bnk
93SBB22	USGS/GD/93	Box and others (2001)	522317	5258253	P	FB	Lc	f	msr cm	strat span	81	lat marsh
93SBB23	USGS/GD/93	Box and others (2001)	522333	5258176	RU	LV	Lb	f	msr cm	strat span	5	straight bnk
93SBC10	USGS/GD/93	Box and others (2001)	549480	5265355	RU	LV	Ub	f	msr cm	strat span	8	inside bnk
93SBC15	USGS/GD/93	Box and others (2001)	548107	5265684	U	LV	Ua	p	msr cm	strat span	4	alluv terrace
93SBC39	USGS/GD/93	Box and others (2001)	554595	5266545	RU	LV	Ua	f	msr cm	strat span	8	outside bnk
93SBC40	USGS/GD/93	Box and others (2001)	536505	5243065	RU	LV	SJRV	loPb	msr cm	strat span	10	st joe bnk
93SBL27	USGS/GD/93	Box and others (2001)	535274	5263833	RU	LV	Mb	f	msr cm	strat span	0	outside bnk
93SBL27B	USGS/GD/93	Box and others (2001)	535206	5263729	U	LV	Mb	f	msr cm	strat span	57	outside rlv
93SBL30	USGS/GD/93	Box and others (2001)	534930	5263450	U	LV	Mb	f	msr cm	strat span	366	outside rlv
93SBL31	USGS/GD/93	Box and others (2001)	534327	5262268	U	LV	Mb	p	msr cm	strat span	333	splay
93SBL32	USGS/GD/93	Box and others (2001)	534428	5261668	U	LV	Mb	f	msr cm	strat span	114	inside rlv
93SBR13	USGS/GD/93	Box and others (2001)	541836	5264028	RU	LV	Uc	p	msr cm	strat span	9	inside bnk
94GID3	USGS/GD/94	Box and others (2001)	535357	5262890	U	LV	Mb	f	msr cm	strat span	43	inside rlv
94GID5	USGS/GD/94	Box and others (2001)	535320	5262892	P	FB	Mb	f	msr cm	intrvl>aa	67	lat marsh
94GID6	USGS/GD/94	Box and others (2001)	535274	5262893	P	FB	Mb	f	msr cm	intrvl>aa	103	lat marsh
94xb08	USGS/GD/94	Bookstrom unpub data (1994)	520645	5258923	RU	LV	Lc	f	msr cm	strat span	0	outside bnk
94xb19	USGS/GD/94	Bookstrom unpub data (1994)	520742	5258871	RU	LV	Lb	p	msr cm	strat span	0	inside bnk
94xb22	USGS/GD/94	Bookstrom unpub data (1994)	520695	5258958	RU	LV	Lc	p	msr cm	strat span	0	outside bnk
94xb27	USGS/GD/94	Bookstrom unpub data (1994)	520725	5258970	RU	LV	Lc	f	msr cm	strat span	0	outside bnk
94xb33	USGS/GD/94	Bookstrom unpub data (1994)	520933	5258874	RU	LV	Lb	f	msr cm	strat span	0	straight bnk
94xc03	USGS/GD/94	Bookstrom unpub data (1994)	547092	5266337	RU	LV	Uc	f	msr cm	strat span	0	inside bnk
94xl04	USGS/GD/94	Bookstrom unpub data (1994)	536821	5264394	RU	LV	Ma	p	msr cm	strat span	4	inside bnk
94xl13	USGS/GD/94	Bookstrom unpub data (1994)	536635	5263927	RU	LV	Ma	f	msr cm	strat span	1	straight bnk
94xr06	USGS/GD/94	Bookstrom unpub data (1994)	546489	5266116	RU	LV	Uc	f	msr cm	strat span	1	outside bnk
94xr12	USGS/GD/94	Bookstrom unpub data (1994)	546388	5265952	RU	LV	Uc	f	msr cm	strat span	1	straight bnk
94xr17	USGS/GD/94	Bookstrom unpub data (1994)	546262	5265503	RU	LV	Uc	p	msr cm	strat span	1	straight bnk
94xr25	USGS/GD/94	Bookstrom unpub data (1994)	546253	5265005	RU	LV	Uc	p	msr cm	strat span	1	inside bnk
94xr30	USGS/GD/94	Bookstrom unpub data (1994)	546076	5264816	RU	LV	Uc	f	msr cm	strat span	1	straight bnk
94xr36	USGS/GD/94	Bookstrom unpub data (1994)	544235	5265435	RU	LV	Uc	f	msr cm	strat span	2	inside bnk
94xr41	USGS/GD/94	Bookstrom unpub data (1994)	544144	5265468	RU	LV	Uc	p	msr cm	strat span	0	inside bnk
94xr44	USGS/GD/94	Bookstrom unpub data (1994)	543392	5265407	RU	LV	Uc	p	msr cm	strat span	1	straight bnk

Appendix 1. Table A. Data

SAMP_NO	ASH_CM	AA_CM	AA_10Y	AA_CM_10Y	BA_CM	BA_10Y	BA_CM_10Y	SR_AABA	JBA_CM	JBA_AA	BA1_CM	PBR_CM	PBR_10Y
91SBKF2	0.0	5.0	1.1	4.5	45.0	7.7	5.8	0.77	5.0	1.0	4.5	50	8.8
M91A	0.0	4.0	1.1	3.6	48.0	7.7	6.2	0.58	4.0	1.0	4.0	52	8.8
T91A	0.0	3.0	1.1	2.7	42.0	7.7	5.5	0.50	2.7	1.0	3.0	48	8.8
M92CS	0.0	5.2	1.2	4.3	26.8	2.9	9.2	0.47	4.8	0.9	4.8	32	4.1
93ABM2	1.0	10.0	1.3	7.7	86.0	7.7	11.2	0.69	11.0	1.1	11.0	97	9.0
93ABM4	1.0	12.0	1.3	9.2	63.0	7.7	8.2	1.13	14.0	1.2	-999.0	76	9.0
93CSC03	0.5	6.0	1.3	4.6	249.5	7.7	-999.0	-999.00	3.5	0.6	-999.0	256	9.0
93SBB21	1.0	9.0	1.3	6.9	101.0	7.7	13.1	0.53	-999.0	-999.0	-999.0	111	9.0
93SBB22	0.5	4.0	1.3	3.1	24.5	7.7	3.2	0.97	4.0	1.0	4.0	29	9.0
93SBB23	1.0	5.0	1.3	3.8	47.0	7.7	6.1	0.63	6.0	1.2	-999.0	53	9.0
93SBC10	0.5	3.0	1.3	2.3	96.5	7.7	12.5	0.18	26.5	8.8	-999.0	100	9.0
93SBC15	1.0	15.0	1.3	11.5	245.0	7.7	-999.0	-999.00	19.0	1.3	-999.0	261	9.0
93SBC39	0.5	5.0	1.3	3.8	26.5	7.7	3.4	1.12	4.5	0.9	4.5	32	9.0
93SBC40	1.0	10.0	1.3	7.7	-999.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	125	-99.9
93SBL27	0.5	7.0	1.3	5.4	52.5	7.7	6.8	0.79	11.5	1.6	-999.0	60	9.0
93SBL27B	1.0	4.0	1.3	3.1	64.0	7.7	8.3	0.37	11.0	2.8	-999.0	69	9.0
93SBL30	0.5	4.0	1.3	3.1	32.5	7.7	4.2	0.73	4.5	1.1	4.5	37	9.0
93SBL31	0.5	6.0	1.3	4.6	204.5	7.7	-999.0	-999.00	11.5	1.9	-999.0	211	9.0
93SBL32	0.5	3.0	1.3	2.3	20.5	7.7	2.7	0.87	7.0	2.3	-999.0	24	9.0
93SBR13	1.0	15.0	1.3	11.5	275.0	7.7	-999.0	-999.00	36.0	2.4	-999.0	291	9.0
94GID3	0.5	3.0	1.4	2.1	153.5	7.7	19.9	0.11	9.0	3.0	-999.0	157	9.1
94GID5	0.5	5.0	1.4	3.6	37.5	7.7	4.9	0.73	-999.0	-999.0	-999.0	43	9.1
94GID6	1.0	3.0	1.4	2.1	16.0	7.7	2.1	1.03	-999.0	-999.0	-999.0	20	9.1
94xb08	-999.0	9.0	1.4	6.4	102.0	7.7	13.2	0.49	-999.0	-999.0	-999.0	111	9.1
94xb19	-999.0	10.0	1.4	7.1	160.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	170	9.1
94xb22	-999.0	15.0	1.4	10.7	130.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	145	9.1
94xb27	-999.0	17.0	1.4	12.1	95.0	7.7	12.3	0.98	-999.0	-999.0	-999.0	112	9.1
94xb33	-999.0	5.0	1.4	3.6	20.0	7.7	2.6	1.38	-999.0	-999.0	-999.0	25	9.1
94xc03	-999.0	40.0	1.4	28.6	120.0	7.7	15.6	1.83	-999.0	-999.0	-999.0	160	9.1
94xl04	-999.0	10.0	1.4	7.1	290.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	300	9.1
94xl13	-999.0	15.0	1.4	10.7	128.0	7.7	16.6	0.64	-999.0	-999.0	-999.0	143	9.1
94xr06	-999.0	20.0	1.4	14.3	80.0	7.7	10.4	1.38	-999.0	-999.0	-999.0	100	9.1
94xr12	-999.0	7.0	1.4	5.0	273.0	7.7	35.5	0.14	-999.0	-999.0	-999.0	280	9.1
94xr17	-999.0	17.0	1.4	12.1	118.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	135	9.1
94xr25	-999.0	22.0	1.4	15.7	223.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	245	9.1
94xr30	-999.0	13.0	1.4	9.3	167.0	7.7	21.7	0.43	-999.0	-999.0	-999.0	180	9.1
94xr36	-999.0	7.0	1.4	5.0	34.0	7.7	4.4	1.13	-999.0	-999.0	-999.0	41	9.1
94xr41	-999.0	10.0	1.4	7.1	163.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	173	9.1
94xr44	-999.0	5.0	1.4	3.6	175.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	180	9.1

Appendix 1. Table A. Data

SAMP_NO	PBR_CM_10Y	PBR_PB	AA_PB	BA_PB	PB_AABA	JBA_PB	BA1_PB	PBAA_BA1	SAMP_NO
91SBKF2	5.7	11050	4400	12000	0.37	4100	4100	1.07	91SBKF2
M91A	5.9	5012	5200	5000	1.04	5900	5900	0.88	M91A
T91A	5.5	7593	2800	7800	0.36	2800	2800	1.00	T91A
M92CS	7.8	-999	-999	-999	-999.00	-999	-999	-999.00	M92CS
93ABM2	10.8	4698	4200	4756	0.88	4000	4000	1.05	93ABM2
93ABM4	8.4	5438	3700	5767	0.64	3875	-999	-999.00	93ABM4
93CSC03	28.4	14129	3211	-999	-999.00	6804	-999	0.47	93CSC03
93SBB21	12.3	4446	3090	4566	0.68	-999	-999	-999.00	93SBB21
93SBB22	3.2	6313	1180	7154	0.16	2620	2620	0.45	93SBB22
93SBB23	5.9	5038	3950	5153	0.77	2530	-999	-999.00	93SBB23
93SBC10	11.1	8297	3310	8452	0.39	3820	-999	-999.00	93SBC10
93SBC15	29.0	6244	740	-999	-999.00	1470	-999	-999.00	93SBC15
93SBC39	3.6	3341	3315	3519	0.94	2820	2820	1.18	93SBC39
93SBC40	-999.0	-999	21	23	0.91	-999	-999	-999.00	93SBC40
93SBL27	6.7	4523	4610	4511	1.02	4230	-999	-999.00	93SBL27
93SBL27B	7.7	5200	4460	5246	0.85	4910	-999	-999.00	93SBL27B
93SBL30	4.1	5658	5200	5715	0.91	5150	5150	1.01	93SBL30
93SBL31	23.4	3937	4720	-999	-999.00	4300	-999	-999.00	93SBL31
93SBL32	2.7	9968	2650	11044	0.24	4800	-999	-999.00	93SBL32
93SBR13	32.3	5362	5350	-999	-999.00	5650	-999	-999.00	93SBR13
94GID3	17.3	4512	4935	-999	-999.00	4070	-999	-999.00	94GID3
94GID5	4.7	5408	-999	-999	-999.00	-999	-999	-999.00	94GID5
94GID6	2.2	7210	-999	-999	-999.00	-999	-999	-999.00	94GID6
94xb08	12.2	-999	-999	-999	-999.00	-999	-999	-999.00	94xb08
94xb19	18.7	-999	-999	-999	-999.00	-999	-999	-999.00	94xb19
94xb22	15.9	-999	-999	-999	-999.00	-999	-999	-999.00	94xb22
94xb27	12.3	-999	-999	-999	-999.00	-999	-999	-999.00	94xb27
94xb33	2.7	-999	-999	-999	-999.00	-999	-999	-999.00	94xb33
94xc03	17.6	-999	-999	-999	-999.00	-999	-999	-999.00	94xc03
94xl04	33.0	-999	-999	-999	-999.00	-999	-999	-999.00	94xl04
94xl13	15.7	-999	-999	-999	-999.00	-999	-999	-999.00	94xl13
94xr06	11.0	-999	-999	-999	-999.00	-999	-999	-999.00	94xr06
94xr12	30.8	-999	-999	-999	-999.00	-999	-999	-999.00	94xr12
94xr17	14.8	-999	-999	-999	-999.00	-999	-999	-999.00	94xr17
94xr25	26.9	-999	-999	-999	-999.00	-999	-999	-999.00	94xr25
94xr30	19.8	-999	-999	-999	-999.00	-999	-999	-999.00	94xr30
94xr36	4.5	-999	-999	-999	-999.00	-999	-999	-999.00	94xr36
94xr41	19.0	-999	-999	-999	-999.00	-999	-999	-999.00	94xr41
94xr44	19.8	-999	-999	-999	-999.00	-999	-999	-999.00	94xr44

Appendix 1. Table A. Data

SAMP_NO	DATA_SET	REF	UTM_E	UTM_N	SYS	ENV	SEG	SEC	AAMTD	ASSAY_INT	M_TO_R	FLUV_FTR
94xr49	USGS/GD/94	Bookstrom unpub data (1994)	543190	5265382	RU	LV	Uc	p	msr cm	strat span	1	straight bnk
94xr53	USGS/GD/94	Bookstrom unpub data (1994)	543378	5265520	RU	LV	Uc	p	msr cm	strat span	0	straight bnk
94xr64	USGS/GD/94	Bookstrom unpub data (1994)	542667	5265014	RU	LV	Uc	f	msr cm	strat span	2	inside bnk
94xr70	USGS/GD/94	Bookstrom unpub data (1994)	542414	5264366	RU	LV	Uc	f	msr cm	strat span	3	straight bnk
94xr73	USGS/GD/94	Bookstrom unpub data (1994)	542407	5264357	RU	LV	Uc	f	msr cm	strat span	4	straight bnk
94xr81	USGS/GD/94	Bookstrom unpub data (1994)	541020	5264420	RU	LV	Uc	p	msr cm	strat span	1	straight bnk
94xr88	USGS/GD/94	Bookstrom unpub data (1994)	540548	5264633	RU	LV	Uc	f	msr cm	strat span	2	straight bnk
94xr98	USGS/GD/94	Bookstrom unpub data (1994)	539776	5264882	RU	LV	Uc	p	msr cm	strat span	0	outside bnk
94xra15	USGS/GD/94	Bookstrom unpub data (1994)	539515	5264615	RU	LV	Ma	f	msr cm	strat span	3	inside bnk
94xra21	USGS/GD/94	Bookstrom unpub data (1994)	539071	5264498	RU	LV	Ma	p	msr cm	strat span	1	inside bnk
94xra24	USGS/GD/94	Bookstrom unpub data (1994)	538204	5264692	RU	LV	Ma	f	msr cm	strat span	1	inside bnk
K95A	USGS/GD/95	Box and others (2001)	533152	5262100	Ldd	FB	Mc	fna	nd	na	840	lat lk delta
96K114E	USGS/GD/96	Box and others (2001)	535490	5262885	U	LV	Mb	p	msr cm	strat span	209	outside rlv
96K178E	USGS/GD/96	Box and others (2001)	535555	5262882	U	LV	Mb	p	msr cm	strat span	240	outside rlv
96K89E	USGS/GD/96	Box and others (2001)	535474	5262886	U	LV	Mb	f	msr cm	strat span	1	outside rlv
96LD-105S	USGS/GD/96	Box and others (2001)	544095	5265464	U	LV	Uc	f	msr cm	strat span	136	inside rlv
T98C-1	USGS/GD/98	Box and others (2001)	554982	5266215	P	FB	Ua	loPb	msr cm	strat span	470	lat marsh
T98C-12	USGS/GD/98	Box and others (2001)	548414	5265979	U	LV	Ub	p	msr cm	strat span	350	alluv terrace
T98C-15	USGS/GD/98	Box and others (2001)	554438	5266433	P	FB	Ub	f	msr cm	strat span	100	lat marsh
T98C-16	USGS/GD/98	Box and others (2001)	548325	5265879	U	LV	Ub	p	msr cm	aatp, ba1btm	240	alluv terrace
T98C-17	USGS/GD/98	Box and others (2001)	547855	5266330	U	LV	Ub	f	msr cm	strat spot	45	inside rlv
T98C-18	USGS/GD/98	Box and others (2001)	549029	5266296	U	LV	Ub	f	msr cm	strat spot	1025	alluv terrace
T98C-21	USGS/GD/98	Box and others (2001)	548101	5266521	P	FB	Ub	p	msr cm	aatp, ba1btm	440	lat marsh
T98C-25	USGS/GD/98	Box and others (2001)	550599	5265753	U	LV	Ub	loPb	msr cm	strat spot	450	alluv terrace
T98C-4	USGS/GD/98	Box and others (2001)	554640	5266523	U	LV	Ua	loPb	msr cm	strat spot	50	alluv terrace
T98C-5	USGS/GD/98	Box and others (2001)	554544	5266345	P	FB	Ua	f	msr cm	strat spot	200	lat marsh
T98C-6	USGS/GD/98	Box and others (2001)	551049	5266713	U	LV	Ub	f	msr cm	strat spot	14	alluv terrace
T98C-7	USGS/GD/98	Box and others (2001)	551215	5266659	U	LV	Ub	p	msr cm	strat spot	280	alluv terrace
T98C-8	USGS/GD/98	Box and others (2001)	550294	5266184	U	LV	Ub	p	msr cm	strat spot	125	alluv terrace
T98L-36	USGS/GD/98	Box and others (2001)	536966	5264051	U	LV	Ma	p	msr cm	aatp, ba1btm	330	splay
T98M-43	USGS/GD/98	Box and others (2001)	532442	5259956	U	LV	Mc	f	msr cm	strat spot	150	inside rlv
T98R-13	USGS/GD/98	Box and others (2001)	546142	5266950	PA	FB	Uc	f	msr cm	aatp, ba1btm	890	marsh artif
T98R-14	USGS/GD/98	Box and others (2001)	547013	5267146	UA	LV	Uc	p	msr cm	aatp, ba1btm	660	uplnd artif
T98R-28	USGS/GD/98	Box and others (2001)	538865	5264852	U	LV	Ma	f	msr cm	aatp, ba1btm	230	distrib lv
T98R-30	USGS/GD/98	Box and others (2001)	537972	5264424	U	LV	Ma	f	msr cm	aatp, ba1btm	200	inside rlv
T98R-31	USGS/GD/98	Box and others (2001)	546916	5266067	U	LV	Uc	p	msr cm	aatp, ba1btm	120	inside rlv
H90-123	USGS/WRD/90	Horowitz and others (1995)	513590	5255470	DLT	FB	DLTT	f	msr cm	1-2.5 span	1800	main delta
BL9323	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	520589	5259868	P	FB	Lc	loPb	msr in	0-5aaba, 5-15	911	lat marsh
BL9333	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	522869	5258382	RU	LV	Lb	p	msr in	0-5aaba, 5-15	0	outside bnk

Appendix 1. Table A. Data

SAMP_NO	ASH_CM	AA_CM	AA_10Y	AA_CM_10Y	BA_CM	BA_10Y	BA_CM_10Y	SR_AABA	JBA_CM	JBA_AA	BA1_CM	PBR_CM	PBR_10Y
94xr49	-999.0	7.0	1.4	5.0	143.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	150	9.1
94xr53	-999.0	9.0	1.4	6.4	111.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	120	9.1
94xr64	-999.0	16.0	1.4	11.4	74.0	7.7	9.6	1.19	-999.0	-999.0	-999.0	90	9.1
94xr70	-999.0	25.0	1.4	17.9	35.0	7.7	4.5	3.93	-999.0	-999.0	-999.0	60	9.1
94xr73	-999.0	15.0	1.4	10.7	8.0	7.7	1.0	10.31	-999.0	-999.0	-999.0	23	9.1
94xr81	-999.0	12.0	1.4	8.6	168.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	180	9.1
94xr88	-999.0	12.0	1.4	8.6	150.0	7.7	19.5	0.44	-999.0	-999.0	-999.0	162	9.1
94xr98	-999.0	4.0	1.4	2.9	89.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	93	9.1
94xra15	-999.0	12.0	1.4	8.6	11.0	7.7	1.4	6.00	-999.0	-999.0	-999.0	23	9.1
94xra21	-999.0	10.0	1.4	7.1	213.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	223	9.1
94xra24	-999.0	4.0	1.4	2.9	14.0	7.7	1.8	1.57	-999.0	-999.0	-999.0	18	9.1
K95A	0.0	-999.0	1.5	-999.0	-999.0	7.7	-999.0	-999.0	-999.0	-999.0	-999.0	193	9.2
96K114E	1.0	33.0	1.6	20.6	141.0	7.7	-999.0	-999.00	28.0	0.8	-999.0	175	9.3
96K178E	1.0	18.0	1.6	11.3	121.0	7.7	-999.0	-999.00	16.0	0.9	16.0	140	9.3
96K89E	1.0	22.0	1.6	13.8	109.0	7.7	14.2	0.97	26.0	1.2	-999.0	132	9.3
96LD-105S	0.5	5.0	1.6	3.1	28.5	7.7	3.7	0.84	12.5	2.5	-999.0	34	9.3
T98C-1	1.0	3.0	1.8	1.7	-999.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	-999.0	9.5
T98C-12	1.0	5.0	1.8	2.8	74.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	80	9.5
T98C-15	0.2	4.0	1.8	2.2	41.8	7.7	5.4	0.41	-999.0	-999.0	-999.0	46	9.5
T98C-16	0.2	9.9	1.8	5.5	199.9	7.7	-999.0	-999.00	9.9	1.0	9.9	210	9.5
T98C-17	1.0	8.0	1.8	4.4	83.0	7.7	10.8	0.41	-999.0	-999.0	-999.0	92	9.5
T98C-18	1.0	3.0	1.8	1.7	27.0	7.7	3.5	0.48	-999.0	-999.0	-999.0	31	9.5
T98C-21	1.0	14.0	1.8	7.8	185.0	7.7	-999.0	-999.00	6.0	0.4	-999.0	200	9.5
T98C-25	1.5	5.0	1.8	2.8	-999.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	175	9.5
T98C-4	1.0	6.0	1.8	3.3	-999.0	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	90	9.5
T98C-5	0.2	-999.0	1.8	2.8	104.8	7.7	13.6	0.20	-999.0	-999.0	-999.0	110	9.5
T98C-6	0.2	3.0	1.8	1.7	12.8	7.7	1.7	1.00	-999.0	-999.0	-999.0	16	9.5
T98C-7	0.2	5.0	1.8	2.8	19.8	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	25	9.5
T98C-8	0.2	3.0	1.8	1.7	19.8	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	23	9.5
T98L-36	0.5	16.5	1.8	9.2	178.0	7.7	-999.0	-999.00	8.0	0.5	-999.0	195	9.5
T98M-43	0.5	2.0	1.8	1.1	27.5	7.7	3.6	0.31	-999.0	-999.0	-999.0	30	9.5
T98R-13	4.0	6.0	1.8	3.3	25.0	7.7	3.2	1.03	14.0	2.3	-999.0	35	9.5
T98R-14	0.5	3.0	1.8	1.7	116.5	7.7	-999.0	-999.00	17.0	5.7	-999.0	120	9.5
T98R-28	1.0	2.5	1.8	1.4	26.5	7.7	3.4	0.40	8.0	3.2	-999.0	30	9.5
T98R-30	0.9	4.0	1.8	2.2	9.1	7.7	1.2	1.88	4.0	1.0	4.0	14	9.5
T98R-31	1.0	5.5	1.8	3.1	183.5	7.7	-999.0	-999.00	14.5	2.6	-999.0	190	9.5
H90-123	1.5	20.5	1.0	20.5	88.0	7.7	11.4	1.79	16.5	0.8	-999.0	110	8.7
BL9323	0.6	3.2	1.3	2.5	-999.0	7.7	-999.0	-999.00	1.2	0.4	-999.0	15	9.0
BL9333	0.3	1.0	1.3	0.8	13.4	7.7	-999.0	-999.00	3.7	3.7	-999.0	15	9.0

Appendix 1. Table A. Data

SAMP_NO	PBR_CM_10Y	PBR_PB	AA_PB	BA_PB	PB_AABA	JBA_PB	BA1_PB	PBAA_BA1	SAMP_NO
94xr49	16.5	-999	-999	-999	-999.00	-999	-999	-999.00	94xr49
94xr53	13.2	-999	-999	-999	-999.00	-999	-999	-999.00	94xr53
94xr64	9.9	-999	-999	-999	-999.00	-999	-999	-999.00	94xr64
94xr70	6.6	-999	-999	-999	-999.00	-999	-999	-999.00	94xr70
94xr73	2.5	-999	-999	-999	-999.00	-999	-999	-999.00	94xr73
94xr81	19.8	-999	-999	-999	-999.00	-999	-999	-999.00	94xr81
94xr88	17.8	-999	-999	-999	-999.00	-999	-999	-999.00	94xr88
94xr98	10.2	-999	-999	-999	-999.00	-999	-999	-999.00	94xr98
94xra15	2.5	-999	-999	-999	-999.00	-999	-999	-999.00	94xra15
94xra21	24.5	-999	-999	-999	-999.00	-999	-999	-999.00	94xra21
94xra24	2.0	-999	-999	-999	-999.00	-999	-999	-999.00	94xra24
K95A	21.0	-999	-999	-999	-999.00	-999	-999	-999.00	K95A
96K114E	18.8	6010	5554	-999	-999.00	5913	-999	0.94	96K114E
96K178E	15.1	6230	5665	-999	-999.00	6735	6735	0.84	96K178E
96K89E	14.2	5256	5104	5287	0.97	5290	-999	-999.00	96K89E
96LD-105S	3.7	6931	3858	7472	0.52	4380	-999	-999.00	96LD-105S
T98C-1	-999.0	-999	712	600	1.19	-999	-999	-999.00	T98C-1
T98C-12	8.4	4720	-999	-999	-999.00	4720	-999	-999.00	T98C-12
T98C-15	4.8	13369	7460	13940	0.54	-999	-999	-999.00	T98C-15
T98C-16	22.1	5876	1960	-999	-999.00	4150	4150	0.47	T98C-16
T98C-17	9.7	8347	1630	8991	0.18	7550	-999	-999.00	T98C-17
T98C-18	3.3	7675	1380	8364	0.16	-999	-999	-999.00	T98C-18
T98C-21	21.1	3116	1870	-999	-999.00	3290	-999	0.57	T98C-21
T98C-25	-999.0	-999	839	325	2.58	-999	-999	-999.00	T98C-25
T98C-4	-999.0	-999	-999	-999	-999.00	-999	-999	-999.00	T98C-4
T98C-5	11.6	3650	-999	3695	-999.00	-999	-999	-999.00	T98C-5
T98C-6	1.7	1890	1890	1890	1.00	-999	-999	-999.00	T98C-6
T98C-7	2.6	4300	4300	-999	-999.00	-999	-999	-999.00	T98C-7
T98C-8	2.4	6160	6160	-999	-999.00	-999	-999	-999.00	T98C-8
T98L-36	20.5	4533	5100	-999	-999.00	4495	-999	1.13	T98L-36
T98M-43	3.2	3003	1620	3104	0.52	5110	-999	-999.00	T98M-43
T98R-13	3.7	4750	1500	5437	0.28	6050	-999	-999.00	T98R-13
T98R-14	12.6	3017	1610	-999	-999.00	2360	-999	-999.00	T98R-14
T98R-28	3.2	7537	6130	7668	0.80	9810	-999	-999.00	T98R-28
T98R-30	1.5	4406	1820	5506	0.33	5440	5440	0.33	T98R-30
T98R-31	20.0	10215	1520	-999	-999.00	3980	-999	-999.00	T98R-31
H90-123	12.6	7096	5380	7507	0.71	4436	-999	1.21	H90-123
BL9323	-999.0	-999	285	355	0.80	355	-999	0.80	BL9323
BL9333	1.7	3183	3000	-999	-999.00	2900	-999	-999.00	BL9333

SAMP_NO	DATA_SET	REF	UTM_E	UTM_N	SYS	ENV	SEG	SEC	AAMTD	ASSAY_INT	M_TO_R	FLUV_FTR
BL9339	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	523502	5258644	U	LV	Lb	p	msr in	0-5aaba, 5-15	264	distrib lv
BL9345	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	525268	5257143	RU	LV	Lb	p	msr in	0-5aaba, 5-15	19	outside bnk
BL9346	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	524865	5257941	U	LV	Lb	p	msr in	0-5aaba, 5-15	32	straight rlv
BL9347	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	524190	5259138	Llt	FB	Lb	p	msr in	0-5aaba, 5-15	912	lat lk littoral
BL9353	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	525770	5257540	P	FB	Lb	p	msr in	0-5aaba, 5-15	350	lat marsh
BL9354	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	525540	5256770	RU	LV	Lb	p	msr in	0-5aaba, 5-15	0	outside bnk
BL9355	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	525673	5255911	Llt	FB	Lb	p	msr in	0-5aaba, 5-15	307	lat lk littoral
BL9360	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	526820	5255638	P	FB	La	loPb	msr in	0-5aaba, 5-15	454	lat marsh
BL9369	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	527358	5258230	Llt	FB	La	f	msr in	0-5aaba, 5-15	1377	lat lk littoral
BL9370	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	527614	5256597	U	LV	La	p	msr in	0-5aaba, 5-15	119	inside rlv
BL9371	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	527949	5256503	U	LV	La	p	msr in	0-5aaba, 5-15	8	outside rlv
C93235	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	547755	5266574	U	LV	Uc	p	msr in	0-5aaba, 5-15	37	outside rlv
C93236	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	547304	5266260	RU	LV	Uc	p	msr in	0-5aaba, 5-15	6	outside bnk
C93243	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	548224	5265680	RU	LV	Uc	p	msr in	0-5aaba, 5-15	5	straight bnk
C93244	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	548238	5266483	U	LV	Ub	p	msr in	0-5aaba, 5-15	414	alluv terrace
C93249	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	549118	5266463	U	LV	Ub	p	msr in	0-5aaba, 5-15	1033	alluv terrace
C93250	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	549225	5266186	U	LV	Ub	p	msr in	0-5aaba, 5-15	825	alluv terrace
C93256	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	550802	5264930	P	FB	Ub	loPb	msr in	0-5aaba, 5-15	1000	lat marsh
C93273	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	552608	5268250	U	LV	Ua	f	msr in	0-5aaba, 5-15	173	alluv terrace
C93280	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	553175	5268348	U	LV	Ua	p	msr in	0-5aaba, 5-15	149	alluv terrace
C93281	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	553709	5267056	U	LV	Ua	p	msr in	0-5aaba, 5-15	0	alluv terrace
C93288	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	554878	5266848	U	LV	Ua	p	msr in	0-5aaba, 5-15	66	alluv terrace
C93296	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	555834	5270014	U	LV	NF	loPb	msr in	0-5aaba, 5-15	87	alluv terrace
C93307	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	556204	5268438	RU	LV	NF	loPb	msr in	0-5aaba, 5-15	0	n fk bnk
H934.2	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	518000	5256575	Llt	FB	Lc	p	msr in	0-5aaba, 5-15	170	lat lk littoral
L93118	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	533262	5261100	U	LV	Mc	p	msr in	0-5aaba, 5-15	10	inside rlv
L93119	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	533010	5261649	U	LV	Mc	p	msr in	0-5aaba, 5-15	488	distrib lv
L93121	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	532930	5264182	P	FB	Mc	f	msr in	0-5aaba, 5-15	2373	lat marsh
L93128	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	534326	5261476	U	LV	Mc	p	msr in	0-5aaba, 5-15	19	straight rlv
L93135	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	534890	5261603	P	FB	Mb	p	msr in	0-5aaba, 5-15	103	lat marsh
L93137	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	535146	5263795	P	FB	Mb	p	msr in	0-5aaba, 5-15	122	lat marsh
L93154	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	537037	5262913	Llt	FB	Ma	loPb	msr in	0-5aaba, 5-15	457	lat lk littoral
L93156	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	537069	5264488	U	LV	Ma	p	msr in	0-5aaba, 5-15	35	outside rlv
L93162	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	537428	5263873	U	LV	Ma	p	msr in	0-5aaba, 5-15	126	outside rlv
M93104	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	532255	5260499	P	FB	Mc	p	msr in	0-5aaba, 5-15	574	lat marsh
M93106	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	531496	5259395	P	FB	Mc	p	msr in	0-5aaba, 5-15	260	lat marsh
M93107	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	532169	5258253	P	FB	Mc	loPb	msr in	0-5aaba, 5-15	434	lat marsh
M93108	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	531523	5257139	Llt	FB	Mc	p	msr in	0-5aaba, 5-15	1410	lat lk littoral
M93109	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	531763	5256085	P	FB	Mc	loPb	msr in	0-5aaba, 5-15	2330	lat marsh

Appendix 1. Table A. Data

SAMP_NO	ASH_CM	AA_CM	AA_10Y	AA_CM_10Y	BA_CM	BA_10Y	BA_CM_10Y	SR_AABA	JBA_CM	JBA_AA	BA1_CM	PBR_CM	PBR_10Y
BL9339	1.3	5.1	1.3	3.9	7.7	7.7	-999.0	-999.00	8.6	1.7	-999.0	15	9.0
BL9345	0.3	1.9	1.3	1.5	12.8	7.7	-999.0	-999.00	2.8	1.5	-999.0	15	9.0
BL9346	-999.0	1.9	1.3	1.5	13.1	7.7	-999.0	-999.00	3.1	1.6	-999.0	15	9.0
BL9347	1.3	5.1	1.3	3.9	9.9	7.7	-999.0	-999.00	8.6	1.7	-999.0	15	9.0
BL9353	-999.0	-999.0	-99.9	-999.0	-999.0	-99.9	-999.0	-999.00	-999.0	-999.0	-999.0	-999.0	-99.9
BL9354	0.7	5.1	1.3	3.9	9.3	7.7	-999.0	-999.00	9.2	1.8	-999.0	15	9.0
BL9355	0.3	1.6	1.3	1.2	13.4	7.7	-999.0	-999.00	3.1	1.9	-999.0	15	9.0
BL9360	0.3	1.9	1.3	1.5	-999.0	7.7	-999.0	-999.00	2.8	1.5	-999.0	-999.0	9.0
BL9369	0.5	3.8	1.3	2.9	4.5	7.7	0.6	4.99	0.7	0.2	-999.0	5	9.0
BL9370	0.3	3.8	1.3	2.9	10.6	7.7	-999.0	-999.00	0.8	0.2	-999.0	15	9.0
BL9371	0.5	3.2	1.3	2.5	11.2	7.7	-999.0	-999.00	1.3	0.4	-999.0	15	9.0
C93235	0.3	5.1	1.3	3.9	9.3	7.7	-999.0	-999.00	9.6	1.9	-999.0	15	9.0
C93236	0.3	11.4	1.3	8.8	3.0	7.7	-999.0	-999.00	3.3	0.3	-999.0	15	9.0
C93243	1.0	2.5	1.3	1.9	10.8	7.7	-999.0	-999.00	1.5	0.6	-999.0	15	9.0
C93244	0.3	2.2	1.3	1.7	12.2	7.7	-999.0	-999.00	2.5	1.1	2.5	15	9.0
C93249	0.3	0.0	1.3	0.0	14.4	7.7	-999.0	-999.00	4.7	-999.0	-999.0	15	9.0
C93250	0.3	0.0	1.3	0.0	14.4	7.7	-999.0	-999.00	4.7	-999.0	-999.0	15	9.0
C93256	0.6	5.1	1.3	3.9	-999.0	7.7	-999.0	-999.00	9.3	1.8	-999.0	-999.0	9.0
C93273	0.3	1.6	1.3	1.2	7.8	7.7	1.0	1.21	3.1	1.9	-999.0	5	9.0
C93280	-999.0	5.1	1.3	3.9	9.9	7.7	-999.0	-999.00	9.9	1.9	-999.0	15	9.0
C93281	0.3	3.8	1.3	2.9	10.6	7.7	-999.0	-999.00	0.9	0.2	-999.0	15	9.0
C93288	0.3	5.1	1.3	3.9	9.6	7.7	-999.0	-999.00	9.6	1.9	-999.0	15	9.0
C93296	0.2	6.4	1.3	4.9	-999.0	7.7	-999.0	-999.00	8.4	1.3	-999.0	15	9.0
C93307	0.3	5.1	1.3	3.9	-999.0	7.7	-999.0	-999.00	9.6	1.9	-999.0	-999.0	9.0
H934.2	0.3	5.1	1.3	3.9	-999.0	7.7	-999.0	-999.00	9.6	1.9	-999.0	15	9.0
L93118	0.3	5.1	1.3	3.9	9.3	7.7	-999.0	-999.00	9.6	1.9	-999.0	15	9.0
L93119	0.3	2.5	1.3	1.9	11.9	7.7	-999.0	-999.00	1.3	0.5	-999.0	15	9.0
L93121	0.3	3.8	1.3	2.9	0.0	7.7	0.0	-999.00	-999.0	-999.0	-999.0	5	9.0
L93128	1.0	2.5	1.3	1.9	12.2	7.7	-999.0	-999.00	1.5	0.6	-999.0	15	9.0
L93135	0.2	5.1	1.3	3.9	9.3	7.7	-999.0	-999.00	9.7	1.9	-999.0	15	9.0
L93137	0.3	2.5	1.3	1.9	11.9	7.7	-999.0	-999.00	2.2	0.9	-999.0	15	9.0
L93154	0.3	1.6	1.3	1.2	-999.0	7.7	-999.0	-999.00	3.1	1.9	-999.0	15	9.0
L93156	0.3	2.9	1.3	2.2	11.5	7.7	-999.0	-999.00	1.8	0.6	-999.0	15	9.0
L93162	0.3	3.8	1.3	2.9	10.6	7.7	-999.0	-999.00	0.9	0.2	-999.0	15	9.0
M93104	0.5	0.0	1.3	0.0	14.4	7.7	-999.0	-999.00	4.5	-999.0	-999.0	15	9.0
M93106	0.3	2.5	1.3	1.9	11.9	7.7	-999.0	-999.00	2.2	0.9	2.2	15	9.0
M93107	0.3	1.3	1.3	1.0	-999.0	7.7	-999.0	-999.00	3.4	2.6	-999.0	-999.0	9.0
M93108	0.3	0.6	1.3	0.5	14.4	7.7	-999.0	-999.00	4.1	6.8	-999.0	15	9.0
M93109	0.3	1.3	1.3	1.0	-999.0	7.7	-999.0	-999.00	3.4	2.6	-999.0	-999.0	9.0

Appendix 1. Table A. Data

SAMP_NO	PBR_CM_10Y	PBR_PB	AA_PB	BA_PB	PB_AABA	JBA_PB	BA1_PB	PBAA_BA1	SAMP_NO
BL9339	1.7	3567	4500	-999	-999.00	3200	-999	-999.00	BL9339
BL9345	1.7	3950	2800	-999	-999.00	3300	-999	-999.00	BL9345
BL9346	1.7	3933	4000	-999	-999.00	4000	-999	-999.00	BL9346
BL9347	1.7	1600	790	-999	-999.00	1600	-999	-999.00	BL9347
BL9353	-999.0	-999	1400	-999	-999.00	2900	-999	-999.00	BL9353
BL9354	1.7	3433	3500	-999	-999.00	3400	-999	-999.00	BL9354
BL9355	1.7	4550	2800	-999	-999.00	3700	-999	-999.00	BL9355
BL9360	-999.0	-999	210	356	0.59	375	-999	-999.00	BL9360
BL9369	0.6	-999	2100	2900	1.19	2900	-999	0.72	BL9369
BL9370	1.7	3633	2300	-999	-999.00	3500	-999	0.66	BL9370
BL9371	1.7	3300	2400	-999	-999.00	3300	-999	0.73	BL9371
C93235	1.7	2767	2300	-999	-999.00	3000	-999	-999.00	C93235
C93236	1.7	2267	1800	-999	-999.00	2500	-999	0.72	C93236
C93243	1.7	3325	2750	-999	-999.00	2200	-999	1.25	C93243
C93244	1.7	2533	1700	-999	-999.00	1900	1900	0.89	C93244
C93249	1.7	6775	-999	-999	-999.00	4900	-999	-999.00	C93249
C93250	1.7	6675	-999	-999	-999.00	3300	-999	-999.00	C93250
C93256	-999.0	-999	74	66	1.12	66	-999	-999.00	C93256
C93273	0.6	-999	1800	1200	1.50	1200	-999	-999.00	C93273
C93280	1.7	4833	2500	-999	-999.00	6000	-999	-999.00	C93280
C93281	1.7	3300	2200	-999	-999.00	3400	-999	0.65	C93281
C93288	1.7	1300	965	-999	-999.00	1300	-999	-999.00	C93288
C93296	-999.0	-999	110	110	1.00	110	-999	-999.00	C93296
C93307	-999.0	-999	185	555	0.33	555	-999	-999.00	C93307
H934.2	-999.0	3800	3500	-999	-999.00	3900	-999	-999.00	H934.2
L93118	1.7	3933	4000	-999	-999.00	3900	-999	-999.00	L93118
L93119	1.7	1583	1900	-999	-999.00	2000	-999	0.95	L93119
L93121	0.6	-999	1100	775	1.42	775	-999	1.42	L93121
L93128	1.7	3883	4400	-999	-999.00	2900	-999	1.52	L93128
L93135	1.7	3767	4100	-999	-999.00	3600	-999	-999.00	L93135
L93137	1.7	4650	4200	-999	-999.00	4100	4100	1.02	L93137
L93154	-999.0	915	715	940	0.76	990	-999	-999.00	L93154
L93156	1.7	4167	4000	-999	-999.00	3200	-999	1.25	L93156
L93162	1.7	4150	3600	-999	-999.00	3300	-999	1.09	L93162
M93104	1.7	4100	-999	-999	-999.00	3300	-999	-999.00	M93104
M93106	1.7	3767	3600	-999	-999.00	3000	3000	1.20	M93106
M93107	-999.0	-999	165	211	0.78	320	-999	-999.00	M93107
M93108	1.7	1617	1600	-999	-999.00	2100	-999	-999.00	M93108
M93109	-999.0	-999	220	144	1.53	240	-999	-999.00	M93109

Appendix 1. Table A. Data

SAMP_NO	DATA_SET	REF	UTM_E	UTM_N	SYS	ENV	SEG	SEC	AAMTD	ASSAY_INT	M_TO_R	FLUV_FTR
M9378	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	528694	5257714	P	FB	La	p	msr in	0-5aaba, 5-15	99	lat marsh
M9394	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	531194	5256615	Llt	FB	Mc	p	msr in	0-5aaba, 5-15	1647	lat lk littoral
M9395	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	531083	5257630	U	LV	La	p	msr in	0-5aaba, 5-15	669	distrib lv
M9396	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	530536	5258183	RU	LV	La	p	msr in	0-5aaba, 5-15	0	outside bnk
M9397	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	530829	5258681	RU	LV	Mc	f	msr in	0-5aaba, 5-15	18	outside bnk
RL93161	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	538090	5264836	RU	LV	Ma	p	msr in	0-5aaba, 5-15	1	outside bnk
RL93171	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	538948	5264429	U	LV	Ma	p	msr in	0-5aaba, 5-15	8	outside rlv
RL93177	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	539261	5265299	U	LV	Ma	p	msr in	0-5aaba, 5-15	667	distrib lv
RL93178	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	539405	5265123	U	LV	Ma	p	msr in	0-5aaba, 5-15	437	distrib lv
RL93193	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	541398	5264301	U	LV	Uc	p	msr in	0-5aaba, 5-15	56	straight rlv
RL93198	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	542194	5264121	RU	LV	Uc	p	msr in	0-5aaba, 5-15	2	inside bnk
RL93206	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	543680	5267131	P	FB	Uc	loPb	msr in	0-5aaba, 5-15	1450	lat marsh
RL93207	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	544275	5265402	RU	LV	Uc	p	msr in	0-5aaba, 5-15	35	inside bnk
RL93213	USGS/WRD/93	Fousek (1996), Fousek (unpub data, 1993)	544778	5265252	RU	LV	Uc	p	msr in	0-5aaba, 5-15	0	straight bnk

Appendix 1. Table A. Data

SAMP_NO	ASH_CM	AA_CM	AA_10Y	AA_CM_10Y	BA_CM	BA_10Y	BA_CM_10Y	SR_AABA	JBA_CM	JBA_AA	BA1_CM	PBR_CM	PBR_10Y
M9378	0.3	2.5	1.3	1.0	9.2	7.7	-999.0	-999.00	2.2	0.9	2.2	15	9.0
M9394	2.5	3.8	1.3	2.9	11.2	7.7	-999.0	-999.00	8.7	2.3	-999.0	15	9.0
M9395	0.3	4.5	1.3	3.4	10.3	7.7	-999.0	-999.00	0.2	0.0	-999.0	15	9.0
M9396	0.2	2.5	1.3	1.9	11.9	7.7	-999.0	-999.00	2.3	0.9	-999.0	15	9.0
M9397	0.3	2.5	1.3	1.9	6.9	7.7	0.9	2.13	2.2	0.9	-999.0	5	9.0
RL93161	0.3	2.2	1.3	1.7	12.5	7.7	-999.0	-999.00	2.5	1.1	-999.0	15	9.0
RL93171	-999.0	-999.0	1.3	1.9	11.9	7.7	-999.0	-999.00	-999.0	-999.0	-999.0	15	9.0
RL93177	0.3	1.0	1.3	0.8	13.4	7.7	-999.0	-999.00	3.7	3.7	-999.0	15	9.0
RL93178	0.3	1.6	1.3	1.2	13.1	7.7	-999.0	-999.00	3.1	1.9	-999.0	15	9.0
RL93193	0.2	2.5	1.3	1.9	12.2	7.7	-999.0	-999.00	2.3	0.9	-999.0	15	9.0
RL93198	0.2	2.2	1.3	1.7	12.2	7.7	-999.0	-999.00	2.6	1.2	-999.0	15	9.0
RL93206	0.5	1.6	1.3	1.2	-999.0	7.7	-999.0	-999.00	2.9	1.8	-999.0	-999.0	9.0
RL93207	0.3	1.9	1.3	1.5	12.5	7.7	-999.0	-999.00	2.8	1.5	-999.0	15	9.0
RL93213	0.3	1.6	1.3	1.2	13.4	7.7	-999.0	-999.00	3.1	1.9	-999.0	15	9.0

Appendix 1. Table A. Data

SAMP_NO	PBR_CM_10Y	PBR_PB	AA_PB	BA_PB	PB_AABA	JBA_PB	BA1_PB	PBAA_BA1	SAMP_NO
M9378	1.7	3167	2600	-999	-999.00	2800	2800	0.93	M9378
M9394	1.7	2767	1300	-999	-999.00	620	-999	-999.00	M9394
M9395	1.7	3800	2100	-999	-999.00	3500	-999	0.60	M9395
M9396	1.7	3300	3650	-999	-999.00	2550	2550	1.43	M9396
M9397	0.6	-999	1800	1500	1.20	1500	1500	1.20	M9397
RL93161	1.7	4533	4100	-999	-999.00	4700	4700	-999.00	RL93161
RL93171	1.7	4675	5500	-999	-999.00	6000	-999	-999.00	RL93171
RL93177	1.7	2700	850	-999	-999.00	-999	-999	-999.00	RL93177
RL93178	1.7	5800	6600	-999	-999.00	-999	-999	-999.00	RL93178
RL93193	1.7	6417	6000	-999	-999.00	6100	6100	0.98	RL93193
RL93198	1.7	6792	5150	-999	-999.00	5400	-999	-999.00	RL93198
RL93206	-999.0	-999	330	628	0.53	260	-999	-999.00	RL93206
RL93207	1.7	3267	2400	-999	-999.00	3600	-999	-999.00	RL93207
RL93213	1.7	2567	2100	-999	-999.00	2900	-999	-999.00	RL93213

Identification_Information:
  Citation:
    Citation_Information:
      Originator: Bookstrom, A.A.
      Originator: Box, S.E.
      Originator: Fousek, R.S.
      Originator: Jackson, B.L.
      Originator: Wallis, J.C.
      Originator: Kayser, H.Z.
      Publication_Date: 2004
      Title: Spatial database in Baseline and Historic Depositional Rates and Lead Concentrations, Floodplain Sediments, Lower Coeur d'Alene River, Idaho
      Geospatial_Data_Presentation_Form: vector digital data
      Series_Information:
        Series_Name: U.S. Geological Survey Open-File Report
        Issue_Identification: 04-1211
      Online_Linkage: http://pubs.usgs.gov/of/2004-1211
  Description:
    Abstract:
      Lead-rich sediments, containing at least 1,000 ppm of lead cover about 60 km2 of the 84-km2 floor of the main stem of the Coeur d'Alene River valley (Bookstrom and others, 2001). Large-scale mining and milling of veins enriched in silver (Ag), lead (Pb), zinc (Zn), and other metals began in 1886 in the Coeur d'Alene mining region. Until 1968, some mills discarded pulverized tailings, containing particulate metallic-sulfide minerals, directly into streams of the upper Coeur d'Alene River drainage basin. The discarded tailings washed down-stream, mixed with other sediments in transport, and were re-deposited down-valley.
      Frequent floods continue to transport metal-enriched sediment down-valley and onto the floodplain. Thick deposits of lead-rich sediments are present in the low-gradient river channel west of Cataldo Landing. These river-channel deposits of lead-rich sediments are an important secondary source of lead-rich sediments, vulnerable to transport during floods. Floodwaters continue to mobilize and re-deposit lead-rich sediments from this large secondary source, even though tailings have not been discarded into tributary streams since 1968, and large volumes of lead-rich sediments were removed from tributary streams and floodplains during the late 1990's. Furthermore, floodwaters will continue to remobilize lead-rich sediments from the river channel, as well as from smaller secondary sources along its banks and levees, and will continue to deposit lead-rich sediments in lateral flood basins, where waterfowl commonly feed, until these secondary sources are removed, stabilized and covered, or effectively separated from the flood basins.
      The "May 1980 Mt. St. Helens volcanic-ash layer" provided an excellent 1980 time-stratigraphic marker layer, referred to as the"1980 volcanic-ash layer". The pre-remedial baseline interval is defined as sediment above the 1980 time-stratigraphic horizon at the time of measurement and sampling, most of which was done between 1991 and 1995 (1993 +/- 2y), and all of which was done between 1990 and 1998.
    Purpose: The primary purpose of this study is to quantify pre-remedial baseline depositional rates and lead concentrations in sediments deposited between 1980 and about 1993, in various settings on the floodplain of the main stem of the Coeur d'Alene River, and compare baseline to historic and background depositional rates and lead concentrations. The secondary purpose is to explain the implications of this information for environmental remediation in the context of fluvial processes still acting on secondary sources of lead-rich sediments, previously deposited along floodwater flow paths. The CDA_SR_PB spatial database was created to enable the authors to display sample sites, showing baseline sediment deposition rates, and lead concentrations in baseline-interval sediments, in the context of surficial geologic units, mapped on the floodplain of the main stem of the Coeur d'Alene River. This information was gathered and organized in support of ongoing studies of the environmental impacts of lead-rich floodplain sediments, and long-term cleanup plans being formulated by the U.S. Environmental Protection Agency and others.
    Supplemental_Information: The CDA_SR_PB spatial dataset is an ESRI-formatted shapefile (that consists of a collection of files of the same name having the

following file extensions: DBF, SBN, SBX, SHP, and SHX). It is not merely a new "revision" of the pre-existing data (Bookstrom and others, 2001) from which it was built: the addition of one sample site, the deletion of a few others, and a significant amount of new sedimentation-rate data make it a new product. The dataset contains information for 131 sample localities.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 2004
    Currentness_Reference: publication date
  Status:
    Progress: Complete for informal Open-File Report publication; however, minor revisions are likely to be made to the spatial database when the report is superseded by a U.S. Geological Survey Scientific Investigations Report.
    Maintenance_and_Update_Frequency: Minor revisions may likely be made to the spatial database when it is formally published as a U.S. Geological Survey Scientific Investigations Report.
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -116.820096
      East_Bounding_Coordinate: -116.252574
      North_Bounding_Coordinate: 47.585365
      South_Bounding_Coordinate: 47.340604
  Keywords:
    Theme:
      Theme_Keyword_Thesaurus: Glossary of Geology, American Geological Institute
      Theme_Keyword: Surficial geology
      Theme_Keyword: Lead
      Theme_Keyword: Tailings
      Theme_Keyword: Sediment
      Theme_Keyword: Sedimentation rate
    Place:
      Place_Keyword: Coeur d'Alene River
      Place_Keyword: Kootenai County
      Place_Keyword: Shoshone County
      Place_Keyword: Idaho
      Place_Keyword: Pacific Northwest
      Place_Keyword: United States
      Place_Keyword: USA
  Access_Constraints: none
  Use_Constraints: Any hardcopies utilizing these data sets shall clearly indicate their source. If the users have modified the data in any way they are obligated to describe the type of modifications they have performed. User specifically agrees not to misrepresent these data sets, nor to imply that changes they made were approved by the U.S. Geological Survey.
  Point_of_Contact:
    Contact_Information:
      Contact_Person_Primary:
        Contact_Person: Arthur A. Bookstrom
        Contact_Organization: U.S. Geological Survey
      Contact_Position: Geologist
      Contact_Address:
        Address_Type: mailing and physical address
        Address: 904 W. Riverside Avenue, Rm. 202
        City: Spokane
        State_or_Province: Washington
        Postal_Code: 99201
        Country: USA
      Contact_Voice_Telephone: 1-509-368-3119
      Contact_Facsimile_Telephone: 1-509-368-3199
      Contact_Electronic_Mail_Address: abookstrom@usgs.gov
  Data_Set_Credit: John C. Wallis and Helen Z. Kayser (contractors) wrote the metadata, and Gary L. Raines reviewed the digital data and metadata.

```
  Security_Information:
    Security_Classification_System: none
    Security_Classification: Unclassified
  Native_Data_Set_Environment: Microsoft Windows 2000 Version 5.0 (Build 2195)
Service Pack 4; ESRI ArcCatalog 9.0.0.535
Data_Quality_Information:
  Attribute_Accuracy:
    Attribute_Accuracy_Report: Accuracy was verified by manual comparison of the
source data with hardcopy printouts, and on screen evaluations.
  Logical_Consistency_Report: These data are believed to be logically consistent,
though no tests were performed other than using the data for analysis.
  Completeness_Report: Original vector data was assumed to be complete.
  Positional_Accuracy:
    Horizontal_Positional_Accuracy:
      Horizontal_Positional_Accuracy_Report: The horizontal positional accuracy for
the digital data is no better than about 15 meters based on digitizing RMS error.
      Quantitative_Horizontal_Positional_Accuracy_Assessment:
        Horizontal_Positional_Accuracy_Value: 15 meters
    Vertical_Positional_Accuracy:
      Vertical_Positional_Accuracy_Report: No vertical data.
  Lineage:
    Source_Information:
      Source_Citation:
        Citation_Information:
          Originator: Bookstrom, A.A.
          Originator: Box, S.E.
          Originator: Campbell, J.K.
          Originator: Foster, K.I.
          Originator: Jackson, B.L.
          Publication_Date: 2001
          Title: Lead rich sediments, Coeur d'Alene River valley, Idaho: Area,
volume, tonnage, and lead content
          Edition: 1.0
          Geospatial_Data_Presentation_Form: digital map
          Series_Information:
            Series_Name: Open-File Report
            Issue_Identification: 01-140
          Publication_Information:
            Publication_Place: Menlo Park, CA
            Publisher: U.S. Geological Survey
          Online_Linkage: http://geopubs.wr.usgs.gov/open-file/of01-140/
      Source_Scale_Denominator: 24000
      Type_of_Source_Media: map
      Source_Time_Period_of_Content:
        Time_Period_Information:
          Single_Date/Time:
            Calendar_Date: 2001
        Source_Currentness_Reference: publication date
      Source_Citation_Abbreviation: Bookstrom and others (2001)
      Source_Contribution: Two dBase4 files (ALSAMPB.DBF and THXPB11.DBF) provided
sample site locations. ESRI shape files (CDASURF4_UTM.SHP, FPAREAM2.SHP,
SEGMENTS.SHP and PB1000.SHP) were incorporated into the accompanying map plates to
provide a basemap on which to overlay data from the CDA_SR_PB spatial database.
    Source_Information:
      Source_Citation:
        Citation_Information:
          Originator: Horowitz, A.J.
          Originator: Erlick, K.A.
          Originator: Robbins, J.A.
          Originator: Cook, R.B.
          Publication_Date: 1995
          Title: Effect of mining and related activities on the sediment
          Edition: 1.0
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Geospatial_Data_Presentation_Form: tabular digital data
Publication_Information:
Publication_Place: New York, New York
Publisher: John Wiley and Sons, LTD
Type_of_Source_Media: GPS Receiver
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 1995
Source_Currentness_Reference: publication date
Source_Citation_Abbreviation: Horowitz and others (1995)
Source_Contribution: One sample point from this tabular report was added to the CDA_SR_PB dataset. The sample point location was obtained by a GPS receiver.
Process_Step:
Process_Description: A new sample point location (from Horowitz and others, 1995), and new data on sedimentation rate and lead concentration were added to the dBase4 file (Bookstrom and others, 2001) using Microsoft Excel. The dBase4 file was then imported into ArcView and converted to a shape file CDA_SR_PB. An ArcView legend file, CDA_SR_PB.AVL, was made to format the theme.
Process_Date: Unknown
Process_Step:
Process_Description: The CDASURF4_UTM, FPAREAM2, SEGMENTS and PB1000 shapefiles (Bookstrom and others, 2001) were imported into an ArcView project and used to provide a basemap on which sedimentation-rate and lead- concentration data could be shown. These data were used without modification with the exception of subsetting the SEGMENTS shapefile (to exclude valley boundary lines numbered 1 through 8, due to their irrelevance in this study.
Source_Used_Citation_Abbreviation: Bookstrom and others (2001), Horowitz and others (1995)
Process_Date: 2001 - 2005
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Arthur A. Bookstrom
Contact_Organization: U.S. Geological Survey
Contact_Position: Geologist
Contact_Address:
Address_Type: mailing and physical address
Address: 904 W. Riverside Avenue, Rm. 202
City: Spokane
State_or_Province: WA
Postal_Code: 99201
Country: USA
Contact_Voice_Telephone: 1-509-368-3119
Contact_Facsimile_Telephone: 1-509-368-3199
Contact_Electronic_Mail_Address: abookstrom@usgs.gov
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation:
C:\WRDIA\CDA_meta\6th_time_Jan05\2_OFR\metadata\cda_sr_pb-meta.xml
Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Entity point
Point_and_Vector_Object_Count: 131
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 11

```
          Transverse_Mercator:
            Scale_Factor_at_Central_Meridian: 0.999600
            Longitude_of_Central_Meridian: -117.000000
            Latitude_of_Projection_Origin: 0.000000
            False_Easting: 500000.000000
            False_Northing: 0.000000
        Planar_Coordinate_Information:
          Planar_Coordinate_Encoding_Method: coordinate pair
          Coordinate_Representation:
            Abscissa_Resolution: 0.000064
            Ordinate_Resolution: 0.000064
          Planar_Distance_Units: meters
      Geodetic_Model:
        Horizontal_Datum_Name: North American Datum of 1927
        Ellipsoid_Name: Clarke 1866
        Semi-major_Axis: 6378206.400000
        Denominator_of_Flattening_Ratio: 294.978698
Entity_and_Attribute_Information:
  Detailed_Description:
    Entity_Type:
      Entity_Type_Label: cda_sr_pb
      Entity_Type_Definition: ESRI point shapefile (which contains files with the
extensions .SHP, .SHX, .SBX, .SBN, .DBF) of sedimentation rates and lead
concentrations for 131 location points in the study area.
    Attribute:
      Attribute_Label: FID
      Attribute_Definition: Internal feature number.
      Attribute_Definition_Source: ESRI
      Attribute_Domain_Values:
        Unrepresentable_Domain: Sequential unique whole numbers that are
automatically generated.
    Attribute:
      Attribute_Label: Shape
      Attribute_Definition: Feature geometry.
      Attribute_Definition_Source: ESRI
      Attribute_Domain_Values:
        Unrepresentable_Domain: Coordinates defining the features.
    Attribute:
      Attribute_Label: SAMP_NO
      Attribute_Definition: SAMPLE NUMBER - from original study (see Bookstrom and
others, 2001)
      Attribute_Domain_Values:
    Attribute:
      Attribute_Label: DATA_SET
      Attribute_Definition: DATA-SET IDENTIFIER - It consists of initials
researcher's affiliation, researcher's last name, and year that data were collected.
      Attribute_Domain_Values:
    Attribute:
      Attribute_Label: REF
      Attribute_Definition: REFERENCE IDENTIFIER - The data source citation.
Complete references are provided in the report text in the List of References
section.
    Attribute:
      Attribute_Label: UTM_E
      Attribute_Definition: UTM EAST - The coordinate (in meters) of sample site,
(UTM map projection: Universal Transverse Mercator, zone 11, North American Datum of
1927)
    Attribute:
      Attribute_Label: UTM_N
      Attribute_Definition: UTM NORTH - The coordinate (in meters) of sample site,
(UTM map projection: Universal Transverse Mercator, zone 11, North American Datum of
1927)
    Attribute:
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Attribute_Label: SYS
Attribute_Definition: SYSTEM IDENTIFIER - The label used to identify wetland system
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: RU
Enumerated_Domain_Value_Definition: River bank Upland - wedge shaped deposits of lead-rich sediments on the river-facing slope of the natural levee
Enumerated_Domain:
Enumerated_Domain_Value: U
Enumerated_Domain_Value_Definition: (Levee/) Upland - Floodplain-facing slope of the natural levee, from the levee crest to the adjacent lateral marsh or lateral lake
Enumerated_Domain:
Enumerated_Domain_Value: P
Enumerated_Domain_Value_Definition: Palustrine - lateral marshes, seasonally to perinnally flooded to less than 2 meters deep
Enumerated_Domain:
Enumerated_Domain_Value: L
Enumerated_Domain_Value_Definition: Lacustrine - lateral lakes, wetlands, and deepwater habitats
Enumerated_Domain:
Enumerated_Domain_Value: Ldd
Enumerated_Domain_Value_Definition: a distributary delta in a Lacustrine environment
Enumerated_Domain:
Enumerated_Domain_Value: Llt
Enumerated_Domain_Value_Definition: Lacustrine, littoral - a subset of the Lacustrine system, wetlands and deepwater habitats less than 2 meters deep (margins) at summer water level
Enumerated_Domain:
Enumerated_Domain_Value: Llm
Enumerated_Domain_Value_Definition: Lacustrine, limnetic - a subset of the Lacustrine system, wetlands and deepwater habitats more than 2m deep (bottoms) at summer water level
Enumerated_Domain:
Enumerated_Domain_Value: A
Enumerated_Domain_Value_Definition: Anthropogenic - man-made features (includes roads, railroad embankments, and dredge-spoil deposits)
Enumerated_Domain:
Enumerated_Domain_Value: DLT
Enumerated_Domain_Value_Definition: Coeur d'Alene River delta - the area from the mouth of the river to floor of the lake
Enumerated_Domain:
Enumerated_Domain_Value: UA
Enumerated_Domain_Value_Definition: Upland Anthropogenic - artificial features above summer water level
Enumerated_Domain:
Enumerated_Domain_Value: PA
Enumerated_Domain_Value_Definition: Palustrine Anthropogenic - artificial features within the wetlands
Attribute:
Attribute_Label: ENV
Attribute_Definition: ENVIRONMENT IDENTIFIER - The label used to identify sedimentary floodplain environment
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: LV
Enumerated_Domain_Value_Definition: Levee - man-made embankment to prevent flooding
Enumerated_Domain:
Enumerated_Domain_Value: FB
Enumerated_Domain_Value_Definition: Flood basin - an area of the earth

which holds water at times of floods due to the strata dip usually from the sides toward the middle (the river)
    Attribute:
      Attribute_Label: SEG
      Attribute_Definition: SEGMENT IDENTIFIER - The label used to identify a segment of the river valley
      Attribute_Domain_Values:
        Enumerated_Domain:
          Enumerated_Domain_Value: Ua
          Enumerated_Domain_Value_Definition: Kingston segment (located in the upper part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: Ub
          Enumerated_Domain_Value_Definition: Cataldo segment (located in the upper part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: Uc
          Enumerated_Domain_Value_Definition: Dudley segment (located in the upper part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: Ma
          Enumerated_Domain_Value_Definition: Rose Lake segment (located in the middle part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: Mb
          Enumerated_Domain_Value_Definition: Lane segment (located in the middle part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: Mc
          Enumerated_Domain_Value_Definition: Killarney segment (located in the middle part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: La
          Enumerated_Domain_Value_Definition: Medimont segment (located in the lower part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: Lb
          Enumerated_Domain_Value_Definition: Blue Lake segment (located in the lower part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: Lc
          Enumerated_Domain_Value_Definition: Harrison segment (located in the lower part of the main stem of the Coeur d'Alene River valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: DLTT
          Enumerated_Domain_Value_Definition: Coeur d'Alene River delta toe segment (located in the Coeur d'Alene Lake)
        Enumerated_Domain:
          Enumerated_Domain_Value: NF
          Enumerated_Domain_Value_Definition: North Fork segment (located in the North Fork of the Coeur d'Alene River Valley)
        Enumerated_Domain:
          Enumerated_Domain_Value: SJRV
          Enumerated_Domain_Value_Definition: St. Joe segment (located in the St. Joe River valley)
    Attribute:
      Attribute_Label: SEC
      Attribute_Definition: SECTION IDENTIFIER - Descriptions of completeness of the stratigraphic section of mining-era sediments
      Attribute_Domain_Values:
        Enumerated_Domain:
          Enumerated_Domain_Value: f
          Enumerated_Domain_Value_Definition: Full stratigraphic section (includes

```
1980 ash layer)
        Enumerated_Domain:
          Enumerated_Domain_Value: fna
          Enumerated_Domain_Value_Definition: Full stratigraphic section (does NOT
include 1980 ash layer)
        Enumerated_Domain:
          Enumerated_Domain_Value: nfna
          Enumerated_Domain_Value_Definition: Nearly full stratigraphic section
(does NOT include 1980 ash layer)
        Enumerated_Domain:
          Enumerated_Domain_Value: p
          Enumerated_Domain_Value_Definition: Partial stratigraphic section
(includes 1980 ash layer and bottoms in lead-rich sediments)
        Enumerated_Domain:
          Enumerated_Domain_Value: loPb
          Enumerated_Domain_Value_Definition: Stratigraphic section with less than
1000 ppm of lead in sediments above and below the 1980 ash layer
    Attribute:
      Attribute_Label: AAMTD
      Attribute_Definition: AA METHOD  - the method used to identify and measure
thickness of post-1980 sediments
      Attribute_Domain_Values:
        Enumerated_Domain:
          Enumerated_Domain_Value: msr cm
          Enumerated_Domain_Value_Definition: Thickness above 1980 ash layer,
measured in centimeters
        Enumerated_Domain:
          Enumerated_Domain_Value: msr in
          Enumerated_Domain_Value_Definition: Thickness above 1980 ash layer,
measured in inches
        Enumerated_Domain:
          Enumerated_Domain_Value: Cs isotp
          Enumerated_Domain_Value_Definition: Thickness in centimeters of sediment
deposited after about 1980 (half of the thickness of the sediment deposited after
1969), as indicated by Cesium isotopic dating of the contact between silty
lamentated sediment and overlying non-layered sediment in freeze box core M92CS.
        Enumerated_Domain:
          Enumerated_Domain_Value: correl
          Enumerated_Domain_Value_Definition: Thickness in centimeters of sediment
deposited after about 1980 (half of the thickness of the sediment deposited after
1969), as indicated by correlation of the contact between silty lamentated sediment
and overlying non-layered sediment, as dated by correlation with freeze box core
M92CS in which the 1969 contact was dated by the Cesium isotopic method.
        Enumerated_Domain:
          Enumerated_Domain_Value: nd
          Enumerated_Domain_Value_Definition: Thickness was not determined
    Attribute:
      Attribute_Label: ASSAY_INT
      Attribute_Definition: ASSAY INTERVAL - The sample-assay depth-interval
criteria
      Attribute_Domain_Values:
        Enumerated_Domain:
          Enumerated_Domain_Value: 2 span
          Enumerated_Domain_Value_Definition: Samples were taken in a continuous
series of 2-cm thick intervals.
        Enumerated_Domain:
          Enumerated_Domain_Value: 1-2.5 span
          Enumerated_Domain_Value_Definition: Samples were taken in a continuous
series of 1- to 2.5-cm thick intervals.
        Enumerated_Domain:
          Enumerated_Domain_Value: 0-5 aaba, 5-15
          Enumerated_Domain_Value_Definition: Sample intervals were chosen by the
following criteria: a 0-5 cm interval (split into above-ash and below-ash parts) and
```

a 5-15 cm interval
Enumerated_Domain:
Enumerated_Domain_Value: strat span
Enumerated_Domain_Value_Definition: Continuous samples represent variable depth spans, based on stratigraphic layering
Enumerated_Domain:
Enumerated_Domain_Value: strat spot
Enumerated_Domain_Value_Definition: Discontinuous spot samples taken from the midpoint of the stratigraphic interval represented+
Enumerated_Domain:
Enumerated_Domain_Value: aatp, ba1btm
Enumerated_Domain_Value_Definition: Spot samples were collected at top of AA interval, at bottom of BA1 interval, and at variable depth intervals below the BA1 interval.
Enumerated_Domain:
Enumerated_Domain_Value: na
Enumerated_Domain_Value_Definition: Sample was collected but not analyzed for lead.
Enumerated_Domain:
Enumerated_Domain_Value: intrvl>aa
Enumerated_Domain_Value_Definition: Recorded thickness of sampling interval includes but exceeds thickness of sediments above the 1980 ash layer. This information was not used in this study.
Attribute:
Attribute_Label: M_TO_R
Attribute_Definition: METERS to RIVER - The distance (measured in meters) from sample site to the nearest riverbank
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 2373
Attribute_Units_of_Measure: meters
Attribute:
Attribute_Label: FLUV_FTR
Attribute_Definition: FLUVIAL FEATURE - the type of feature found at sample site
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: alluv terrace
Enumerated_Domain_Value_Definition: alluvial terrace
Enumerated_Domain:
Enumerated_Domain_Value: distrib lv
Enumerated_Domain_Value_Definition: distributary levee
Enumerated_Domain:
Enumerated_Domain_Value: inside bnk
Enumerated_Domain_Value_Definition: inside bank - inside margin of a river channel on a curve, bend or meander
Enumerated_Domain:
Enumerated_Domain_Value: inside rlv
Enumerated_Domain_Value_Definition: inside river levee - inside margin of a river levee on a curve, bend or meander
Enumerated_Domain:
Enumerated_Domain_Value: lat lk delta
Enumerated_Domain_Value_Definition: lateral lake delta
Enumerated_Domain:
Enumerated_Domain_Value: lat lk limetic
Enumerated_Domain_Value_Definition: lateral lake limnetic bottoms (in more than 2 meters deep at summer water level)
Enumerated_Domain:
Enumerated_Domain_Value: lat lk littoral
Enumerated_Domain_Value_Definition: lateral lake littoral margins (in less than 2 meters deep at summer water level)
Enumerated_Domain:

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          Enumerated_Domain_Value: lat marsh
          Enumerated_Domain_Value_Definition: lateral marsh
        Enumerated_Domain:
          Enumerated_Domain_Value: main delta
          Enumerated_Domain_Value_Definition: main delta of the river
        Enumerated_Domain:
          Enumerated_Domain_Value: marsh anthr
          Enumerated_Domain_Value_Definition: anthropogenic marsh
        Enumerated_Domain:
          Enumerated_Domain_Value: n fk bank
          Enumerated_Domain_Value_Definition: bank of the North Fork River
        Enumerated_Domain:
          Enumerated_Domain_Value: outside bnk
          Enumerated_Domain_Value_Definition: outside bank - outside margin of a
river channel on a curve, bend or meander
        Enumerated_Domain:
          Enumerated_Domain_Value: outside rlv
          Enumerated_Domain_Value_Definition: outside river levee - outside margin
of a river levee on a curve, bend or meander
        Enumerated_Domain:
          Enumerated_Domain_Value: splay
          Enumerated_Domain_Value_Definition: sand splay
        Enumerated_Domain:
          Enumerated_Domain_Value: st joe bank
          Enumerated_Domain_Value_Definition: bank of the St. Joe River
        Enumerated_Domain:
          Enumerated_Domain_Value: straight bnk
          Enumerated_Domain_Value_Definition: straight bank - bank on a straight
portion of the river channel
        Enumerated_Domain:
          Enumerated_Domain_Value: straight rlv
          Enumerated_Domain_Value_Definition: straight river levee - river levee
along a straight portion of a river channel
        Enumerated_Domain:
          Enumerated_Domain_Value: uplnd anthr
          Enumerated_Domain_Value_Definition: anthropogenic upland
    Attribute:
      Attribute_Label: ASH_CM
      Attribute_Definition: ASH in CENTIMENTERS -Thickness (measured in centimeters)
of the 1980 volcanic-ash layer
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0
          Range_Domain_Maximum: 4
          Attribute_Units_of_Measure: centimeters
    Attribute:
      Attribute_Label: AA_CM
      Attribute_Definition: AA in CENTIMETERS - Thickness (measured in centimeters)
of sediments deposited above the 1980 volcanic-ash layer
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0
          Range_Domain_Maximum: 40
          Attribute_Units_of_Measure: centimeters
    Attribute:
      Attribute_Label: AA_10Y
      Attribute_Definition: AA in 10 YEARS -Maximum time period (measured in decimal
decades) from May 1980 to the sampling date in which sediments could have been
deposited subsequent to (above) the 1980 volcanic-ash layer
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 1
          Range_Domain_Maximum: 1.8
```

```
          Attribute_Units_of_Measure: decimal decades
    Attribute:
      Attribute_Label: AA_CM_10Y
      Attribute_Definition: AA in CENTIMETERS in 10 YEARS -Averaged rate of
deposition (cm/decade) for sediments deposited subsequent to the 1980 volcanic-ash
layer
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0
          Range_Domain_Maximum: 28.6
          Attribute_Units_of_Measure: centimeters per decimal decade
    Attribute:
      Attribute_Label: BA_CM
      Attribute_Definition: BA in CENTIMETERS - Thickness (measured in centimeters)
of lead-rich sediments (containing at least 1000 ppm of lead) deposited prior to
(below) the 1980 volcanic-ash layer (and representing a time span from about 1903 to
1980)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0
          Range_Domain_Maximum: 290
          Attribute_Units_of_Measure: centimeters
    Attribute:
      Attribute_Label: BA_10Y
      Attribute_Definition: BA in 10 YEARS - Maximum time period (measured in
decimal decades from about 1903 and 1980) in which sediments could have been
deposited prior to the 1980
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 2.9
          Range_Domain_Maximum: 7.7
          Attribute_Units_of_Measure: decimal decades
    Attribute:
      Attribute_Label: BA_CM_10Y
      Attribute_Definition: BA in CENTIMETERS in 10 YEARS - Averaged rate of
deposition (cm/decade) for sediments deposited prior to the 1980 volcanic-ash layer.
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0
          Range_Domain_Maximum: 35.5
          Attribute_Units_of_Measure: centimenters per decimal decades
    Attribute:
      Attribute_Label: SR_AABA
      Attribute_Definition: SEDIMENTATION RATE in AABA - Ratio of the sedimentation
rate of sediments deposited after the May 1980 eruption of Mt. St. Helens to
sediments deposited prior to the May 1980 eruption of Mt. St. Helens. (A value of
-999 indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0.11
          Range_Domain_Maximum: 10.31
          Attribute_Units_of_Measure: ratio
    Attribute:
      Attribute_Label: JBA_CM
      Attribute_Definition: JBA in CENTIMETERS -  Thickness (measured in
centimeters) of sample interval just below the base of the 1980 volcanic-ash layer.
(A value of -999 indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0.2
          Range_Domain_Maximum: 36
          Attribute_Units_of_Measure: centimeters
    Attribute:
```

```
      Attribute_Label: JBA_AA
      Attribute_Definition: Ratio of thickness of sample interval immediately below
the base of the 1980 volcanic-ash layer to thickness of sediments overlying the 1980
volcanic-ash layer. (A value of -999 indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0
          Range_Domain_Maximum: 8.8
          Attribute_Units_of_Measure: ratio
    Attribute:
      Attribute_Label: BA1_CM
      Attribute_Definition: BA1 in CENTIMETERS - Thickness of stratigraphic interval
BA1, defined as a JBA interval with thickness equal to thickness of the overlying AA
interval +/- 10%. (BA1_CM therefore ranges from 0.9*AA_CM to 1.1*AA_CM in the same
section). (A value of -999 indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 2.2
          Range_Domain_Maximum: 16
          Attribute_Units_of_Measure: centimeters
    Attribute:
      Attribute_Label: PBR_CM
      Attribute_Definition: PBR in CENTIMETERS - Composite thickness (measured in
centimeters) of sampling intervals which contain lead-rich sediments with values at
or exceeding 1,000 ppm Pb. (A value of -999 indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 5
          Range_Domain_Maximum: 300
          Attribute_Units_of_Measure: centimeters
    Attribute:
      Attribute_Label: PBR_10Y
      Attribute_Definition: PBR in 10 YEARS - Time period (measured in decimal
decades) in which lead-rich sediments were deposited (PBR_10Y = sample date - 1903).
(A value of -999 indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 4.1
          Range_Domain_Maximum: 9.5
          Attribute_Units_of_Measure: decimal decades
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      Attribute_Label: PBR_CM_10Y
      Attribute_Definition: PBR in CENTIMETERS in 10 YEARS - Average sedimentation
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      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0.6
          Range_Domain_Maximum: 33
          Attribute_Units_of_Measure: cemtimeters per decimal decades
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      Attribute_Label: PBR_PB
      Attribute_Definition: PBR LEAD - Weighted-average concentration of lead
(measured in ppm) for the composite thickness of sampling intervals which contain
lead-rich sediments with values at or exceeding 1,000 ppm Pb.  (A value of -999
indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 915
          Range_Domain_Maximum: 14129
          Attribute_Units_of_Measure: ppm (parts per million)
    Attribute:
```

```
      Attribute_Label: AA_PB
      Attribute_Definition: AA LEAD - Weighted-average concentration of lead
(measured in ppm) in sediments deposited above the 1980 volcanic-ash layer. (A value
of -999 indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 21
          Range_Domain_Maximum: 7460
          Attribute_Units_of_Measure: ppm (parts per million)
    Attribute:
      Attribute_Label: BA_PB
      Attribute_Definition: Weighted-average concentration of lead (ppm Pb) in
sediments deposited below the 1980 volcanic-ash layer. (A value of -999 indicates no
data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 23
          Range_Domain_Maximum: 13940
          Attribute_Units_of_Measure: ppm (parts per million)
    Attribute:
      Attribute_Label: PB_AABA
      Attribute_Definition: Ratio of weighted-average lead concentration (ppm Pb) in
sediments deposited above the 1980 volcanic-ash layer. (A value of -999 indicates no
data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 0.16
          Range_Domain_Maximum: 2.58
          Attribute_Units_of_Measure: ratio
    Attribute:
      Attribute_Label: JBA_PB
      Attribute_Definition: JBA LEAD - Concentration of lead (ppm Pb) in the sample
interval immediately below the base of the 1980 volcanic-ash layer. (A value of -999
indicates no data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 66
          Range_Domain_Maximum: 9810
          Attribute_Units_of_Measure: ppm (parts per million)
    Attribute:
      Attribute_Label: BA1_PB
      Attribute_Definition: BA1 LEAD - Concentration of lead (ppm Pb) in sediments
of the BA1 stratigraphic interval (defined above). (A value of -999 indicates no
data.)
      Attribute_Domain_Values:
        Range_Domain:
          Range_Domain_Minimum: 1500
          Range_Domain_Maximum: 6735
          Attribute_Units_of_Measure: ppm (parts per million)
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Mt. St. Helens ash intervals to the concentration of lead in sediments below the
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          Attribute_Units_of_Measure: ratio
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files: CDA_SR_PB.SHP, CDA_SR_PB.SHX, CDA_SR_PB.DBF, CDA_SR_PB.SBN, CDA_SR_PB.SBX
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that together provide spatial data. An ArcView (ver. 3.2) legend, CDA_SR_PB.SHX, was
created (and included) to symbolize the post-1980 sedimentation (measured in
cm/decade). A "-999" in any of the shapefile attributes denotes "no useable data".
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the U.S. Geological Survey)
        Contact_Person: John C. Wallis , Helen Z. Kayser
      Contact_Position: GIS Specialists
      Contact_Address:
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        City: Spokane
        State_or_Province: Washington
        Postal_Code: 99201
        Country: USA
      Contact_Voice_Telephone: 1-509-368-3108, 1-509-368-3162
      Contact_Facsimile_Telephone: 1-509-368-3199
      Contact_Electronic_Mail_Address: jwallis@usgs.gov, hkayser@usgs.gov
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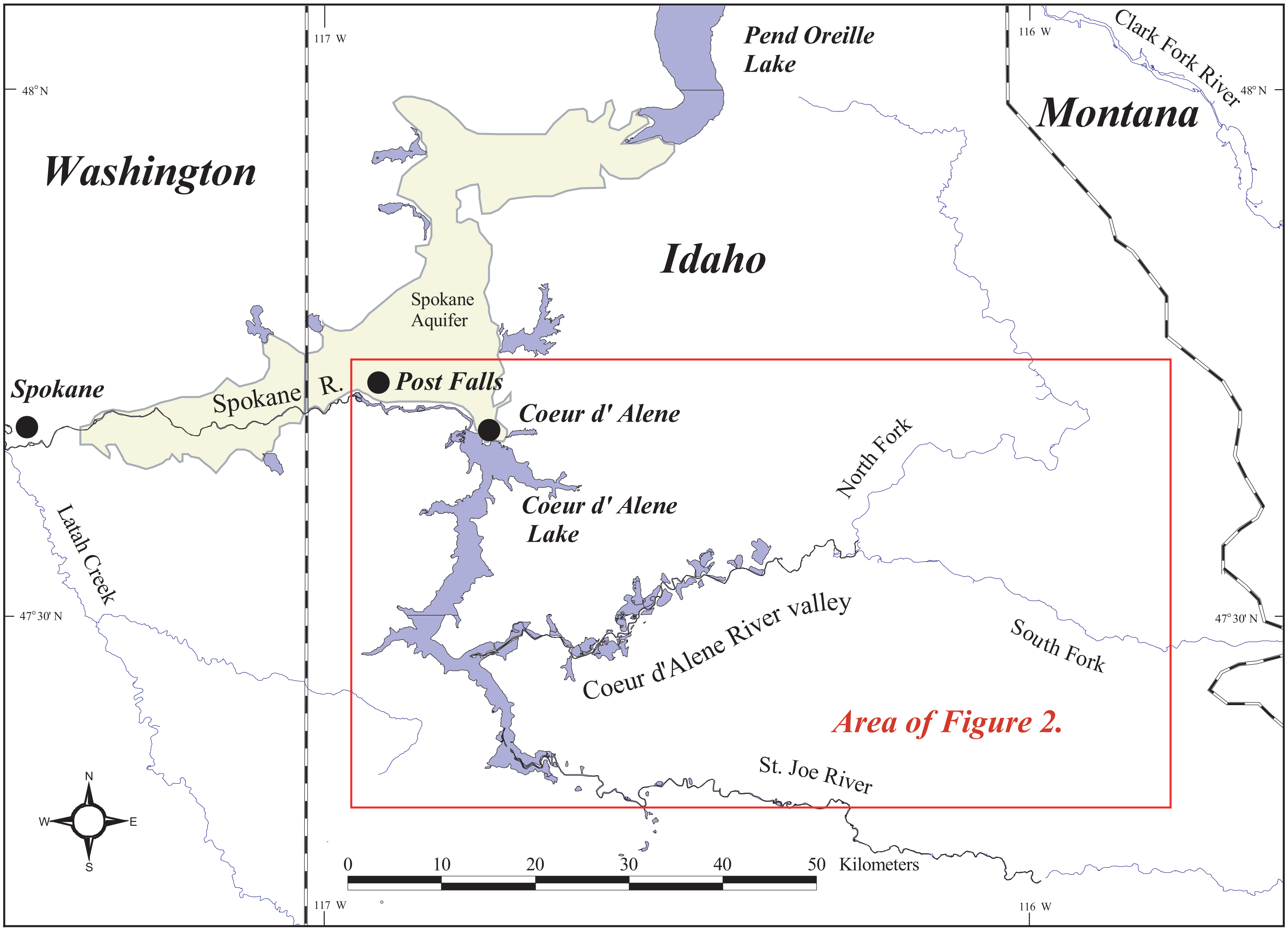

Figure 1. Location map showing the Coeur d'Alene River valley and other major tributary streams of the Spokane River Basin.

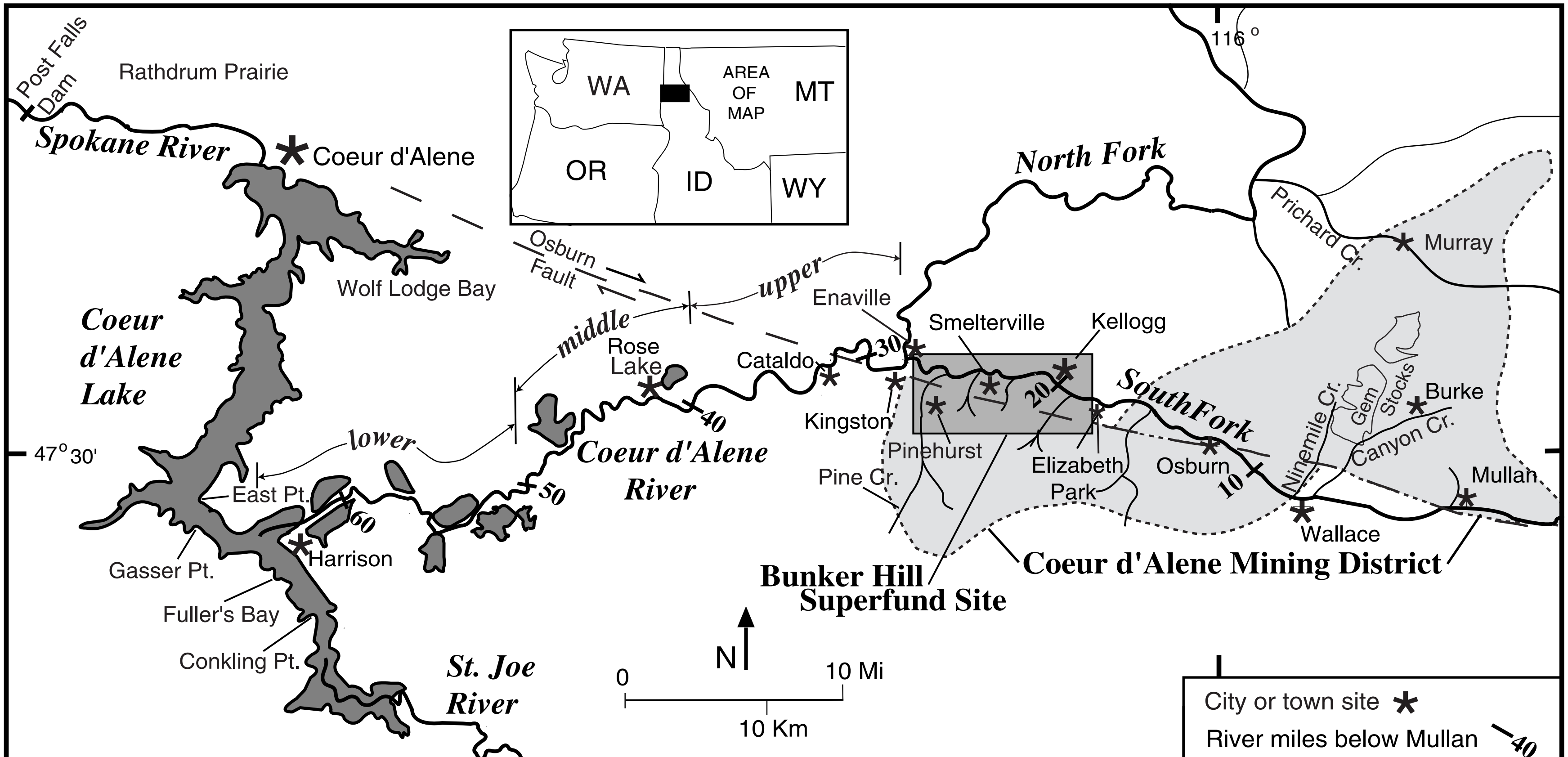

Figure 2. Index and location maps, showing selected features of the Coeur d'Alene (CdA) mining district, the Bunker Hill Superfund Site, the South and North Forks, the CdA River and its lateral lakes, the lower St. Joe River, CdA Lake, and the upper Spokane River.

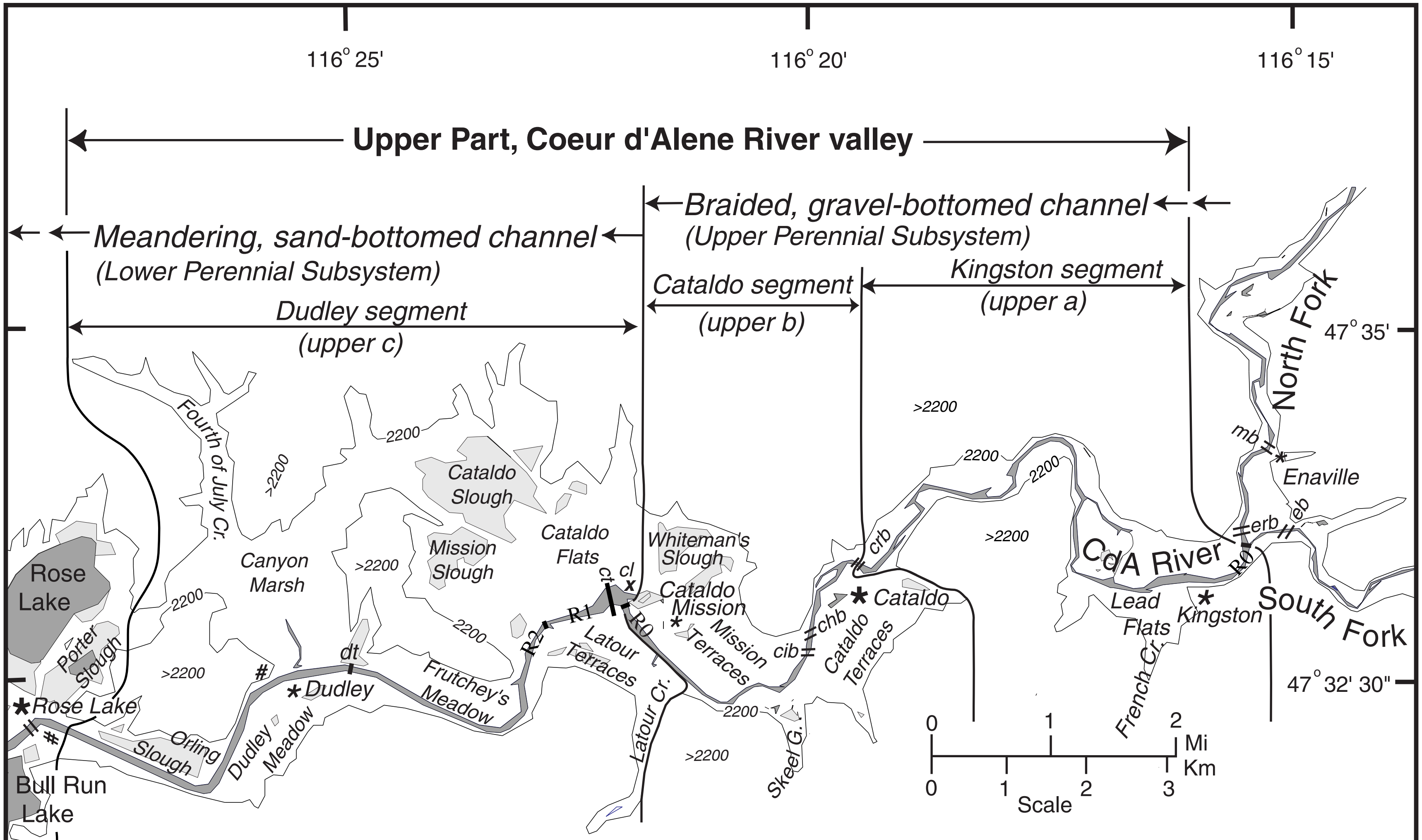

Figure 3. Location map of the Upper CdA River valley, showing the river and the 2,200 ft elevation contour along the hillsides that bound the floodplain. Also shown are locations and names of features described in the text: ★ = town, # = sawmill site (abandoned), cl = Cataldo Landing (x), ct = Cataldo drill transect, dt = Dudley drill transect, mb = McPhee Bridge, eb = Enaville Bridge, erb = Enaville railroad bridge, crb = Cataldo railrooad bridge, chb = Cataldo state highway bridge, cib = Cataldo interstate highway I-90 bridge; R2, R1, R0 = River reaches.

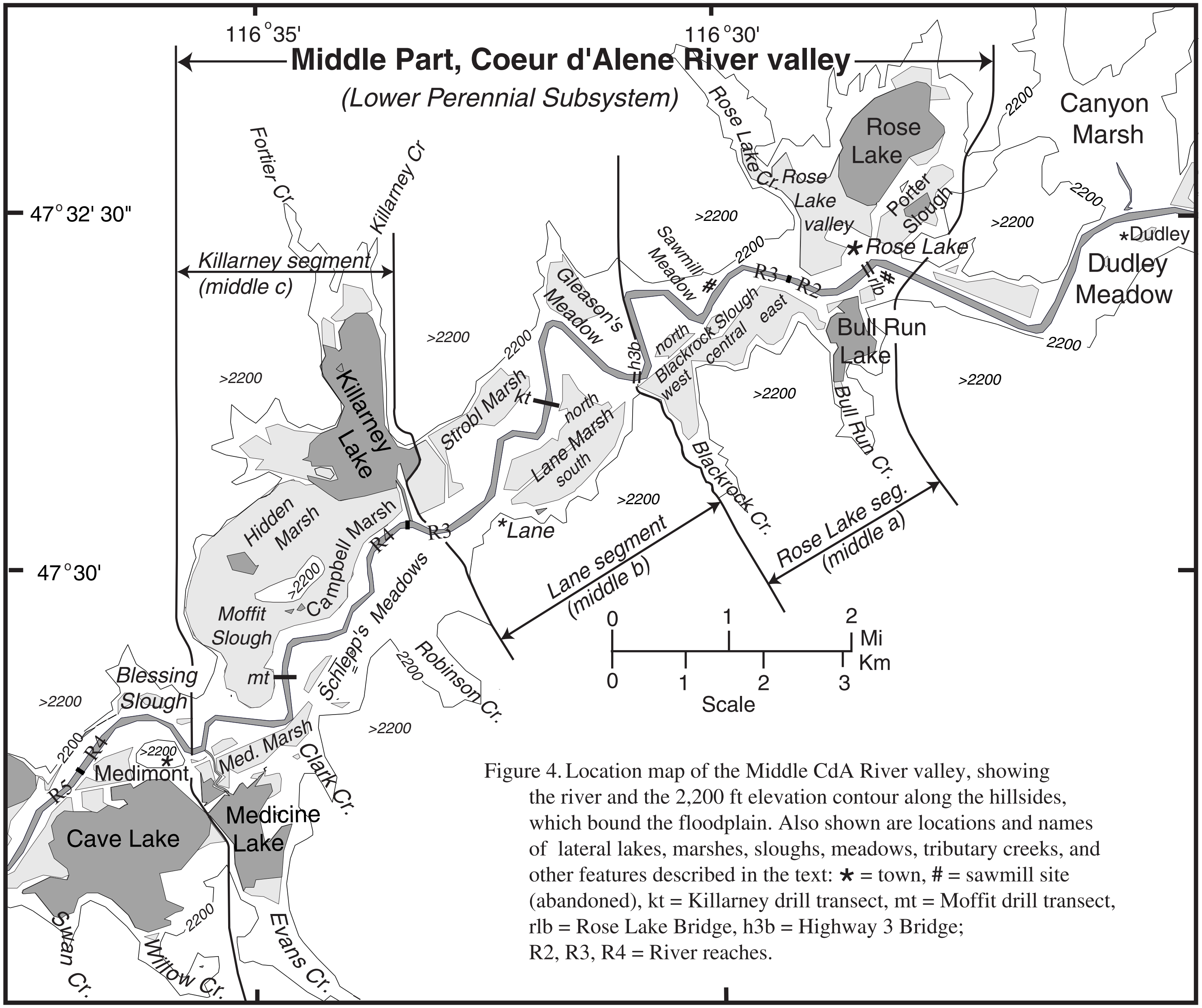

Figure 4. Location map of the Middle CdA River valley, showing the river and the 2,200 ft elevation contour along the hillsides, which bound the floodplain. Also shown are locations and names of lateral lakes, marshes, sloughs, meadows, tributary creeks, and other features described in the text: ★ = town, # = sawmill site (abandoned), kt = Killarney drill transect, mt = Moffit drill transect, rlb = Rose Lake Bridge, h3b = Highway 3 Bridge; R2, R3, R4 = River reaches.

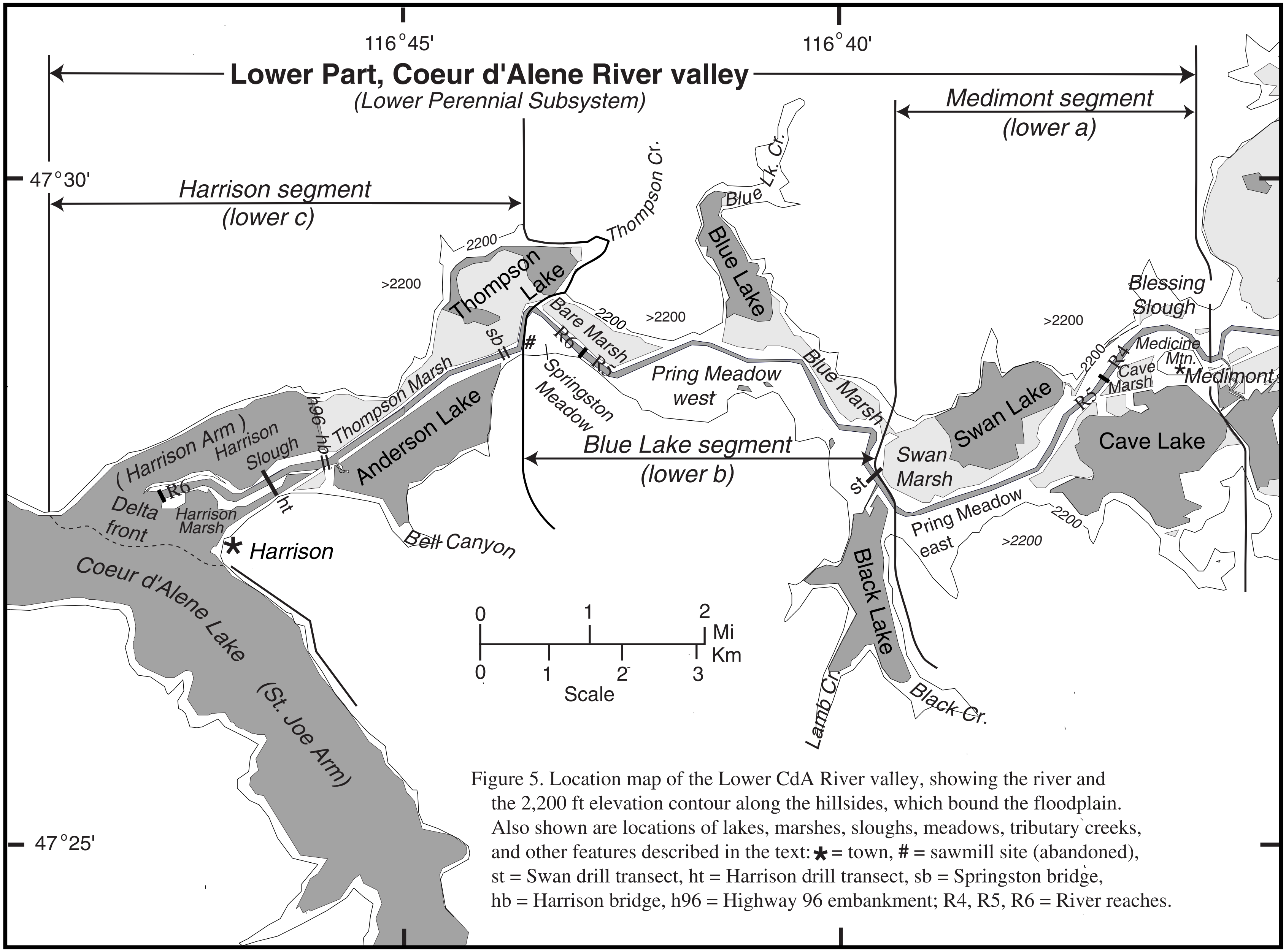

Figure 5. Location map of the Lower CdA River valley, showing the river and the 2,200 ft elevation contour along the hillsides, which bound the floodplain. Also shown are locations of lakes, marshes, sloughs, meadows, tributary creeks, and other features described in the text: * = town, # = sawmill site (abandoned), st = Swan drill transect, ht = Harrison drill transect, sb = Springston bridge, hb = Harrison bridge, h96 = Highway 96 embankment; R4, R5, R6 = River reaches.

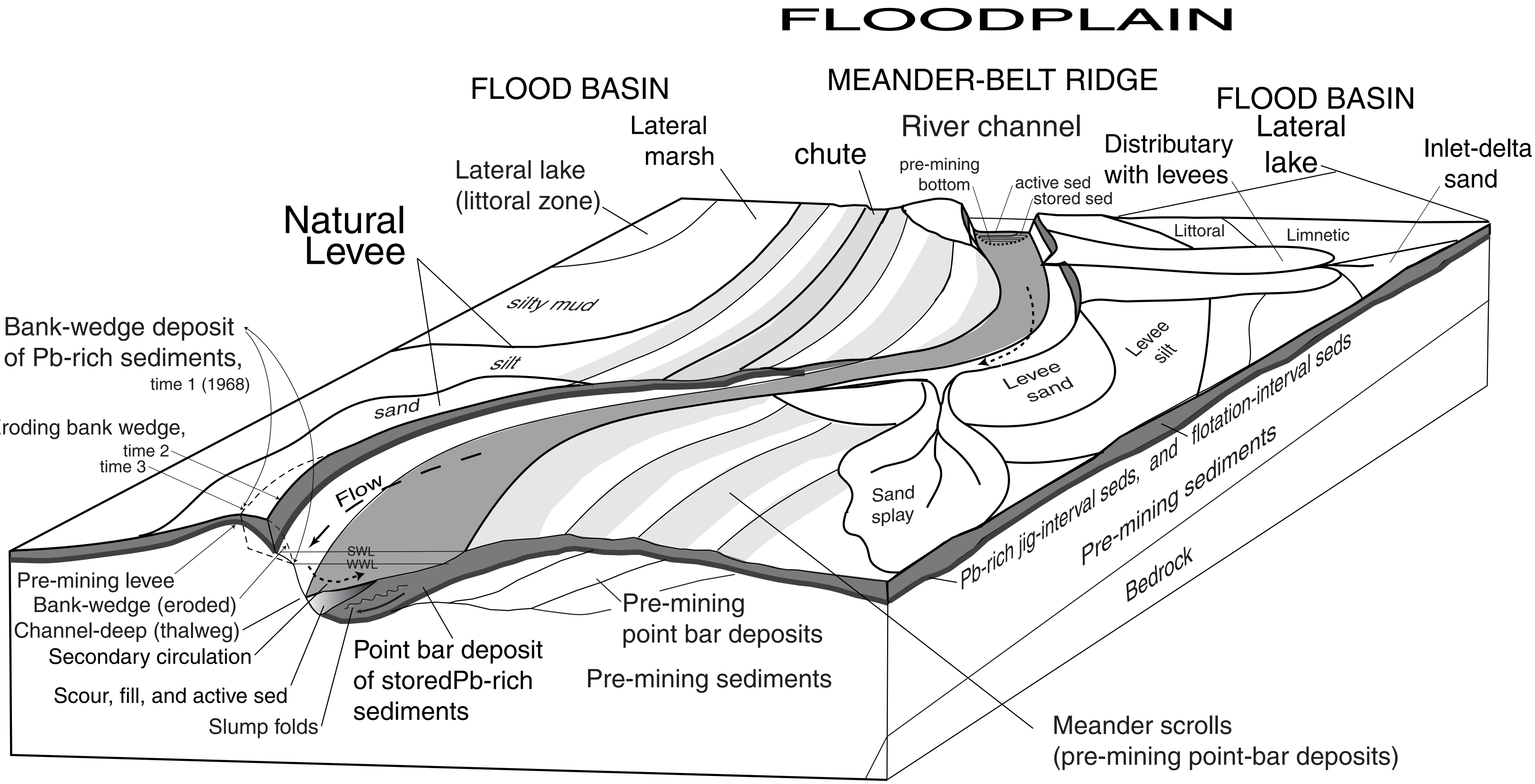

Figure 6. Schematic block diagram, showing features typical of the meandering, sand-bottomed CdA River and its floodplain, between Cataldo Landing and Harrison (modified from Reineck and Singh, 1980; Collinson, 1978; and Leopold, 1997). SWL indicates summer water lever, and WWL indicates winter water level. Dotted arrows represent flow paths. Dark grays on steep faces indicate the section of Pb-rich sediments. Darkest gray indicates highest-Pb sediments, deposited during jig-tailings disposal.

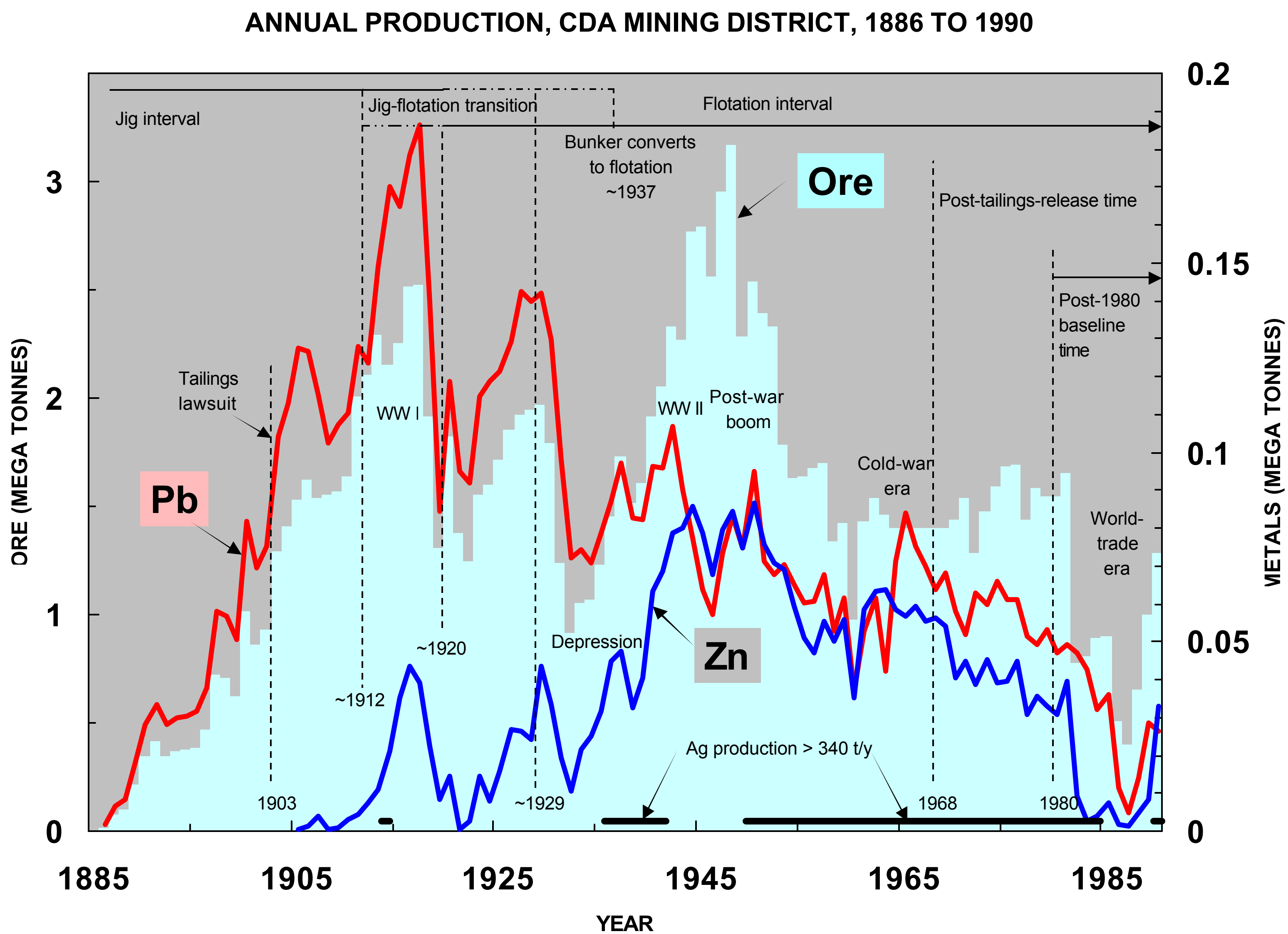

Figure 7a. Graphs showing annual production of ore, Pb and Zn, and major related events. Data are from Ransome and Calkins (1908), Fryklund (1964), Mitchell and Bennett (1983), U.S. Bureau of Mines Yearbooks (1980-1990).

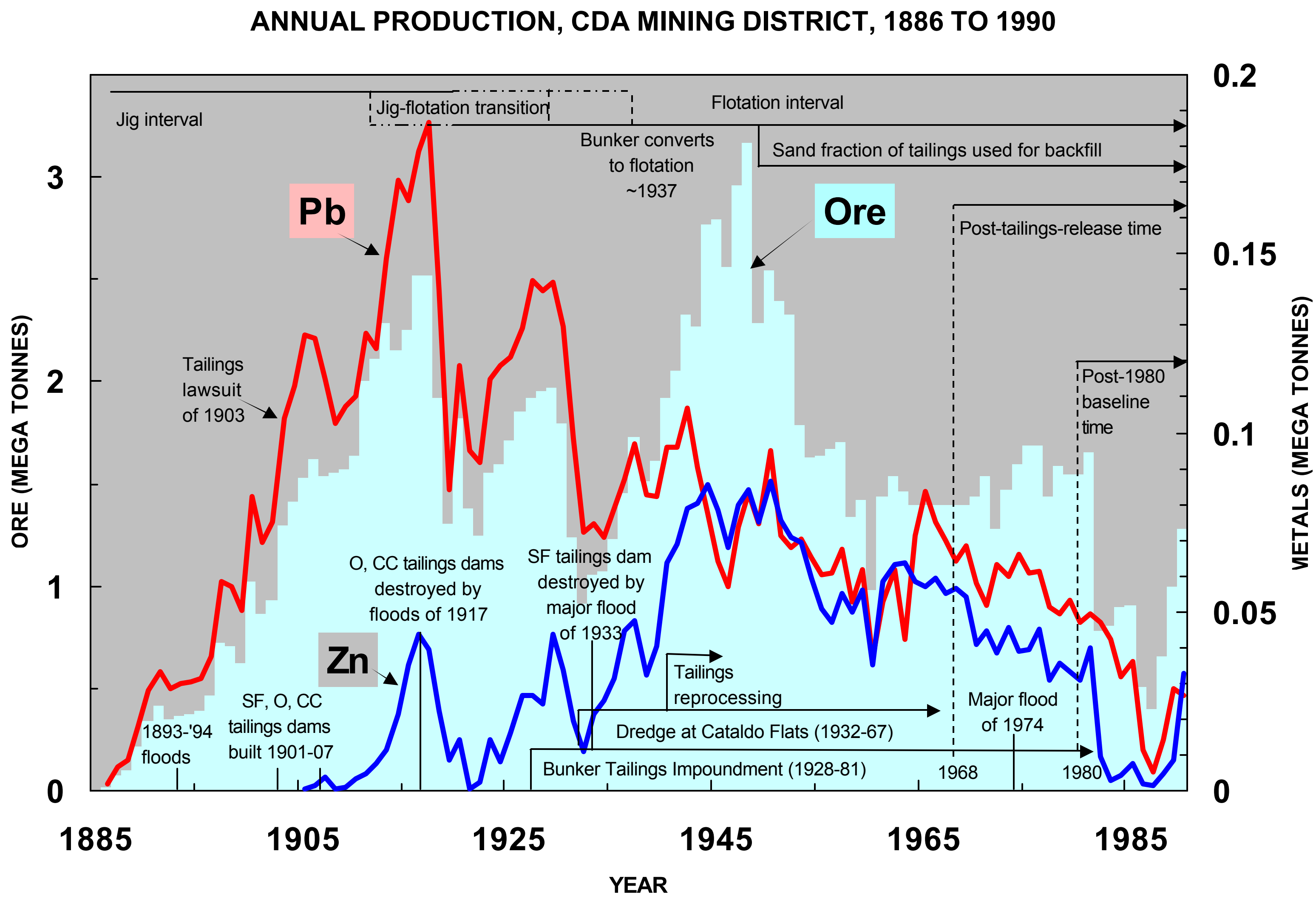

Figure 7b. Time line showing important events in the history of tailings management in the context of annual production (SF = Smelterville Flats, O = Osburn Flats, CC = Canyon Creek).

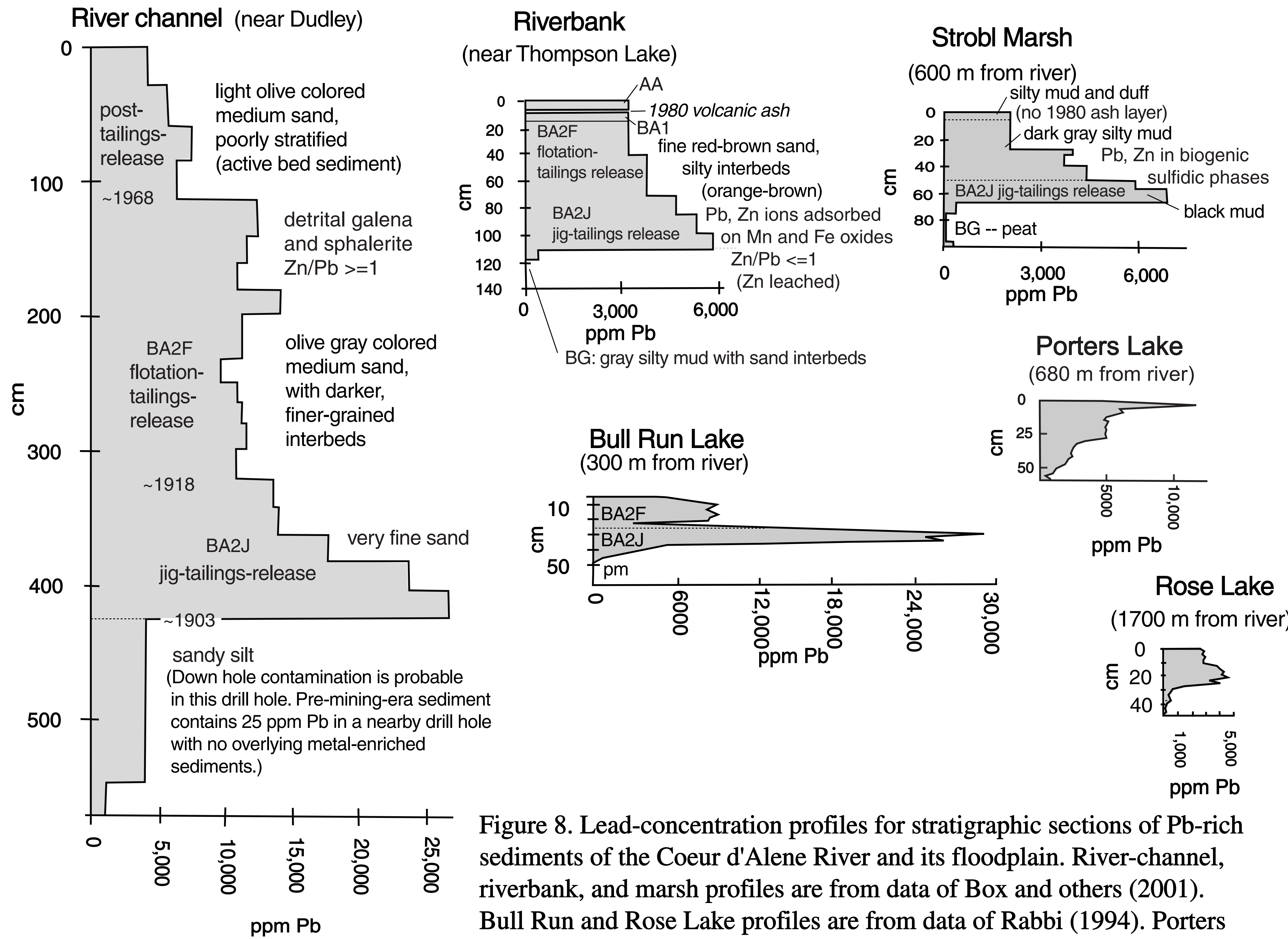

Figure 8. Lead-concentration profiles for stratigraphic sections of Pb-rich sediments of the Coeur d'Alene River and its floodplain. River-channel, riverbank, and marsh profiles are from data of Box and others (2001). Bull Run and Rose Lake profiles are from data of Rabbi (1994). Porters Lake profile is from Sprenke and others (2000). Intervals (AA, BA1, BA2F BA2J, and BG) are defined in text and table 1. Profile scales are different.

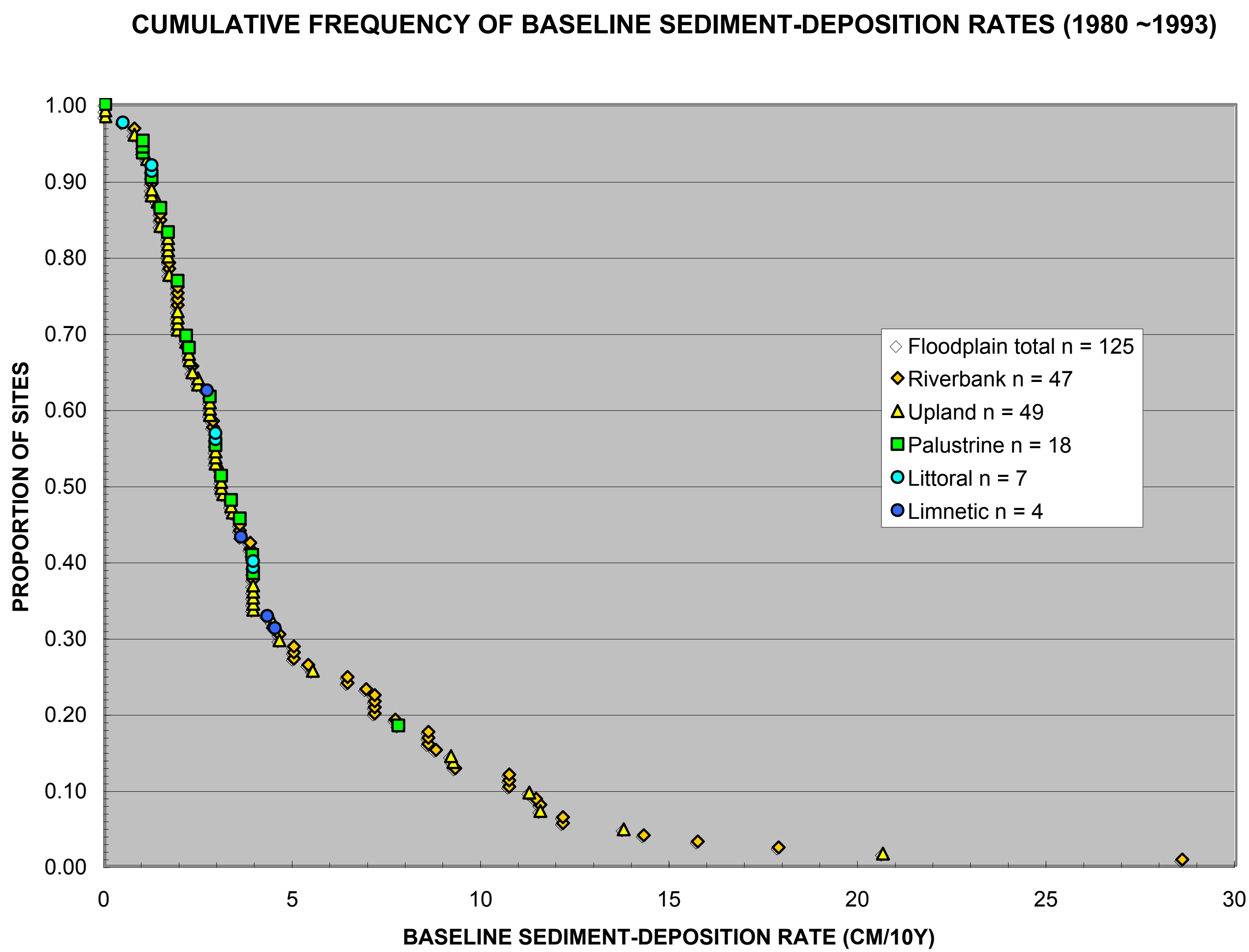

Figure 9. Cumulative frequency diagram showing baseline sediment-deposition rates (sdrAA) for sediments deposited on the floodplain from 1980 to about 1993.

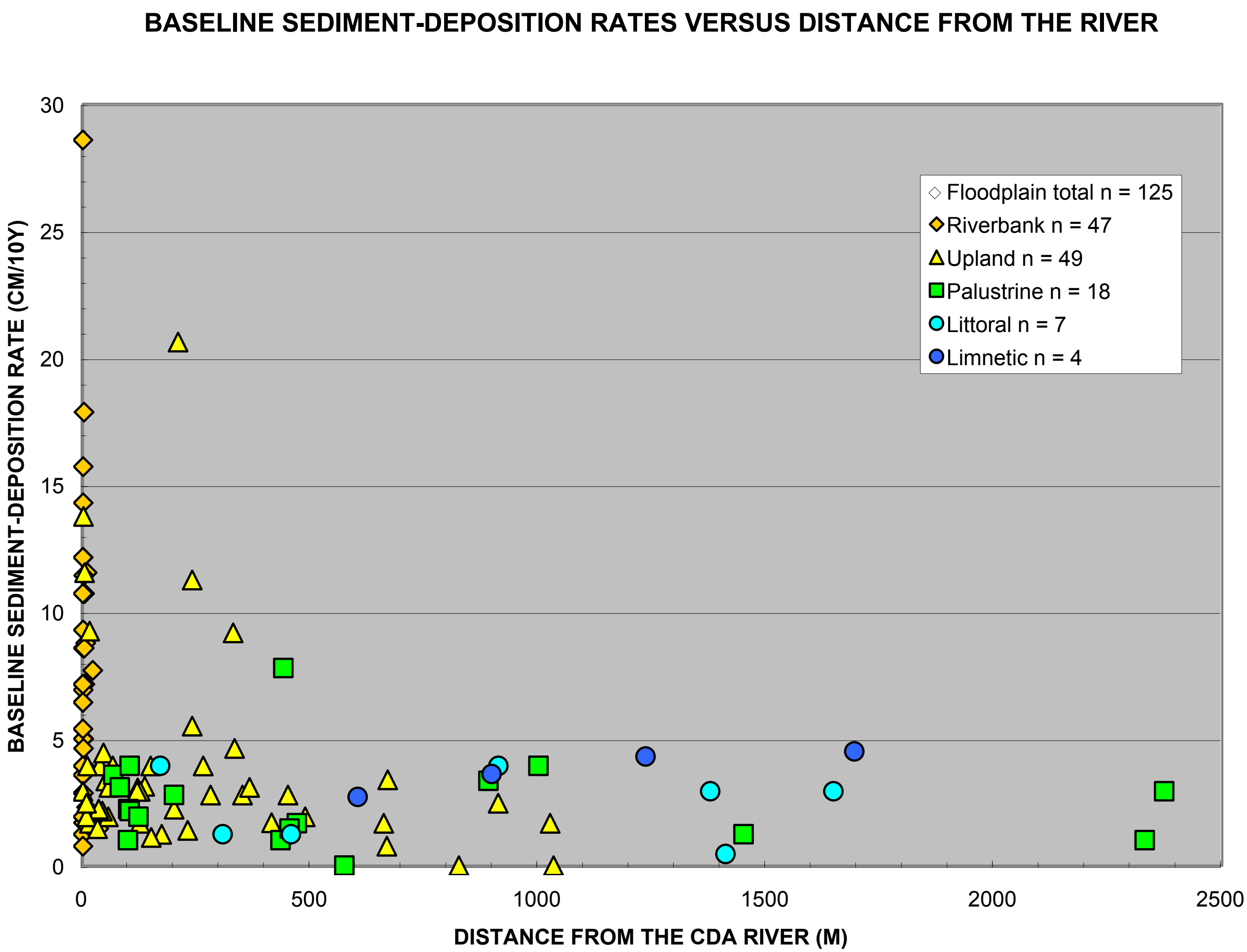

Figure 10. Scatter diagram showing baseline sediment-deposition rates (sdrAA) versus distance (m) from the CdA River. Sample sites are classified by depositional setting.

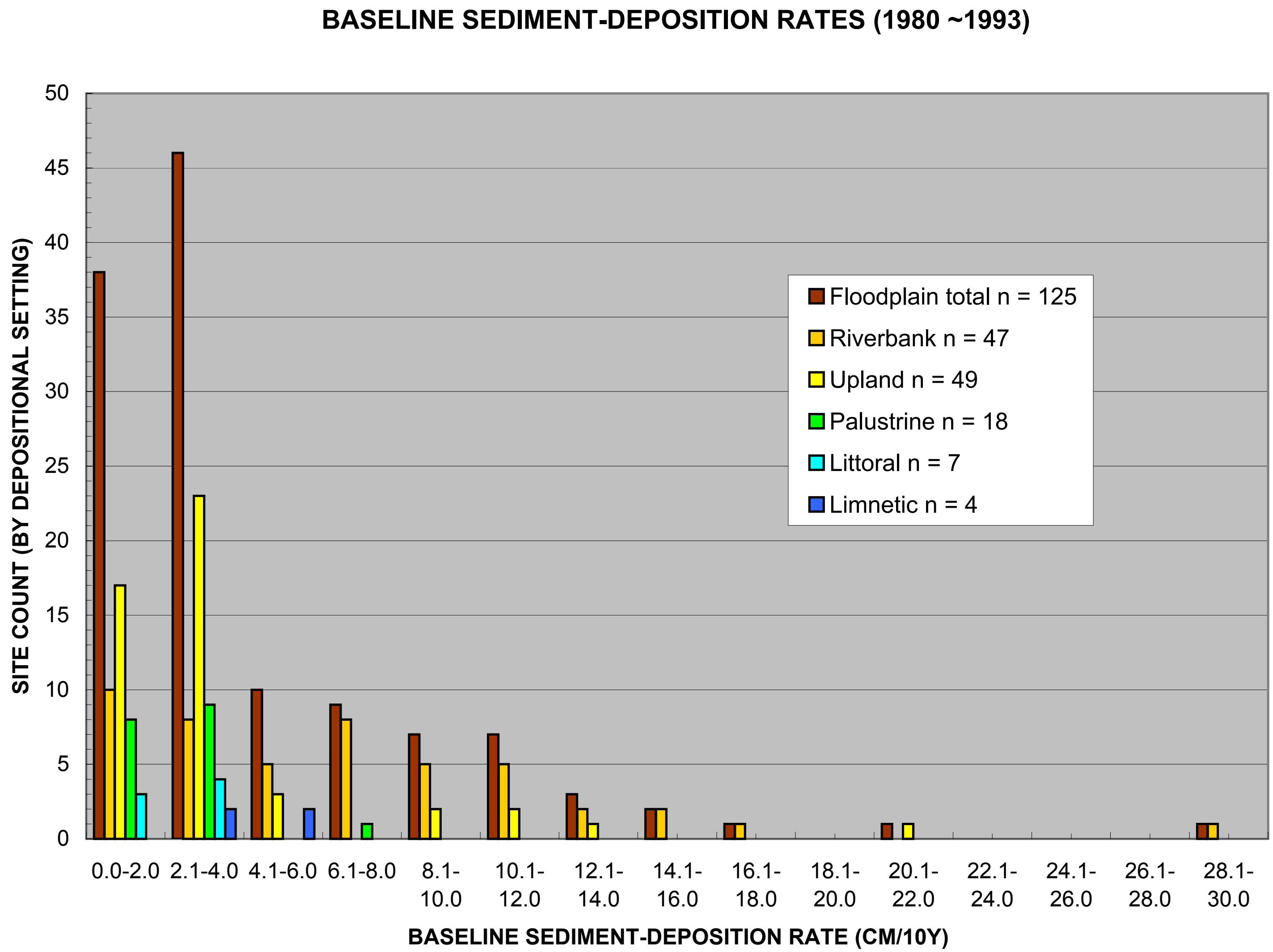

Figure 11. Frequency diagram of baseline sediment-deposition rates (sdrAA).

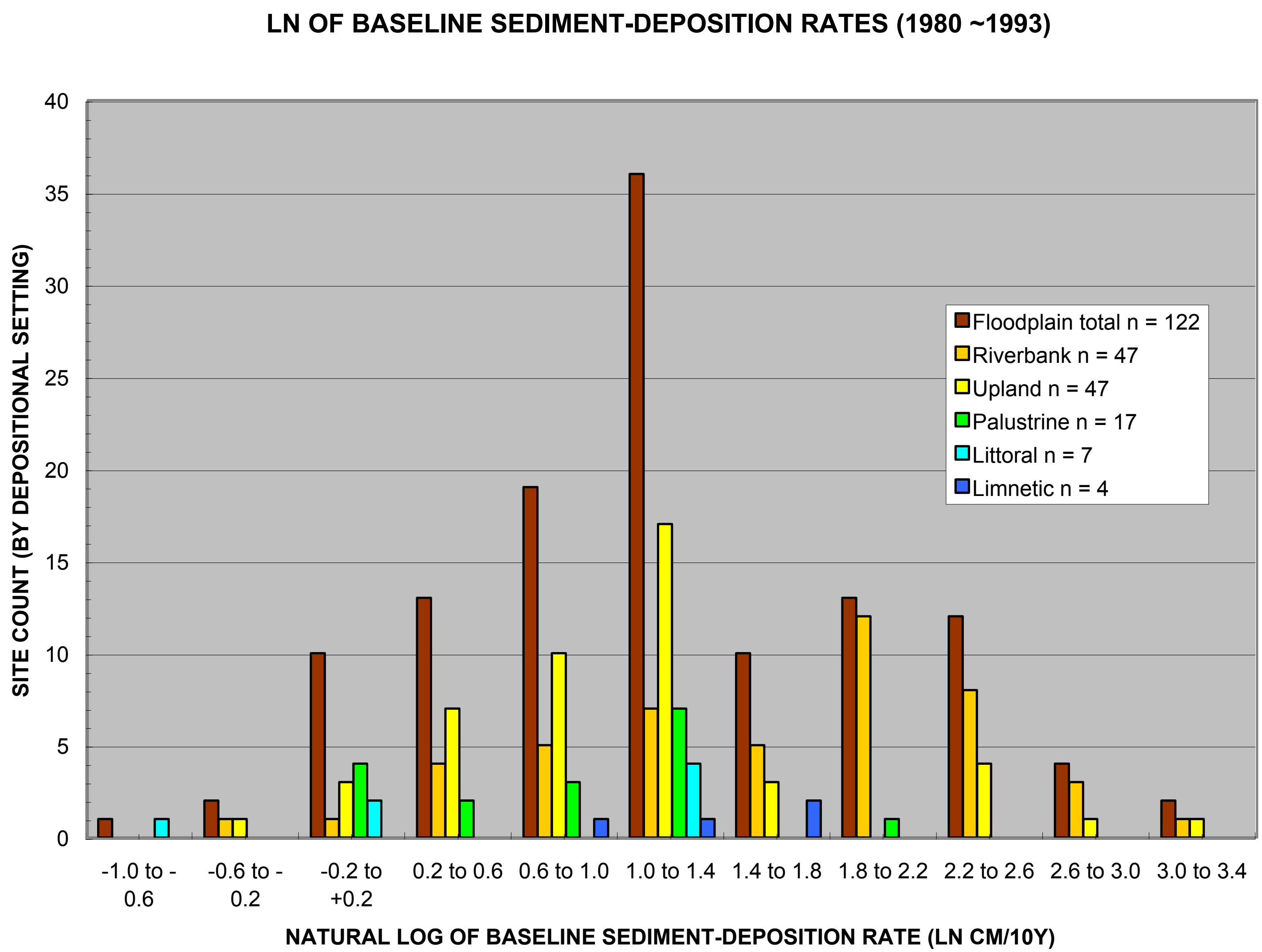

Figure 12. Frequency diagram of natural logs of baseline sediment-deposition rates (ln sdrAA).

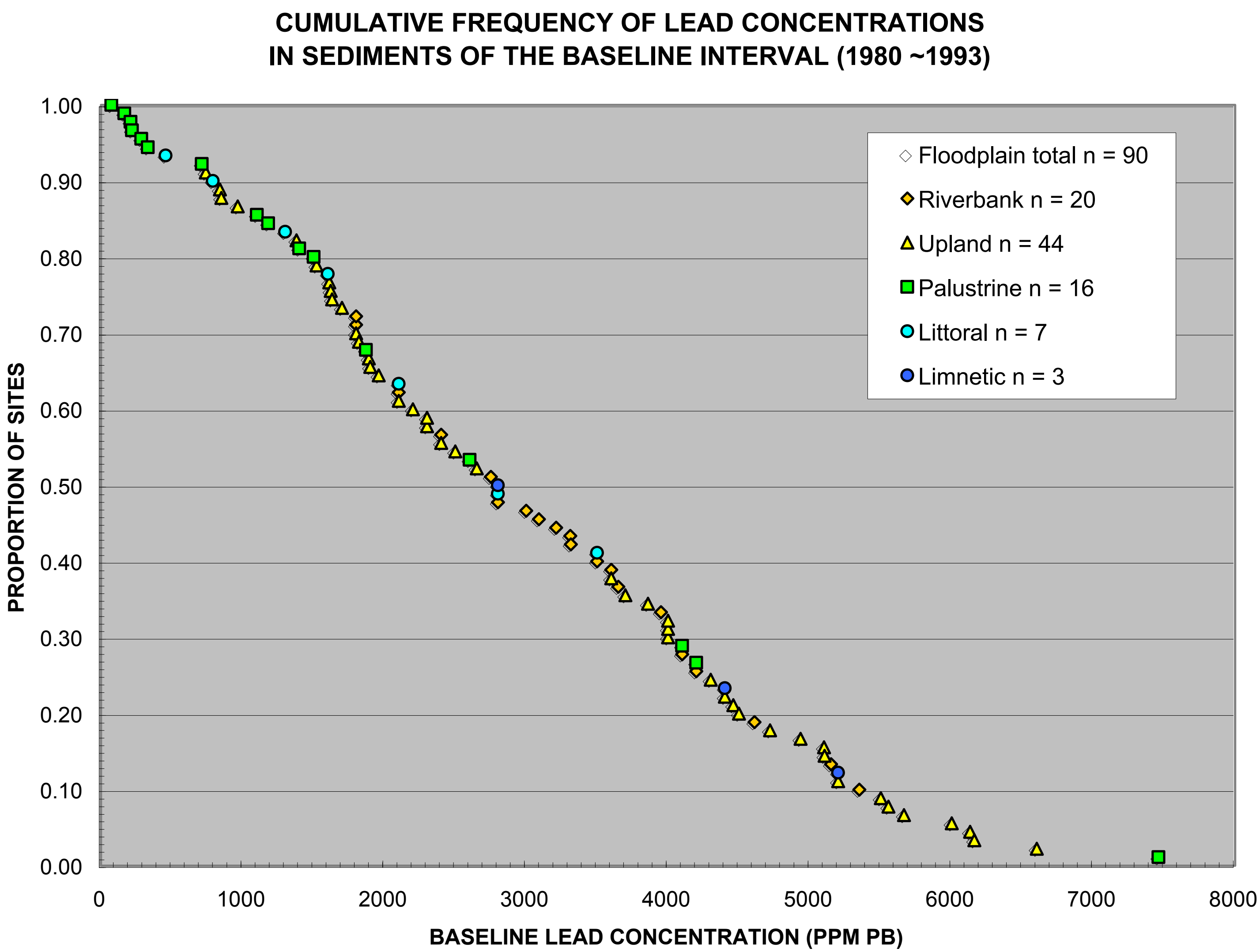

Figure 13. Cumulative frequency distribution of baseline lead concentrations (PbAA) in floodplain sediments of the AA (after-ash) time-stratigraphic interval (1980 ~1993).

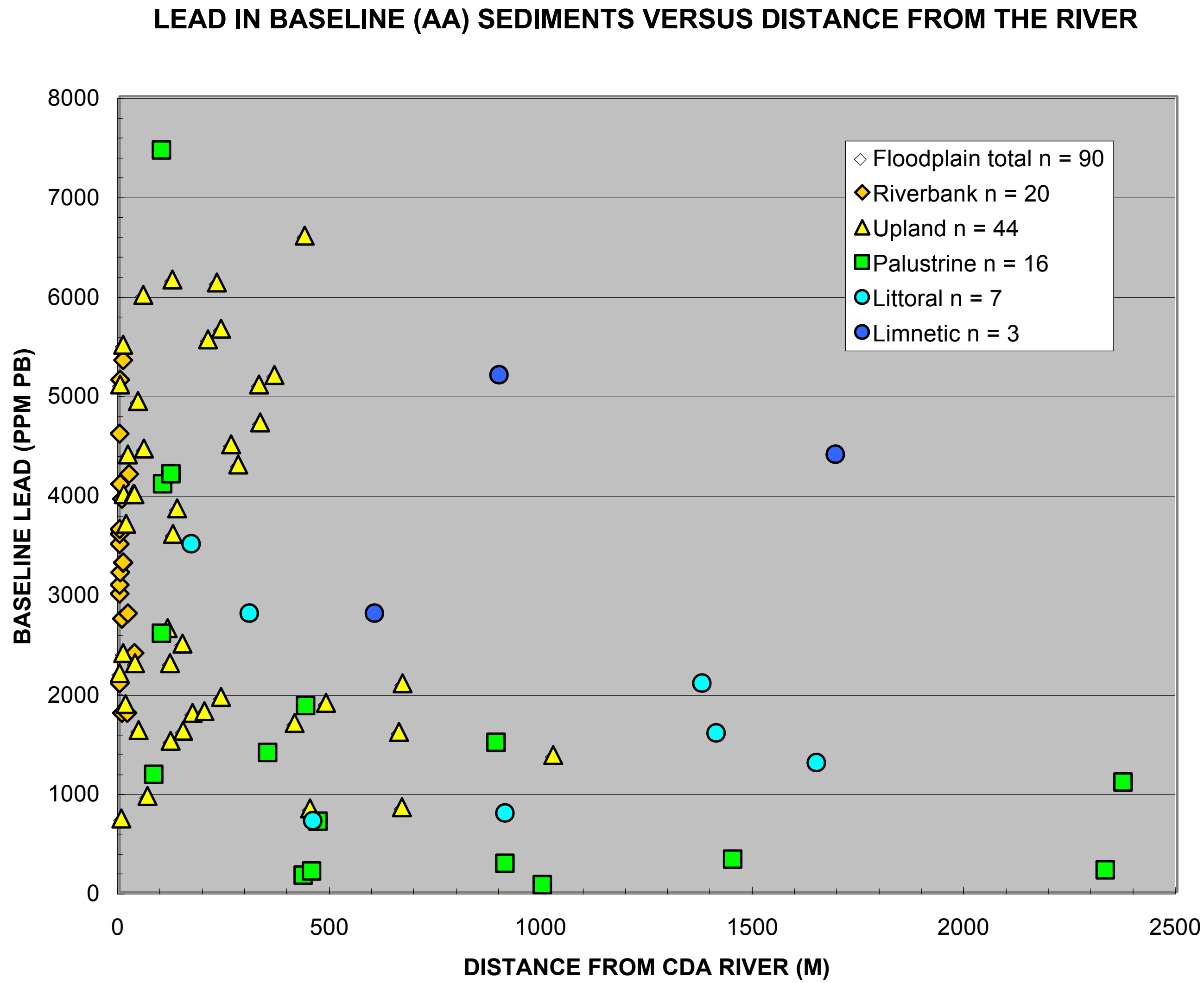

Figure 14. Scatter diagram showing lead concentrations (ppm Pb) in floodplain sediments of the baseline (AA) time-stratigraphic interval (1980 ~1993) versus distance from the CdA River.

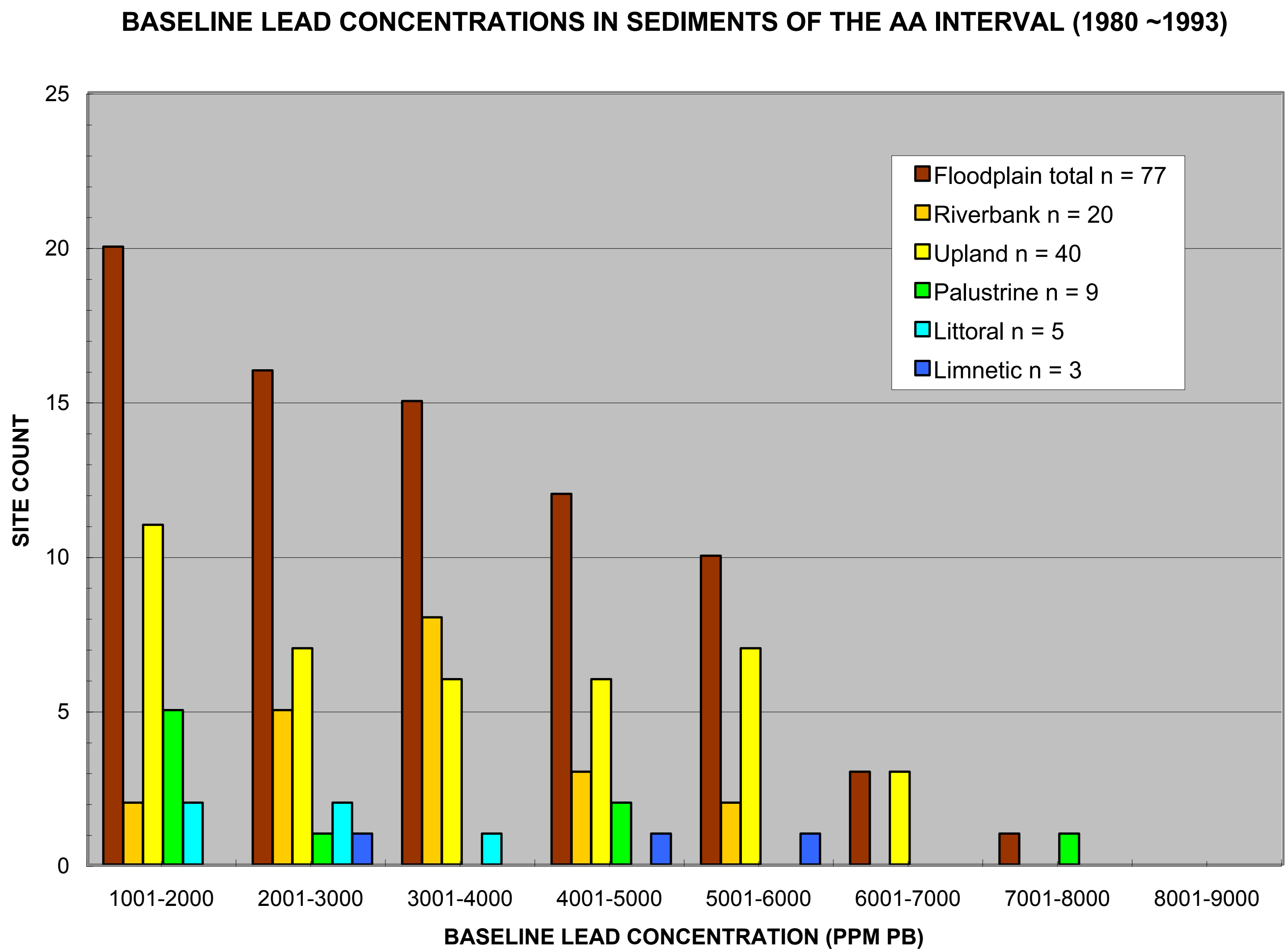

Figure 15. Frequency diagram of baseline lead concentrations (PbAA) in lead-rich floodplain sediments of the AA time-stratigraphic interval (1980 ~1993).

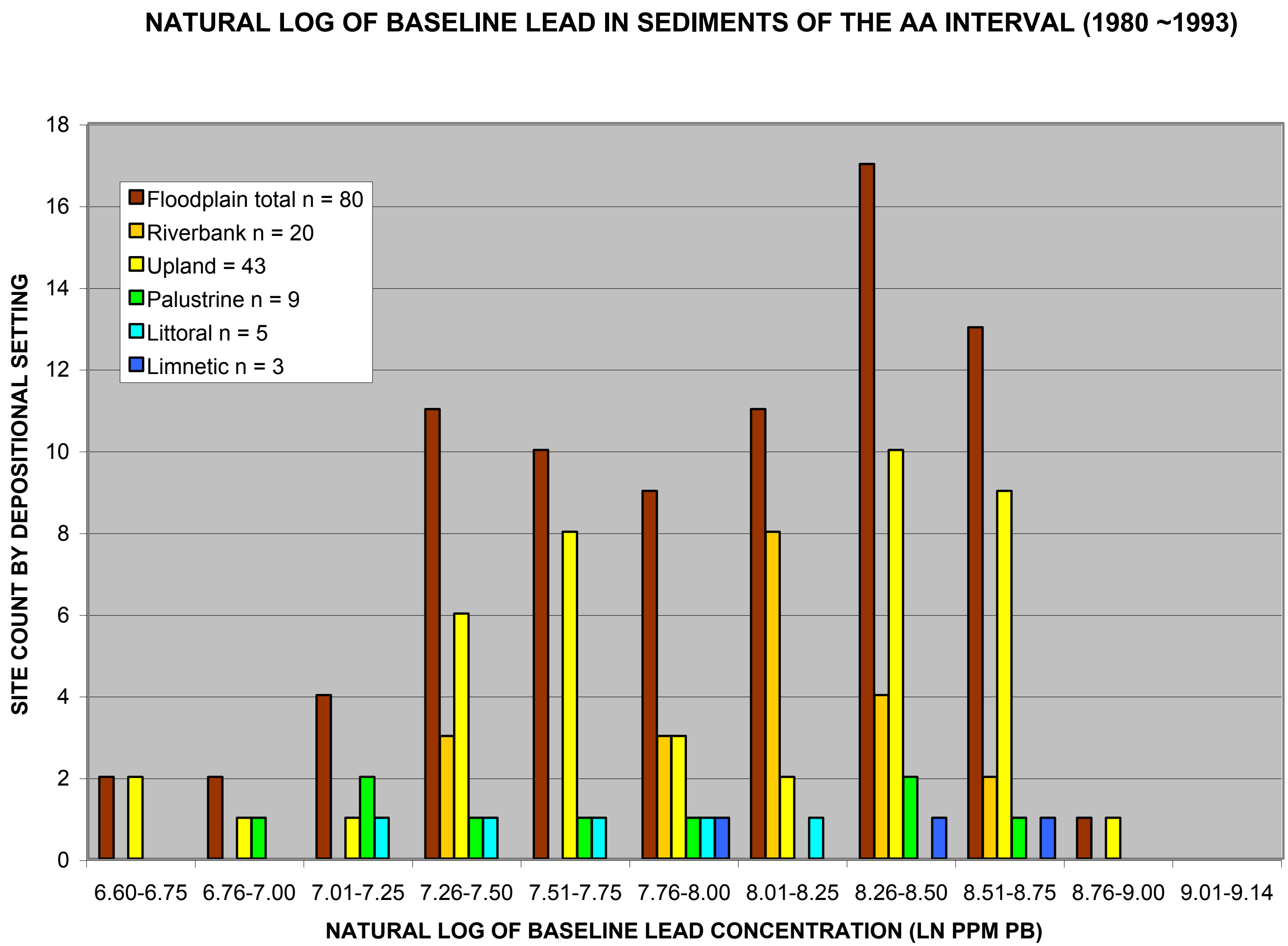

Figure 16. Frequency diagram of natural logs of baseline lead concentrations (PbAA) in Pb-rich floodplain sediments of the AA time-stratigraphic interval (1980 ~1993).

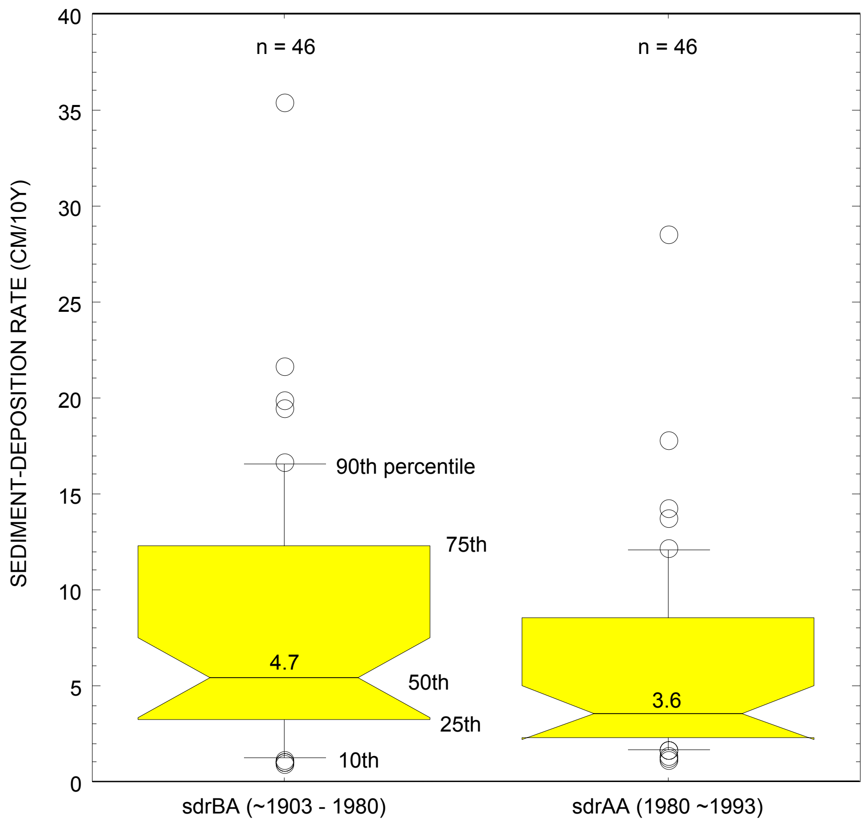

Figure 17. Box-and-whisker plots, comparing sediment-deposition rates for sediments of the historic (BA) and baseline (AA) time-stratigraphic intervals.

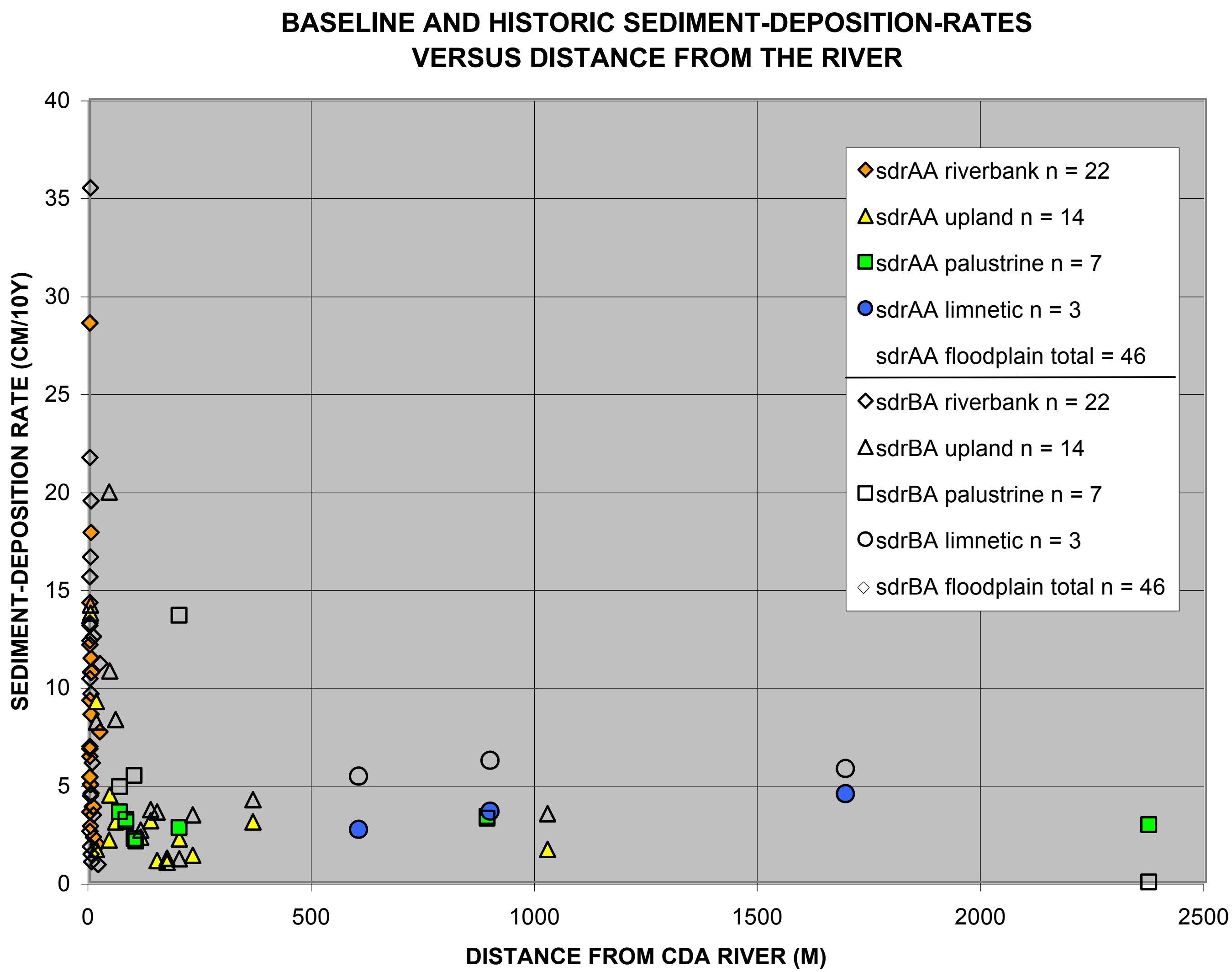

Figure 18. Scatter diagram showing rates of deposition of lead-rich sediments for paired baseline (AA) and historic (BA) time-stratigraphic intervals, as a function of distance from the CdA River.

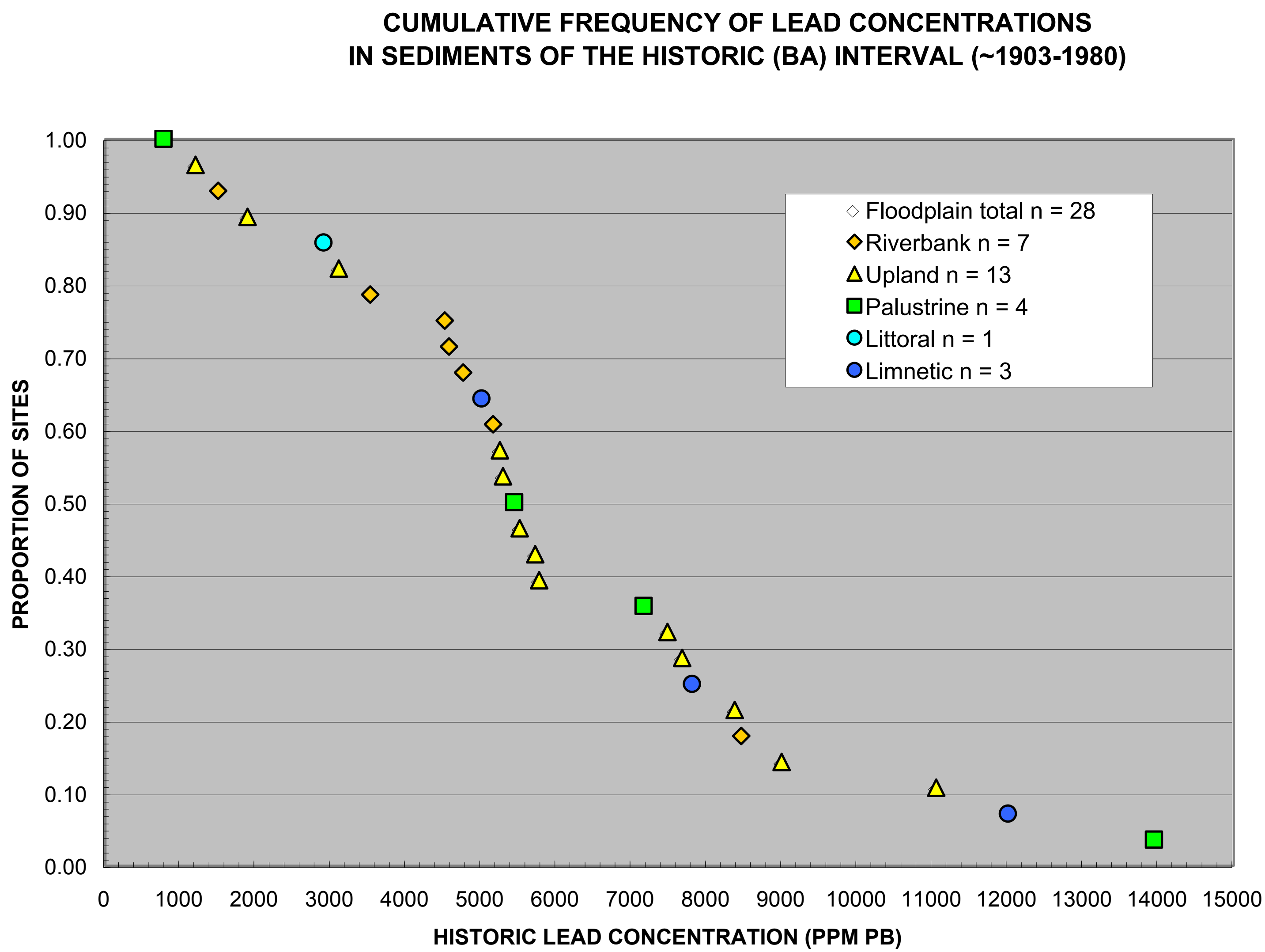

Figure 19. Cumulative frequency distribution of thickness-weighted average lead concentration in floodplain sediments of the historic (BA) time-stratigraphic interval (~1903 - 1980).

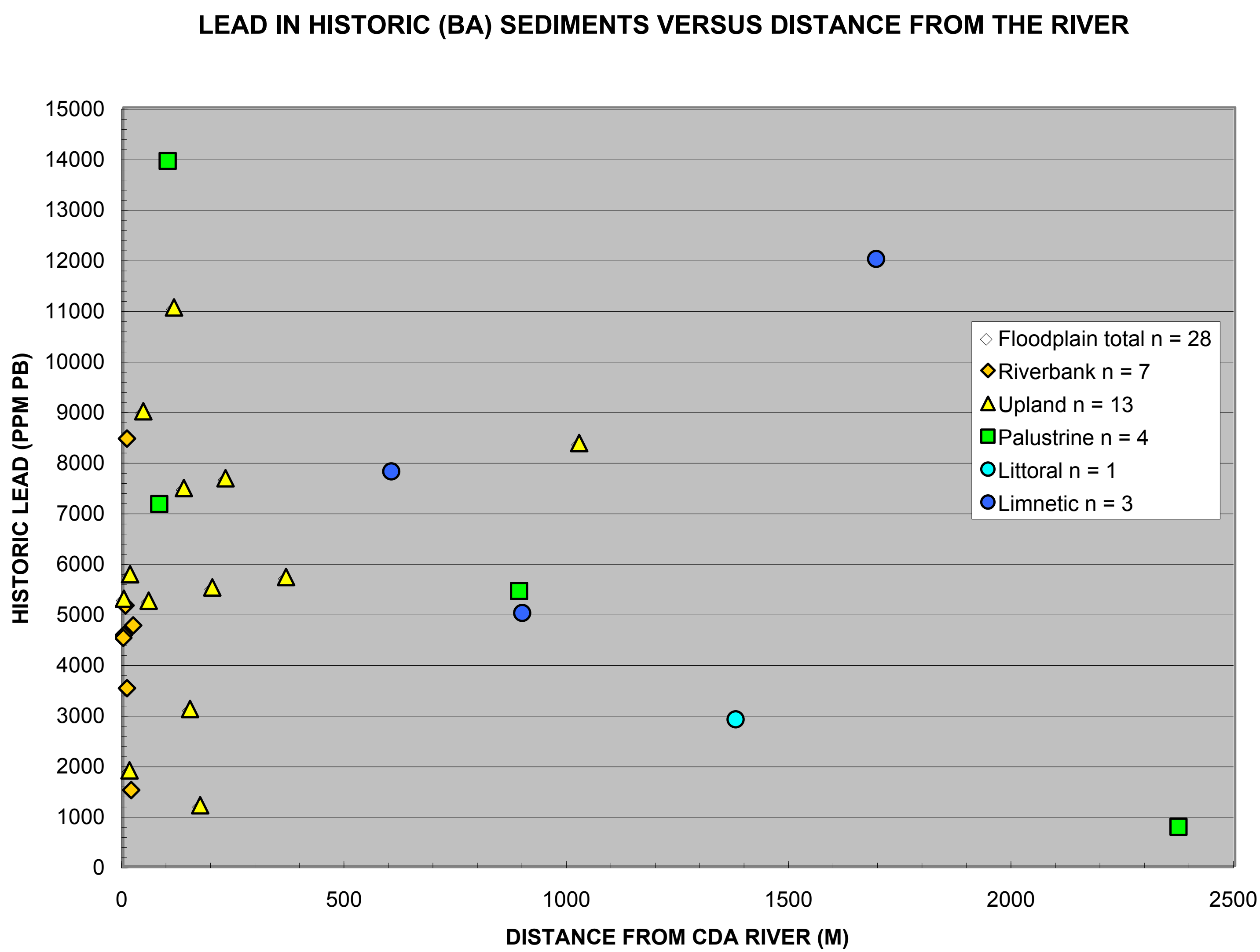

Figure 20. Scatter diagram showing thickness-weighted average lead concentration (ppm Pb) in sediments of the historic (BA) interval (~1903-1980) versus distance from the CdA River.

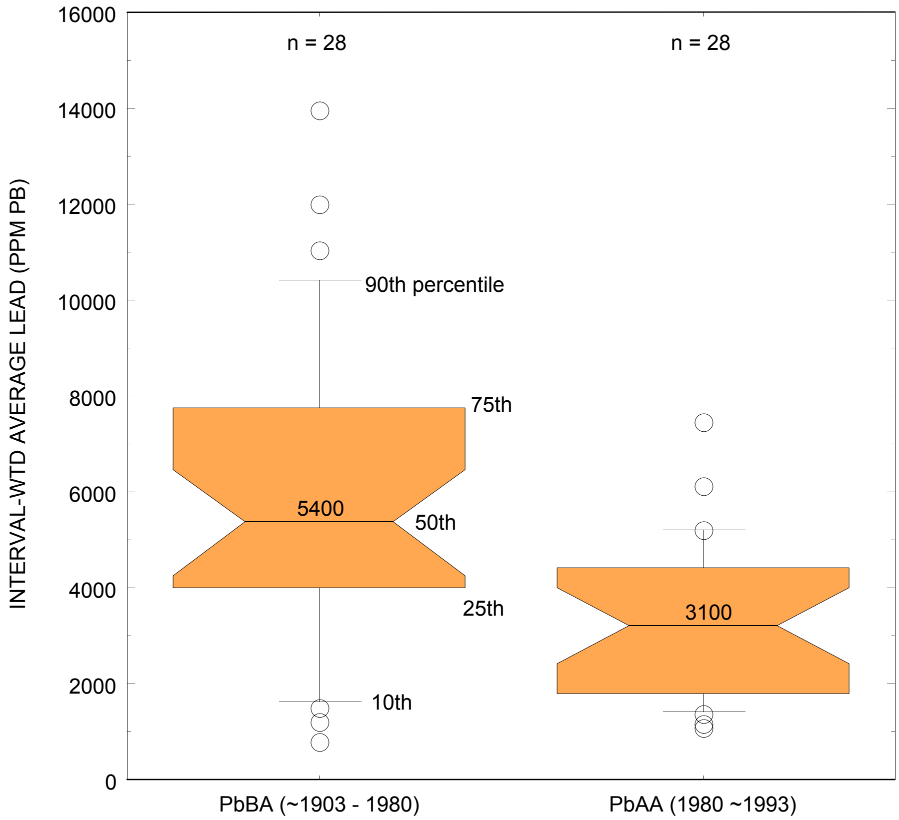

Figure 21. Box-and-whisker plots, comparing interval-weighted average lead (ppm Pb) in sediments of the historic (BA) and baseline (AA) time-stratigraphic intervals.

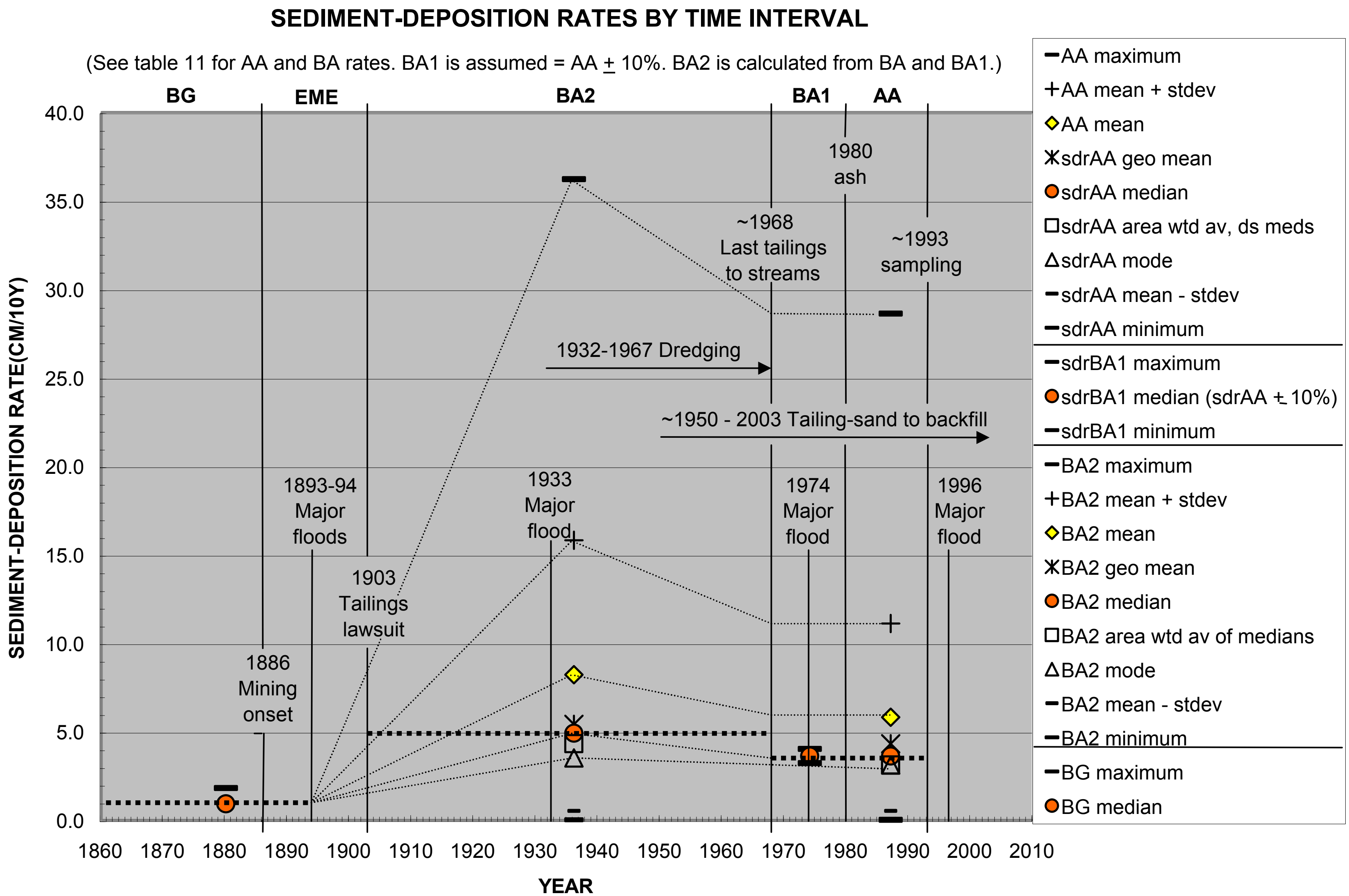

Figure 22. Summary plot showing sediment-deposition-rate statistics for sediments of BG (background), EME (early metals-enrichment), BA2 (tailings-release), BA1 (early post-tailings), and AA (baseline) intervals.

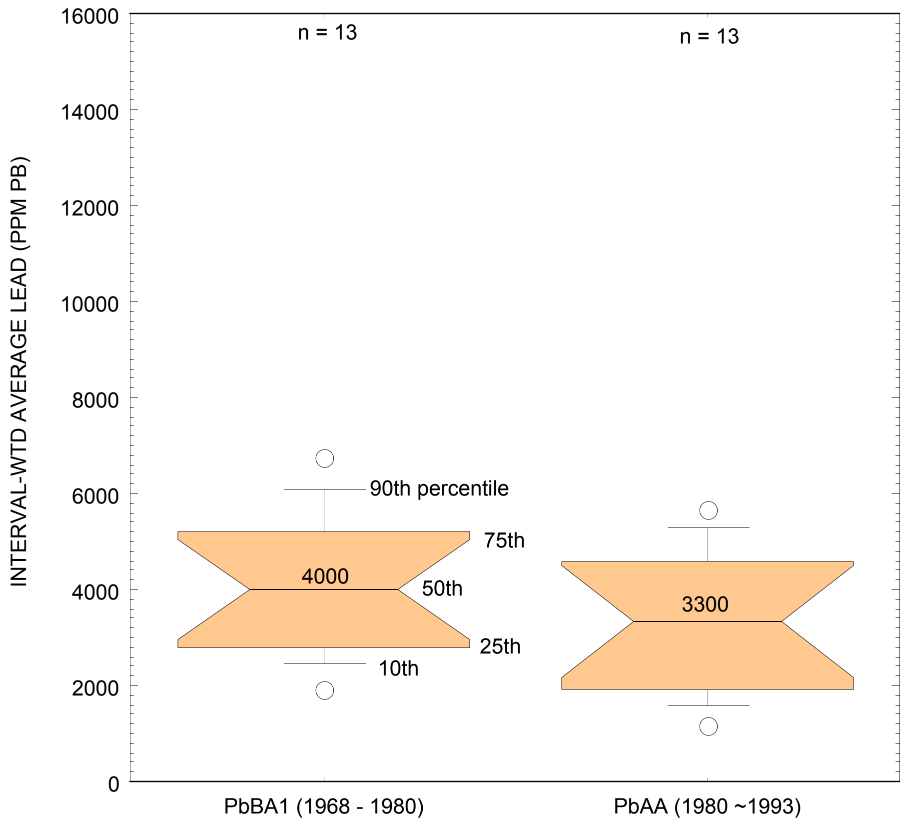

Figure 23. Box-and-whisker plots, comparing interval-weighted average lead (ppm Pb) in sediments of the early post-tailings-release (BA1) and baseline (AA) time-stratigraphic intervals.

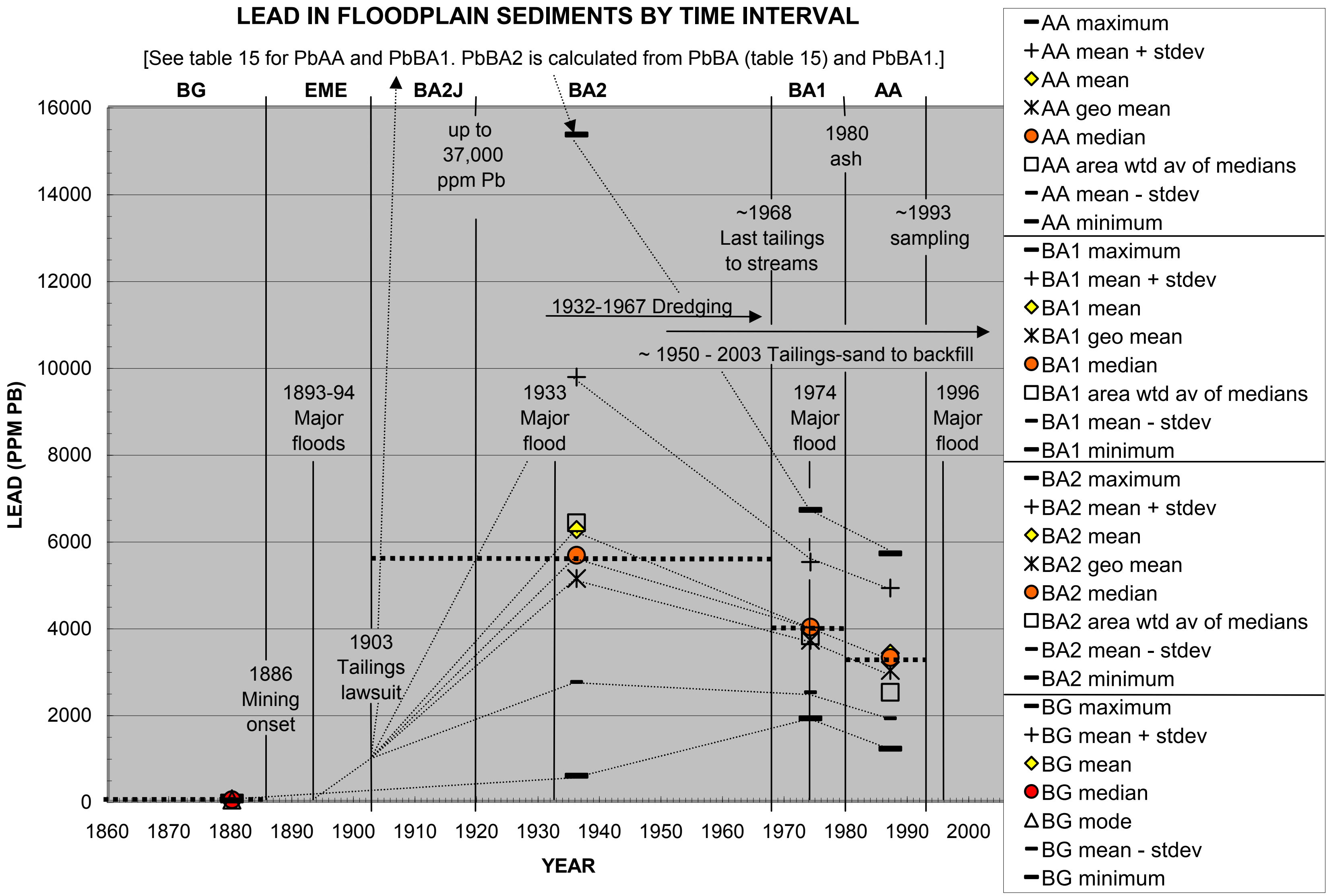

Figure 24. Summary plot of lead-concentration statistics (in ppm) for sediments of BG (background), EME (early metals-enrichment), BA2J (jig), BA2 (tailings-release), BA1 (early post-tailings), and AA (baseline) intervals.

Table 1. Stratigraphic Section of Lead-Rich Sediments from the toe of the Coeur d'Alene River delta in Coeur d'Alene Lake
(data from Horowitz and others, 1995, core sample H123)*

Sediments	Depth (cm)	Lead concentrations, from base to top of interval (approx. ppm Pb)	Time marker, time interval, or time-span of tailings production and management	Years (beginning to end of time span)	Thickness (depth span)	Time span	Sediment-deposition rate (sdr)	Time-averaged interval (sdr)	Time-averaged sub-interval (sdr)		Time-strat interval (wtd av)	Time-strat sub-interval (wtd av)	
top of core			sample-collection date		(cm)	(y)	(cm/10y)	(cm/10y)			(approx. ppm Pb)		
Layered sediments	0-20.5	6000 4600	Pre-remedial baseline interval (AA)	1980 - 1990	20.5	10	20.5	AA (above or after ash) 21			AA ~ 5300 ppm Pb		
Volcanic ash	20-21.5	1300	Mt. St. Helens ash	1980	1			Ash			Ash ~1300 ppm Pb		
Layered sediments: thin tan to brown layers with thinner, darker brown to black interlayers	21.5-40	5900 2700	Early post-tailings-release subinterval (BA1) (also post-river dredging)	~1968 - 1980	18.5	10	18.5	BA (below or before ash) 12	BA1 (early post-tailings) 19		BA ~ 7500 ppm	BA1 ~4300 ppm	
	40-46	2700 4000	Flotation-tailings (BA2F)		20	14	14.3		BA2 (tailings release) 11	BA2F (flotation) 11		BA2 ~8000 ppm	BA2F ~4900 ppm
	46-60		^{137}Cs peak	1964									
			Flotation-tailings										
			^{137}Cs onset	~1954									
	60-75	4000	Flotation-tailings-release sub-subinterval (BA2F)		15	9	16.7						
	75-80	8200 8500	(WWII production peak)	~1940 - 1945	5	5	10.0						
	80-90	6200 6500	Flotation-tailings (BA2F) (river dredging after 1932)	1918 ± 6 to ~1940	10	18	5.6						
	90-95	6500	Jig-flotation transition (WWI production peak)		5	4	12.5						
	95-100	16,000		1903 ± 8y to 1918 ± 5	5	5	10.0			BA2J (jig) 10			BA2J 17,000 ppm
	100-105	27,500	Jig-tailings-release (BA2J) sub-subinterval		5	5	10.0						
	105-110	8,000			5	5	10.0						
Non-layered sediments		~900	Pb-rich section (PBR)	~1903 to 1990	110	85		12.9			PBR ~7100 ppm		
	110-119	~100	Early metal-enrichment interval (EME)	~1895 - 1903	9	~10	~11	EME (early metal-enrichment) ~11			EME ~500 ppm Pb		
	199-126	~12 to ~100	Background section (BG)	before ~1895	7	~70	~1	BG (background) ~1 [a]			BG (33 ppm Pb)[b]		
Bottom of core			Top to bottom of core	~1825 to 1990	126	~165	~8						

*Time-stratigraphic intervals interpreted from stratigraphic, Cs isotopic, and Pb-concentration data from core 123 of Horowitz and others (1995)

a. by analogy with the pre-mining-era sedimentation rate in Killarney Lake, as estimated by Sprenke and others (2000)

b. median of background concentrations in CdA Lake-bottom sediments below the section of Pb-enriched sediments

Table 2. Sediment-Deposition Rates and Lead Concentrations, Coeur d'Alene Lake-Bottom Sediments, below and above the 1980 Volcanic-Ash Layer (after Horowitz and others, 1993, 1995*)

CdA Lake depositional environment	Gravity core-hole number	Direction from river mouth	Kilometers from mouth of CdA River	Sediment-deposition rates: sdrBA (Before Ash)	1980 volcanic ash layer	sdrAA (After Ash)	Sediment-deposition-rate (sdr) ratio	Lead concentration in lake-bottom surface sample nearest core site	
				Time intervals: ~1903 to 1980	May-Oct 1980	1980 to 1990			
				Sediment-deposition rates: cm/10y	cm/y	cm/10y	sdrAA / sdrBA	sample	ppm Pb
Delta Toe	123	NW	1.5	11.5	1.0	20.5	1.90	123	6000
	8	SE	3.5	1.8	0.2	9.6	5.33	LC10264	1460
	6	NW	4.9	nd	1.5	5.0	nd	LC10247	3200
mean				***6.7***	*0.9*	***11.7***			***3550***
mean $_{aa}$/mean $_{ba}$							***1.86***		
Lake Bays									
Windy	9	NW	11.9	3.3	0.2	3.5	1.06	LC10229	880
Wolf Lodge	10	NNE	40.6	2.3	0.2	2.3	1.00	LC10160	540
mean				***2.8***	*0.2*	***2.9***			***710***
mean $_{aa}$/mean $_{ba}$							***1.04***		
Lake Axis	93	NNW	11.9	3.2	0.3	0.5	0.16	LC10211	2150
	71	N	19.4	2.6	0.2	0.5	0.19	LC10196	2020
	47	N	26.1	2.7	0.1	0.3	0.11	LC10171	6830
mean				***2.8***	*0.2*	***0.4***			***3670***
mean $_{aa}$/mean $_{ba}$							***0.14***		

*based on data from Horowitz and others (1993) in USEPA (2001), and Horowitz and others (1995)

Table 3. Baseline Sediment-Deposition Rates (sdrAA) for Floodplain Sediments of Time-Stratigraphic Interval AA (1980 ~1993)

Floodplain Segment	Summary statistics, baseline sediment-deposition rates (sdrAA), floodplain sediments, AA time-stratigraphic interval, (deposited after the 1980 volcanic ash)	Units	Sedimentary environment (se)					**Entire floodplain**
			Levee (lv)		Flood basin (fb)			
			Depositional setting (ds)					
			Riverbank	Upland	Palustrine	Lacustrine		
						littoral	limnetic	
			(rb)	(u)	(p)	(lt)	(lm)	(fp)
Upper main stem, CdA River floodplain (fpu)	sites:ash-layer (a), freeze-box (f)	n	26 a	22 a	7 a	*0*	*0*	
	min sdrAA to max sdrAA	cm/10y	1 to 29	0 to 12	0.1 to 8	*no data*	*no data*	
	arithmetic mean ± stdev of sdrAA	cm/10y	8.1 ± 6.2	3.0 ± 2.3	3.3 ± 2.0			
	coefficient of variation (CV)		0.76	0.77	0.61			
	geometric mean of sdrAA	*cm/10y*	*6.0*	*2.8*	*2.8*			
	median of sdrAA	cm/10y	6.5	3.0	2.0			
Middle main stem, CdA River floodplain (fpm)	sites:ash-layer (a), freeze-box (f)	n	9 a	21 a	8 a	3 a	3 f	
	min sdrAA to max sdrAA	cm/10y	2 to 11	1 to 21	0 to 4	0.5 to 3	3.6 to 4.5	
	arithmetic mean ± stdev of sdrAA	cm/10y	5.3 ± 3.0	4.8 ± 5.1	2.1 ± 1.4	1.5 ± 1.3	4.4 ± 0.5	
	coefficient of variation (CV)		0.57	1.06	0.67	0.87	0.12	
	geometric mean of sdrAA	*cm/10y*	*4.2*	*3.2*	*2.1*	*1.2*	*4.1*	
	median of sdrAA	cm/10y	5.0	2.0	2.0	1.2	4.3	
Lower main stem, CdA River floodplain (fpl)	sites:ash-layer (a), freeze-box (f)	n	12 a	6 a	3 a	4 a	1 f	
	min sdrAA to max sdrAA	cm/10y	1 to 12	1 to 4	1 to 3	1 to 4	*2.7*	
	arithmetic mean ± stdev of sdrAA	cm/10y	5.5 ± 4.0	2.8 ± 1.0	1.8 ± 1.1	3.0 ± 1.3	2.7	
	coefficient of variation (CV)		0.73	0.36	0.61	0.43	0.00	
	geometric mean of sdrAA	*cm/10y*	*4.3*	*2.7*	*1.7*	*2.7*	*2.7*	
	median of sdrAA	cm/10y	5.0	2.5	1.5	3.4	2.7	
Entire main stem, CdA River	sites:ash-layer (a), freeze-box (f)	n	47 a	49 a	18 a	7 a	4 f	125
	min sdrAA to max sdrAA	cm/10y	1 to 29	0 to 21	0 to 8	0.5 to 4	2.7 to 4.5	0 to 29
	mode of sdrAA		1.9	3.9	1.0	1.2		3.9
	arithmetic mean ± stdev of drAA	**cm/10y**	**6.9 ± 5.3**	**3.7 ± 3.8**	**2.5 ± 1.7**	**2.4 ± 1.4**	**3.8 ± 0.8**	**4.7 ± 4.3**
	coefficient of variation (CV)		0.77	1.03	0.68	0.58	0.21	0.91
	peakedness		5.00	8.42	4.19	-1.88	-0.61	7.44
	peakedness (ln of data)		*-0.55*	*-0.89*	*-0.31*	*-0.12*	*0.29*	*-0.29*
	skewness		1.75	2.71	1.59	-0.19	-0.89	2.33
	skewness (ln of data)		*-0.32*	*-0.90*	*-0.20*	*-0.98*	*-1.12*	*0.26*
	geometric mean of sdrAA	*cm/10y*	*5.1*	*3.0*	*2.2*	*1.9*	*3.7*	*3.5*
	median of sdrAA	**cm/10y**	**6.4**	**2.8**	**2.2**	**2.9**	**4.0**	**3.1**
Area-wtd average of med sed rates	fp area of Pb-rich sediments[a]	km^2	2.2	14.0	19.6	8.3	9.6	*53.7*
	(nlm ds km^2) / (nlm fp fldpln km^2)		x 0.04	x 0.26	x 0.36	x 0.15	x 0.18	x 0.99
	($a_{nlm\ ds}$ / $a_{nlm\ fp}$)(med sdrAA)		0.26	+ 0.73	+ 0.79	+ 0.44	*+0.72*	= 2.94
	area-wtd average of medians	**cm/10y**						**2.9**

relative difference in means	**P(T>=t) two-tail**	**df**	**probability of difference in populations[b]**
sdrAA(rb) > sdrAA(lt)	0.00002	37	100% (significantly different)
sdrAA(rb) > sdrAA(u)	0.001	83	99.9% (significantly different)
sdrAA(rb) > sdrAA(p)	0.001	83	99.9% (significantly different)
sdrAA(rb) > sdrAA(lm)	0.001	34	99.9% (significantly different)
sdrAA(p) < sdrAA(lm)	0.05	10	95% (significantly different)
sdrAA(lt) < sdrAA(lm)	0.06	9	94% (probably different)
sdrAA (u) > sdrAA(p)	0.07	62	93% (probably different)
sdrAA(u) > sdrAA(lt)	0.08	22	92% (probably different)
sdrAA(u,fpm) > sdrAA(u,fpl)	0.10	23	90% (probably different)
sdrAA(u,fpu) < sdrAA(u,fpm)	0.15	28	85% (probably different)
sdrAA(p) > sdrAA(lt)	0.90	14	10% (probably not different)
sdrAA(u) < sdrAA(lm)	0.95	19	5% (practically not different)

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Probability that these two compared data sets represent populations that are statistically different.

Table 4. Baseline Lead Concentrations (PbAA) in Lead-Rich Floodplain Sediments of Time-Stratigraphic Interval AA (1980 ~1993)

Summary statistics for thickness-weighted average ppm Pb in sediments of the AA (after-ash) time-stratigraphic interval (PbAA)	Units	Sedimentary environment (se)					**Entire floodplain**
		Levee (lv)		Flood basin (fb)			
		Depositional setting (ds)					
		Riverbank	**Upland**	**Palustrine**	**Lacustrine**		
		(rb)	(u)	(p)	littoral (lt)	limnetic (lm)	(fp)
sites: ash-layer (a), freeze box (f)	n	20 a	40 a	9 a	5 a	3 f	77
min PbAA to max PbAA	ppm Pb	1800 to 5400	1400 to 6600	1100 to 7500	1300 to 3500	2800 to 5200	1100 to 7500
mode of PbAA	ppm Pb						1800
arith mean ± stdev of PbAA	ppm Pb	**3400 ± 990**	**3600 ± 1600**	**2800 ± 2100**	**2300 ± 900**	**4100 ± 1200**	**3400 ± 1500**
coefficient of variation		0.29	0.44	0.75	0.39	0.29	0.44
peakedness		-0.26	-1.39	2.16	-1.24		-0.63
peakedness (ln of data)							-1.03
skewness		0.27	0.21	1.53	0.51	-0.94	0.46
skewness (ln of data)							*-0.22*
geometric mean of PbAA	*ppm Pb*	*3200*	*3200*	*2300*	*2100*	*4000*	*3000*
median of PbAA	**ppm Pb**	**3300**	**3800**	**1900**	**2100**	**4400**	**3300**
fp area of Pb-rich sediments[a]	km^2	2.2	14.0	19.6	8.3	9.6	*53.7*
(ds km^2) / (fp km^2)		x 0.04	x 0.26	x 0.36	x 0.15	x 0.18	x 0.99
(a_{ds} / a_{fp})(median ppm Pb)		132	+ 988	+ 684	+ 315	+ 792	= 2911
area-wtd average of medians	**ppm Pb**						**2900**

relative difference in means	**P(T<=t) two-tail**	**df**	**probability of difference in populations[b]**
PbAA(u) > PbAA(lt)	0.03	8	97% (significantly different)
PbAA(rb) > PbAA(lt)	0.04	7	96% (significantly different)
PbAA(lt) < PbAA(lm)	0.10	3	90% (probably different)
PbAA(p) < PbAA(lm)	0.24	6	76% (probably different)
PbAA(u) > PbAA(p)	0.34	9	66% (possibly different)
PbAA(rb) < PbAA(lm)	0.42	2	58% (possibly different)
PbAA(rb) > PbAA(p)	0.46	8	54% (possibly different)
PbAA(p) > PbAA(lt)	0.49	10	51% (possibly different)
PbAA(u) < PbAA(lm)	0.51	3	49% (possibly not different)
PbAA(rb) < PbAA(u)	0.59	56	41% (possibly not different)

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Probability that these two compared data sets represent populations that are statistically different.

Table 5. Baseline Depositional Rates and Lead Concentrations,[a] and Lead in Surface-Sediments[b] of Selected Wetlands

Area identified for cleanup *and surroundings*	Depositional setting[d]	Setting comments	Sediment-deposition rates (sdr) and Pb concentrations: sites	Baseline interval		Pb concentrations in surface sediments (0 to 5 or 10 cm depth): sites	mean	+/-	std dev	CV	Years to deposit 5 to 10 cm
			n	cm/10y	ppm Pb	n	ppm Pb		ppm Pb		y
Floodplain	*Palustrine mean ± stdev*	*24 to 125 y at ± 1 stdev*	*18*	*2.5 ± 1.7*	*2800 ± 2100*						*20 to 40*
Floodplain	*Littoral mean ± stdev*	*26 to 100 y at ± 1 stdev*	*7*	*2.4 ± 1.4*	*2300 ± 900*						*21 to 42*
Lane Marsh South											
	Palustrine	**Near opening in barrier**	1	**3.9**	**4100**	6	**1600**	+/-	**1500**	**0.94**	**13 to 26**
Lane Marsh North	*Palustrine*	*Between river and barrier*[e]	*0*	*no data*	*no data*	*6*	*4900*	+/-	*1700*	*0.35*	*no data*
	Levee backslope		*3*	*11 to 21*	*5100 to 5700*	*9*	*4300*	+/-	*1500*	*0.35*	*5 to 9*
Medicine Lake											
	Palustrine, Littoral	**Lateral margins of lake**	2	**0.5 to 2.9**	**1300 to 1600**	7	**2200**	+/-	**1200**	**0.55**	**17 to 200**
	Distributary levee	*Distributary-littoral transition*		*3.4*	*2100*						*15 to 29*
	Limnetic	*Lake bottom*	*1 Pb, 2 sdr*	*3.6 to 4.3*	*5200*						*12 to 28*
Medicine Marsh											
	Palustrine	*Behind 2 barriers*	*1*	*1.0*	*170*	*11*	*3400*	+/-	*5700*	*1.68*	*50 to 100*
	Levee backslope	*Between river and barrier*	*0*	*no data*	*no data*	*5*	*5700*	+/-	*5100*	*0.89*	*no data*
Cave Lake											
	Littoral	Behind barrier and distal from Medicine Lake distributary	**0**	no data	no data	8	**440**	+/-	**560**	**1.27**	no data
	Limnetic		*0*	*no data*	*no data*	*6*	*3100*	+/-	*2800*	*0.90*	*no data*
	Levee backslope		*0*	*no data*	*no data*	*5*	*850*	+/-	*460*	*0.54*	*no data*
Bare Marsh											
	Palustrine	Levee-marsh transition, near margin of meander	1	3.1	1200	26	**1500**	+/-	**1600**	**1.07**	16 to 32
	Levee backslope					*4*	*4300*	+/-	*1900*	*0.44*	
Thompson Lake											
	Palustrine, Littoral	**Distal floodplain margin**	1	**2.5**	**290**	20	**4000**	+/-	**3200**	**0.80**	**20 to 40**
	Limnetic	Near outer side of meander	*1*	*2.7*	*2800*	*4*	*3200*	+/-	*630*	*0.20*	*19 to 37*
	Levee backslope		*0*	*no data*	*no data*	*3*	*3800*	+/-	*2600*	*0.68*	*no data*
Thompson Marsh											
	Palustrine	North of straight river reach	0	no data	no data	19	**1400**	+/-	**1600**	**1.14**	no data
	Levee backslope		*0*	*no data*	*no data*	*3*	*6600*	+/-	*4900*	*0.74*	*no data*
Anderson Lake											
	Littoral	South of straight river reach	**0**	no data	no data	6	**600**	+/-	**980**	**1.63**	no data
	Distributary levee	*Transitional to littoral*	*1*	*3.9*	*3500*						*13 to 25*

a. Baseline sample interval was from the sedimentary surface (and below surficial duff) to top of 1980 Mt. St. Helens volcanic-ash interval (or to 1/2 the thickness of the non-layered, homogeneous, water-saturated, organic-rich sediments above laminated sediments in limnetic sections of Pb-rich sediments).

b. Surface sample intervals were 0 to 5 cm (Fousek, 1996), or 0 to 10 cm (Campbell and others, 1999), the sedimentary surface below superficial duff being recorded as the 0 depth.

c. Bold type indicates data for areas under consideration for cleanup. Data for relevant nearby areas are in italics.

d. Depositional settings classified by comparing sample locations with surficial geology mapped by Bookstrom and others (1999).

e. Barriers include the railroad embankment, road embankments, and dikes at various distances from the river.

Table 6. Sediment-Deposition Rates, Medicine-Lake Site M92CS
(after Rember and others, 1993 and Hoffmann, 1995)

Depth (cm)	Medicine Lake-bottom sediments, site M92CS. top of drill core	Time-stratigraphic intervals, Cs isotopic episodes (dates)[a]	Depth span (cm)		Time span (y/10)		Sediment-deposition rate (sdr) (cm/10y)			
	water-saturated, organic-rich sediments	Baseline interval (1980 - 1992)	10	~5.2	2.3	1.2	4.3	sdrAA ~4.3	sdrAA ~4.3	sdr PBR partial interval 7.8
10		Post-tailings-release interval (~1969-1980)		~4.8		1.1		sdrBA1 ~4.3	sdr BA partial interval 9.2	
18	alternating light- and dark-colored layers of sediments of partial BA2 interval	Tailings-release interval ^{137}Cs decay (1964 - 1969)	8		0.5		16.0	sdr BA2 partial interval 12.2		
32		Tailings-release interval ^{137}Cs accumulation, (1951 - 1964)	14		1.3		10.8			
36	bottom of drill core	bottom in BA2 interval			nd	nd	nd	nd	nd	nd

a.Cs isotopic dating by Rember and others (1993) indicates depths to 1951, 1964 and 1969 time-stratigraphic levels. Depth to 1980 time-stratigraphic level is approximated, assuming AA and BA1 sedimentation rates were about the same (after disposal of tailings into streams ended in 1968-69.

Table 7. Lead in Lateral-Lake-Bottom Sediments of Baseline (AA), Post-Tailings-Release (BA1) and Historic (BA) Intervals

Time-stratigraphic interval or sub-interval	depth interval	sediment type	sediment-deposition rate	Pb mean ccn ± stdev
	M91A freeze-box sample site (Hoffmann, 1995)			
	Medicine-Lake distributary inlet delta			
	(cm)	description	(cm/10y)	(ppm Pb)
Baseline AA interval (1980 - 1991)	0 to 4	silt, 68 wt pct sand, 21 wt pct clay, 11 wt pct	3.6	5200 ± 1200
Post-tailings-release BA1 sub-interval (~1969 to 1980)	4 to 8	silt, 68 wt pct sand, 21 wt pct clay, 11 wt pct	3.6	5900 ± 1200
Historic BA interval (~1903 to 1980)	4 to 52 +	silt, 86 wt pct clay, 9 wt pct sand, 6 wt pct	> 6.2	5000 ± 2000
Time-stratigraphic interval or sub-interval	**91SBKF2** freeze-box sample site (Bender, 1991)			
	Killarney Lake, deepest middle part			
	(cm)	description	(cm/10y)	(ppm Pb)
Baseline AA interval (1980 - 1991)	0 to 5	homogeneous, non-layered	4.5	4400 ± 170
Post-tailings-release BA1 sub-interval (~1969 to 1980)	5 to 10	homogeneous, non-layered	4.5	4100 ± 150
Historic BA interval (~1903 to 1980)	5 to 50	inhomogeneous, layered, silty[1]	5.8	12000 ± 9600
Time-stratigraphic interval or sub-interval	**T91A** freeze-box sample site (Hoffmann, 1995)			
	Thompson Lake, deepest eastern part			
	(cm)	description	(cm/10y)	(ppm Pb)
Baseline AA interval (1980 - 1991)	0 to 3	non- layered	2.7	2800 ± 85
Post-tailings-release BA1 sub-interval (~1969 to 1980)	3 to 6	non- layered	2.7	2800 ± 92
Historic BA interval (~1903 to 1980)	6 to 48 +	inhomogeneous, layered	>= 5.5	7800 ± 4500

1. Bender (1991) reported "metallic silt" in nearby piston core KB.

Table 8. Sediment-Deposition Rates for Paired Baseline and Historic Intervals (sdrAA and sdrBA)

Summary statistics, sediment-deposition rates for Pb-rich floodplain sediments, deposited after (AA) and before (BA) the 1980 volcanic ash*	Unit	Depositional setting (ds)					Entire floodplain
		Riverbank	Upland	Palustrine	Lacustrine		
					Littoral	Limnetic	
		(rb)	(u)	(p)	(lt)	(lm)	(fp)
AA depositional rate (sdrAA)							
sites: ash-layer (a), freeze box (f)	n	22 a	14 a	6 a	1 a	3 f	46
min sdrAA to max sdrAA	cm/10y	1.9 - 28.6	1.1 - 13.8	2.1 - 3.6		2.7 - 4.5	1.1 - 28.6
mode sdrAA	cm/10y	3.8	1.7				3.1
arithmetic mean ± stdev sdrAA	**cm/10y**	**8.5 ± 6.1**	**3.6 ± 3.6**	**2.8 ± 0.5**	**3.3**	**3.6 ± 0.9**	**5.8 ± 5.3**
coefficient of variation		0.72	1.00	0.18		0.25	0.91
peakedness		4.71	4.96	-0.77			6.83
skewness		1.87	2.28	0.13		0	2.28
geometric mean of sdrAA	*cm/10y*	*6.9*	*2.7*			*3.6*	*4.3*
median of sdrAA	**cm/10y**	**7.3**	**2.3**	**2.9**	**3.3**	**3.6**	**3.6**
nlt fp area of Pb-rich sediments	km^2	2.2	14.0	19.6	8.3	9.6	53.7
(depo setting area) / (nlt fp area)[b]	(a_{ds}/a_{fp})	x 0.04	x 0.26	x 0.36	x 0.15	x 0.18	x 0.99
$(a_{ds}/a_{nl\ fp})$(med sdrAA)		0.29	+ 0.60	+ 1.04	+ 0.50	+ 0.76	= 3.19
area-wtd median of sdrAA	**cm/10y**						**3.2**
BA sedimentation rate (sdrBA)		(rb)	(u)	(p)	(lt)	(lm)	(nlt fp)
sites: ash-layer (a), freeze box (f)	n	22 a	14 a	6 a	1 a	3 f	46
min sdrBA to max sdrBA	cm/10y	0.9 - 35	1.0 - 20	0.0 - 14		5.4 - 6.2	0 - 35
mode sdrBA	cm/10y						3.4
arithmetic mean ± stdev sdrBA	**cm/10y**	**10 ± 8.4**	**6.1 ± 5.5**	**4.9 ± 4.7**	**3.2**	**5.8 ± 0.4**	**7.8 ± 7.3**
coefficient of variation		0.84	0.9	0.96		0.07	0.94
peakedness		2.6	1.7	3.0			3.5
skewness		1.3	1.5	1.5			1.6
geometric mean of sdrBA	*cm/10y*	*6.8*	*4.3*			*5.8*	*5.2*
median of sdrBA	**cm/10y**	**10**	**3.6**	**4.0**	**3.2**	**5.8**	**4.7**
nlt fp area of Pb-rich sediments	km^2	2.2	14.0	19.6	8.3	9.6	53.7
(depo setting area) / (nlm fp area)	$(a_{ds}/a_{nl\ fp})$	x 0.04	x 0.26	x 0.36	x 0.15	x 0.18	x 0.99
$(a_{ds}/a_{nl\ fp})$(med sdrBA)		0.40	+ 0.94	+ 1.44	+ 0.48	+ 1.04	= 4.30
area-wtd average of medians	**cm/10y**						**4.3**

relative difference in means	**P(T>=t) two-tail**	**df**	**probability of difference in populations[b]**
sdrBA (rb > lm)	0.02	22	98% (significantly different)
sdrBA (rb > p)	0.06	15	94% (probably different)
sdrBA (rb > u)	0.09	34	91% (probably different)
sdrBA (u > p)	0.60	11	40% (possibly not different)
sdrBA (p < lm)	0.65	5	35% (possibly not different)
sdrBA (u > lm)	0.81	14	19% (probably not different)
sdrAA(lm) < sdrBA(lm)	0.03	3	97% (significantly different)
sdrAA(fp) < sdrBA(fp)	0.13	83	87% (probably different)
sdrAA(u) < sdrBA(u)	0.16	22	84% (probably different)
sdrAA(p) < sdrBA(p)	0.33	5	67% (possibly different)
sdrAA(rb) < sdrBA(rb)	0.44	38	56% (possibly different)

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Probability that these two compared data sets represent populations that are statistically different.

Table 9. Sediment-Deposition-Rate Ratios for Paired Baseline and Historic Intervals (sdrAA/sdrBA)* in Non-Littoral Floodplain Settings

Summary statistics for AA/BA sediment-deposition-rate ratios sdrAA/sdrBA ratios	Units	Depositional setting (ds)				non-littoral floodplain
		Riverbank	Upland	Palustrine	Limnetic	
		(rb)	(u)	(p)	(lm)	(nlt fp)
sites: ash-layer (a), freeze-box (f)	n	22 a	14 a	7 a	3 f	43
min ratio to max ratio	sdrAA/sdrBA	0.1 to 10.3	0.1 to 1.9	0.2 to 1.0	0.50 to 0.78	0.1 - 10.3
mean ± stdev of ratios	**sdrAA/sdrBA**	**1.72 ± 2.33**	**0.76 ± 0.46**	**0.65 ± 0.37**	**0.62 ± 0.14**	**1.24 ± 1.75**
coefficient of variation		1.35	0.61	0.48	0.23	1.41
geometric mean of ratios	sdrAA/sdrBA	1.01	0.62	0.54	0.61	0.81
median of ratios	**sdrAA/sdrBA**	**1.05**	**0.79**	**0.73**	**0.58**	**0.84**
nlt fp area of Pb-rich sediments[a]	km^2	2.2	14.0	19.6	9.6	45.4
(depo-setting area) / (nl fp area)	$a_{ds} / a_{nl\ fp}$	x 0.05	x 0.31	x 0.43	x 0.21	
$(a_{ds}/a_{nl\ fp})$(med sdrAA/srBA)		0.05	+ 0.24	+ 0.32	+ 0.12	= 0.73
area-wtd average of medians	**sdrAA/sdrBA**					**0.73**

relative difference in means	**P(T>=t) 2-tail**	**df**	**probability of difference in populations[b]**
sdrAA/BA (rb > lm)	0.04	22	96% (significantly different)
sdrAA/BA (rb > p)	0.05	24	95% (significantly different)
sdrAA/BA (rb > u)	0.07	24	93% (probably different)
sdrAA/BA (u > lm)	0.35	12	65% (possibly different)
sdrAA/BA (u > p)	0.56	15	44% (possibly not different)
sdrAA/BA (p > lm)	0.85	8	15% (probably not different)

Number of sites where:	(rb)	(u)	(p)	(lm)	(nl fp)
sdrAA/sdrBA < 0.95	10	9	4	*3*	**26**
sdrAA/sdrBA = 0.95 to 1.05	*1*	*2*	*3*	*0*	*6*
sdrAA/sdrBA > 1.05	11	3	0	*0*	14

* sdrAA/sdrBA ratios are for sites where both AA and BA sediment-deposition rates were calculated from measurements of full or nearly full sections of Pb-rich sediments, divisible into AA and BA time-stratigraphic intervals.

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Probability that these two compared data sets represent populations that are statistically different.

Table 10. Lead Concentrations in Sediments of Paired Baseline and Historic Intervals
(PbAA and PbBA)

Lead-concentration summary statitstics for pairs of AA and BA intervals (PbAA and PbBA)	Units	Depositional setting (ds)					Entire floodplain
		Riverbank	Upland	Palustrine	Littoral	Limnetic	
PbAA		(rb)	(u)	(p)	(lt)	(lm)	(fp)
sites: ash-layer (a), freeze-box (f)	n	7 a	13 a	4 a	1 a	3 f	28
min PbAA to max PbAA	ppm Pb	1800 - 4600	1400 - 6100	1100 - 7500		2800 to 5200	1100 - 7500
arithmetic mean ± stdev of PbAA	**ppm Pb**	**3500 ± 900**	**3200 ± 1600**	**2800 ± 3100**	**2100**	**4100 ± 1200**	**3100 ± 1700**
coefficient of variation		0.25	0.50	1.11		0.29	0.55
peakedness		1.07	-1.28	3.94			0.09
skewness		-0.81	0.52	1.98		-.94	0.79
geometric mean of PbAA	ppm Pb	3300	2800	2000		4000	2700
median of PbAA	**ppm Pb**	**3300**	**2700**	**1300**	**2100**	**4400**	**3100**
area of Pb-rich sedimets	km^2	2.2	14.0	19.6	8.3	9.6	57.3
(depo setting area) / (floodplain area)[a]	(a_{ds}/a_{fp})	x 0.04	x 0.26	x 0.36	x 0.15	x 0.18	x 0.99
(a_{ds}/a_{fp})(med ppm Pb)		132	+ 702	+ 468	+315	+ 792	= 2409
area-wtd average of medians							**2400**
PbBA	Units	(rb)	(u)	(p)	(lt)	(lm)	(fp)
sites: ash-layer (a), freeze-box (f)	n	7 a	13 a	5 a		3 f	28
min PbBA to max PbBA	ppm Pb	1500 - 8500	1200 - 11,000	780 - 14,000		5000 to 12,000	780 - 14,000
arithmetic mean ± stdev of PbBA	**ppm Pb**	**4600 ± 2100**	**5900 ± 2800**	**6800 ± 5500**	**2900**	**8300 ± 3500**	**5900 ± 3200**
coefficient of variation		0.46	0.47	0.81		0.42	0.54
peakedness		2.34	-0.26	1.2			0.42
skewness		0.61	-0.06	0.56		0.59	0.63
geometric mean of PbBA	ppm Pb	4200	5100	4500		7800	4900
median of PbBA	**ppm Pb**	**4600**	**5700**	**6300**	**2900**	**7800**	**5400**
(depo setting area) / (fldpln area)[a]	(a_{ds}/a_{fp})	x 0.04	x 0.26	x 0.36	x 0.15	x 0.18	x 0.99
(a_{ds}/a_{fp})(median ppm Pb)		184	+ 1482	+ 2268	+ 435	+ 1404	= 5773
area-wtd average of medians	**ppm Pb**						**5800**
differences: med PbAA - med PbBA	ppm Pb	-1300	-3000	-5000	-800	-3400	-2300
	ppm Pb	area-wtd av, PbAA medians - area-wtd av, PbBA medians					-3000
ratios: med PbAA / med PbBA		0.71	0.47	0.2	0.72	0.56	0.57
		area-wtd av, PbAA medians / area-wtd av, PbBA medians					0.41

relative difference in means	P(T<=t) 2-tail	df	probability of difference in populations[b]
PbBA (rb < lm)	0.19	3	81% (probably different)
PbBA (rb < u)	0.26	16	74% (possibly different)
PbBA (u < lm)	0.36	3	64% (possibly different)
PbBA (rb < p)	0.48	4	52% (possibly different)
PbBA (p < lm)	0.69	4	31% (possibly not different)
PbBA (u < p)	0.77	4	23% (probably not different)
PbAA(fp) < PbBA(fp)	0.0004	41	100% (significantly different)
PbAA(u) < PbBA(u)	0.006	19	99% (significantly different)
PbAA(lm) < PbBA(lm)	0.19	2	81% (probably different)
PbAA(rb) < PbBA(rb)	0.21	8	79% (probably different)
PbAA(p) < PbBA(p)	0.25	5	75% (probably different)

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Probability that these two compared data sets represent populations that are statistically different.

Table 11. Lead-Concentration Ratios of Paired Baseline and Historic Intervals
(PbAA / PbBA)

Summary statistics for PbAA/PbBA ratios	Units	Levee		Flood basin			Entire floodplain
		Depositional setting (ds)					
		Riverbank	Upland	Palustrine	Littoral	Limnetic	
		(rb)	(u)	(p)	(lt)	(lm)	(fp)
sites: ash-layer (a), freeze-box (f)	n	7 a	13 a	4 a	1 a	3 f	28
min ratio to max ratio	PbAA/PbBA	0.39 - 1.20	0.16 - 1.50	0.16 - 1.42		0.36 - 1.04	0.16 - 1.50
arithmetic mean ± stdev of ratios	**PbAA/PbBA**	**0.84 ± 0.26**	**0.66 ± 0.39**	**0.60 ± 0.57**	**1.19**	**0.59 ± 0.39**	**0.71 ± 0.38**
coefficient of variation (CV)		0.31	0.59	0.95		0.66	0.54
peakedness		0.57	0.08	2.43			-0.82
skewness		-0.54	0.53	1.58		1.73	0.27
median of ratios	**PbAA/PbBA**	**0.88**	**0.64**	**0.41**	**1.19**	**0.37**	**0.72**
(depo setting area) / (floodplain area)[a]	(a_{ds}/a_{fp})	x 0.04	x 0.26	x 0.36	x 0.15	x 0.18	x 0.99
(a_{ds}/a_{fp})(median of ratios)		0.04	+ 0.17	+ 0.15	+ 0.18	+ 0.07	= 0.61
area-wtd average of medians	**PbAA/PbBA**						**0.61**

relative difference in means	**P(T>=t) two-tail**	**df**	**probability of difference in populations[b]**
PbAA/PbBA (rb > u)	0.24	17	76% (probably different)
PbAA/PbBA (rb > lm)	0.38	3	62% (possibly different)
PbAA/PbBA (rb > p)	0.47	4	53% (possibly different)
PbAA/PbBA (u > lm)	0.79	3	21% (probably not different)
PbAA/PbBA (u > p)	0.84	4	16% (probably not different)
PbAA/PbBA(p > lm)	0.98	5	2% (practically not different)

Number of sites where:	(rb)	(u)	(p)	(lt)	(lm)	(fp)
PbAA/PbBA < 0.95	5	10	3	*0*	2	**20**
PbAA/PbBA = 0.95 to 1.05	*1*	*2*	*0*	*0*	*1*	*4*
PbAA/PbBA > 1.05	1	1	2	*1*	0	5

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Probability that these two compared data sets represent populations that are statistically different.

Table 12. Lead Concentrations of Sediments in Paired Baseline- and Early Post-Tailings-Release Intervals (PbAA and PbBA1)

Lead-concentration summary statistics for AA and BA1 intervals	Units	Depositional setting (ds)				Non-littoral floodplain
		Riverbank	Upland	Palustrine	Limnetic	
AA-interval ppm Pb (PbAA)		(rb)	(u)	(p)	(lm)	(nlt fp)
sites: ash-layer (a), freeze-box (f)	n	3 a	5 a	2 a	3 f	13
min PbAA - max PbAA	ppm Pb	3300 - 4200	1700 -5700	1200 - 2600	2800 - 5200	1200 - 5700
arithmetic mean ± stdev of PbAA	**ppm Pb**	**3700 ± 450**	**3300 ± 2000**	**1900 ± 1000**	**4100 ± 1200**	**3400 ± 1500**
coefficient of variation		0.12	0.61	0.53	0.29	0.44
peakedness			-3.14			-1.33
skewness		0.99	0.63		-0.94	0.14
geometric mean of PbAA	*ppm Pb*	*3700*	*2800*	*1800*	*4000*	*3000*
median of PbAA	**ppm Pb**	**3600**	**2000**	**1900**	**4400**	**3300**
area of Pb-rich sediments	km^2	2.2	14.0	19.6	9.6	45.4
(depo setting area) / (nlt fp area)[a]	$(a_{ds}/a_{nlt\ fp})$	x 0.05	x 0.31	x 0.43	x 0.21	x 1.00
$(a_{ds}/a_{nlt\ fp})$(median ppm Pb)		180	+ 620	+ 817	+ 924	= 2541
area-wtd average of medians of PbAA	**ppm Pb**					**2500**
BA1-interval ppm Pb (PbBA1)		(rb)	(u)	(p)	(lm)	(nlt fp)
sites: ash-layer (a), freeze-box (f)	n	3 a	5 a	2 a	3 f	13
min of Pb BA1 - max of PbBA1	ppm Pb	2800 - 4000	1900 - 6700	2600 - 2800	2800 - 5900	1900 - 6700
arithmetic mean ± stdev of PbBA1	**ppm Pb**	**3300 ± 640**	**4700 ± 1800**	**2700 ± 130**	**4300 ± 1600**	**4000 ± 1500**
coefficient of variation		0.19	0.38	0.05	0.37	0.38
peakedness			1.16			-0.77
skewness		1.58	-0.87		0.48	0.53
geometric mean of PbBA1	*ppm Pb*	*3200*	*4300*	*2700*	*4100*	*3700*
median of PbBA1	**ppm Pb**	**3000**	**5200**	**2700**	**4100**	**4000**
(depo setting area) / (nlt fp area)[a]	$(a_{ds}/a_{nlt\ fp})$	x 0.05	x 0.31	x 0.43	x 0.21	x 1.00
$(a_{ds}/a_{nlt\ fp})$(median ppm Pb)		150	+ 1612	+ 1161	+ 861	= 3784
area-wtd average of medians of PbBA1	**ppm Pb**					**3800**
Comparisons of PbAA vs PbBA1:		(rb)	(u)	(p)	(l)	(nlt fp)
Difference: medPbAA - medPbBA1	ppm Pb	+ 600	- 3200	- 800	+ 300	
area-wtd av of ds medians of PbAA - area-wtd av of ds medians of PbBA1						**- 1300**
Ratio: med PbAA / medPbBA1		1.20	0.38	0.70	1.07	
area-wtd av of medians of PbAA / area-wtd av of medians of PbBA1						**0.66**

relative difference in means	**P(T<=t) two-tail**	**df**	**probability of difference in populations[b]**
PbAA(u) > PbBA1(u)	0.27	8	83% (probably different)
PbAA(nlt fp) < PbBA1(nlt fp)	0.31	24	69% (possibly different)
PbAA(rb) < PbBA1(rb)	0.39	4	61% (possibly different)
PbAA(p) < PbBA1(p)	0.46	1	54% (possibly different)
PbAA(lm) < PbBA1(lm)	0.91	4	9% (probably not different)

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Probability that these two compared data sets represent populations that are statistically different.

Table 13. Lead-Concentration Ratios of Paired Baseline- and Early Post-Tailings-Release Intervals (PbAA / PbBA1)

Summary statistics for PbAA / PbBA1 ratios	Units	Depositional setting (ds)				Non-littoral floodplain
		Riverbank	Upland	Palustrine	Lacustrine limnetic	
		(rb)	(u)	(p)	(lm)	(nlt fp)
sites with 1980 ash layer	n	3	5	2	*3*	13
min ratio to max ratio	PbAA/PbBA1	1.05 - 1.20	0.33 - 1.01	0.45 - 0.93	*0.88 - 1.20*	0.33 - 1.20
arithmetic mean ± stdev of ratios	**PbAA/PbBA1**	**1.14 ± 0.08**	**0.71 ± 0.29**	**0.69 ± 0.34**	**0.98 ± 0.10**	**0.87 ± 0.28**
coeffient of variation		0.07	0.41	0.49	0.1	0.32
peakedness			-2.30			-0.27
skewness		-1.55	-0.53			-0.93
geometric mean of ratios	PbAA/PbBA1	1.14	0.65	0.65	0.98	0.81
median of ratios	**PbAA/PbBA1**	**1.18**	**0.84**	**0.69**	**1.00**	**0.93**
(depo setting area) / (floodplain area)[a]	($a_{ds}/a_{nl\ fp}$)	x 0.05	x 0.31	x 0.43	x 0.21	x 1.00
($a_{ds}/a_{nl\ fp}$)(median ppm Pb)		0.06	+ 0.26	+ 0.30	+ 0.21	= 0.83
area-wtd average of medians	**PbAA/PbBA1**					**0.83**

relative difference in means	**P(T<=t) 2tail**	**df**	**probability of difference in populations[b]**
PbAA/BA1(rb > u)	0.03	5	97% (significantly different)
PbAA/BA1 (rb > lm)	0.09	4	91% (probably different)
PbAA/BA1 (u < lm)	0.11	5	89% (probably different)
PbAA/BA1 (rb > p)	0.31	1	69% (probably different)
PbAA/BA1 (p < lm)	0.44	1	56% (probably different)
PbAA/BA1 (u > p)	0.95	2	5% (practically not different)

Number of sites where:	(rb)	(u)	(p)	(lm)	(nlt fp)
PbAA/PbBA1 < 0.95	0	4	2	1	**7**
PbAA/PbBA1 = 0.95 to 1.05	*0*	*1*	*0*	*1*	*2*
PbAA/PbBA1 > 1.05	3	0	0	1	4

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Probability that these two compared data sets represent populations that are statistically different.

Table 14. Estimated Amounts of Lead-Rich Sediments, and Tonnages of Lead Deposited per Decade during Baseline (AA), Historic (BA), and Background (BG) Intervals, Coeur d'Alene River Floodplain

Lead-deposition rate factor by time-stratigraphic interval	Units	Depositional setting					Fldpln. (area-wtd)	Source
		River-bank	Upland	Palust.	Lacustrine			
					Littoral	Limnetic		
Median of sediment-deposition rate (sdr)								
sdr = decadal average increase in thickness	*cm/10y*	*(rb)*	*(u)*	*(p)*	*(lt)*	*(lm)*	*(fp)*	*Source*
sdrAA (1980 ~1993)	cm/10y	7.3	2.3	2.9	3.3	3.6	3.2	table 8
sdrBA (~1903-1980)	cm/10y	10.0	3.6	4.0	3.2	5.8	4.3	table 8
sdrBG (before 1886)	cm/10y	2.00	0.95	0.95	0.95	0.95	0.99	text
Sediment volume-increase rate (svir)								
*svir = (km^2)(0.01*cm/10y)*	*$Mm_s^3/10y$*	*(rb)*	*(u)*	*(p)*	*(lt)*	*(lm)*	*(fp)*	*Source*
Area of Pb-rich sediments	*km^2*	*2.2*	*14.0*	*19.6*	*8.3*	*9.6*	*53.7*	*Bookstrom* [a]
svirAA (1980 ~1993)	$Mm_s^3/10y$	0.16	0.32	0.57	0.27	0.35	1.72	calculated
svirBA (~1903-1980)	$Mm_s^3/10y$	0.22	0.50	0.78	0.27	0.56	2.20	calculated
svirBG (before 1886)	$Mm_s^3/10y$	0.04	0.13	0.19	0.08	0.09	0.53	calculated
Sediment tonnage-increase rate (stir)								
stir = (t_s/m^3)($Mm_s^3/10y$)	*$Mt_s/10y$*	*(rb)*	*(u)*	*(p)*	*(lt)*	*(lm)*	*(fp)*	*Source*
Median of density of dry Pb-rich seds	*t_s/m_s^3*	*1.51*	*1.34*	*1.00*	*1.13*	*1.07*	*1.13*	*Bookstrom* [b]
proportion of area of Pb-rich sediments		*0.04*	*0.26*	*0.36*	*0.15*	*0.18*	*0.99*	*calculated*
area-wtd average of dry sed density		*0.06*	*0.35*	*0.36*	*0.17*	*0.19*	*1.13*	*calculated*
stirAA (1980 ~1993)	$Mt_s/10y$	0.24	0.43	0.57	0.31	0.37	1.94	calculated
stirBA (~1903-1980)	$Mt_s/10y$	0.33	0.68	0.78	0.30	0.60	2.49	calculated
stirBG (before 1886)	$Mt_s/10y$	0.07	0.18	0.19	0.09	0.10	0.60	calculated
Median of ppm Pb in sediments								
median of thickness-wtd average ppm Pb	*ppm Pb*	*(rb)*	*(u)*	*(p)*	*(lt)*	*(lm)*	*(fp)*	*Source*
ppm PbAA (1980 ~1993)	t_{Pb}/Mt_s	3300	2700	1300	2100	4400	2400	table 10
ppm PbBA (~1903-1980)	t_{Pb}/Mt_s	4600	5700	6300	2900	7800	5800	table 10
ppm PbBG (before 1886)	t_{Pb}/Mt_s	26	26	26	26	26	26	text
Lead tonnage-increase rate (tirPb)								
(tir_{Pb}) = ($Mt_s/10y$)(t_{Pb}/Mt_s)	*$t_{Pb}/10y$*	*(rb)*	*(u)*	*(p)*	*(lt)*	*(lm)*	*(fp)*	*Source*
tirPbAA (1980 ~1993)	$t_{Pb}/10y$	800	1200	740	650	1600	5000	calculated
tirPbBA (~1903-1980)	$t_{Pb}/10y$	1500	3900	4900	870	4600	16,000	calculated
tirPbBG (before 1886)	$t_{Pb}/10y$	1.7	4.6	4.8	2.3	2.5	16	calculated

a. Bookstrom and others (2001) estimated areas of floodplain depositional settings covered by Pb-rich sediments.

b. Bookstrom and others (2001) calculated densities of dry floodplain sediments in different depositional settings, on the basis of data from Balistrieri and others (2000) and USEPA (1998).

Table 15. Estimated Tonnage of Lead in Lead-Rich Sediments on the Floor of the Coeur d'Alene River Valley in about 1993

Pb-tonnage factor by time interval	units	Floodplain	Riverbed	Dredge spoils	Valley floor
Baseline (AA) interval (1980~1993)		(fp)	(rb)	(ds)	(vf)
number of sites	*n*	*48*	*0*	*0*	*48*
Lead deposition rate	(kt Pb/10y)	5.0			
Depositional time interval	*(10 y)	*(1.3)			
Pb tonnage deposited	kt Pb	**6.5**			
Historic (BA) interval (~1903-1980)		(fp)	(rb)	(ds)	(vf)
number of sites	*n*	*48*	*0*	*0*	*48*
Pb deposition rate	kt Pb/10y	16			
Depositional time interval	*(10 y)	*(7.7)			
Pb tonnage deposited	kt Pb	**123**			
Total for Historic and Baseline intervals (~1903~1993)		(fp)	(rb)	(ds)	(vf)
number of sites	*n*	*48*	*0*	*0*	*48*
kt of Pb ± 30%	kt Pb	**123 ± 37**[a]			
Previous estimates of tonnage of lead in lead-rich sediments on CdA River-valley floor[a]					
(Bookstrom and others, 2001)		(fp)	(rb)	(ds)	(vf)
number of sites for thickness of section of Pb-rich sediments	*nThk*	*297*	*336*	*20*	*653*
number of sites for thickness-wtd average ppm Pb	*nPb*	*130*	*31*	*10*	*171*
median-based estimates ± 30%	kt Pb	79 ± 24	129 ± 39	44 ± 13	252 ± 76
mean-based estimates ± 30%	kt Pb	131 ± 39	120 ± 36	69 ± 21	320 ± 96
Combined estimate of tonnage of lead in lead-rich floodplain sediments					
		(fp)	(rb)	(ds)	(vf)
number of sites for wtd av ppm Pb	*nPb*	*48*	*31*	*10*	*89*
rounded median-based estimates[b]	kt Pb	**120 ± 40**	**170 ± 50**		**290 ± 90**
source		this report	Bookstrom and others (2001)		total

a. This median-based estimate for the tonnage of lead in lead-rich floodplain sediments (117 ± 36 kt of Pb) is based on a sub-set of the data included in previous estimations of median- and mean-based estimates by Bookstrom and others (2001). Only full or nearly full sections of lead-rich sediments, in which the AA and BA intervals could be identified, were used in this study. The sum of relative analytical uncertainties was approximated as ± 30 percent by Bookstrom and others (2001).

b. These estimates are rounded to two significant figures.

Table 16. Estimated Tonnage of Lead-Rich Sediment Released Annually by Riverbank Erosion, Coeur d'Alene River, West of Cataldo Landing

Riverbank reach	RBW 0-1*	RBW 2	RBW 3-4	RBW 5-6	Total area of eroding bank face	Total tonnage of eroded sediment
					m^2	kt/y
median-based estimates						
length of reach (m)	14,600	10,300	17,500	17,700		
length of banks (m)	29,200	20,600	35,000	35,400		
med height of Pb-rich bank (m)	0.99	0.79	0.58	0.38		
area of bank face (m^2)	28,908	16,274	20,300	13,452	78,943	
med width (m/y of bank eroded)	0.051	0.051	0.051	0.051		
volume (m^3/y of bank eroded)	1,474	830	1,035	686		
density of sediment (t/m^3)	1.51	1.51	1.51	1.51		
t/y of bank sediment eroded	2,226	1,253	1,563	1,036		6.079
Total of median-based estimates of bank sediments eroded (rounded)						**6.1**
mean-based estimates						
length of reach (m)	14,600	10,300	17,500	17,700		
length of banks (m)	29,200	20,600	35,000	35,400		
mean height of Pb-rich bank (m)	1.03	0.85	0.63	0.49		
area of bank face (m^2)	30,076	17,510	22,050	17,346	86,982	
mean width (m/y of bank eroded)	0.089	0.089	0.089	0.089		
volume (m^3/y of bank eroded)	2,677	1,558	1,962	1,544		
density of sediment (t/m^3)	1.51	1.51	1.51	1.51		
t/y of bank sediment eroded	4,042	2,353	2,963	2,331		11.689
Total of mean-based estimates of bank sediments eroded (rounded)						**11.7**

* RBW 0-1 indicates riverbank-wedge deposits of lead-rich sediments along river segments 0 to 1. Locations of numbered river-segments are shown on maps in figures 3, 4, and 5.

Table 17. Mean Annual Sediment-Transport Rates, Coeur d'Alene River (1992-1999), and Baseline Sediment-Deposition Rates, Coeur d'Alene River Floodplain, and Coeur d'Alene Lake (1980 ~1983)

Sediments eroded from riverbanks, recorded at gauges, and deposited on floodplain	Riverbank sediment eroded	Riverine transport, mean annual rate ± stdev	Bank sed. eroded as percent of sediment transported	
	kt sed/y	kt sed/y		
Bank sediment eroded (table 15, mean)	**12**			
Sediment transport, Rose Lake gauge				
Suspended sand, annual load		7 ± 8		
Suspended silt and finer, annual load		17 ± 12		
Mean annual transport, Rose Lake gage		**24 ± 20**		
Sediment transport, Harrison gage				
Suspended sand, annual load		40 ± 85		
Suspended silt and finer, annual load		33 ± 26		
Mean annual transport, Harrison gage		**73 ± 111**		
Total of sed transport, Rose Lake and Harrison gages		97 ± 131		
Bank sediment eroded (6-12 kt/y) as pct.of mean annual transport at Harrison			**8% to 16%**	
Estimated annual average tonnage of sediment deposited on CdA River floodplain and in CdA Lake (between 1980 and 1993)	Riverbank sediment eroded	Deposition, median of mean annual rates	Bank sed. eroded as percent of sediment deposited	Total transport at RL and H gauges, as percent of Pb-rich sediment deposited
	kt sed/y	kt sed/y		
Bank sediment eroded (table 15, mean)	**12**			
Baseline deposition rates, floodplain[b]				
Sand to silt deposited on levees and sand splays		70		
Silt to mud deposited in marshes and lakes		120		
Total annual deposition on floodplain (median-based estimate)		**190**		
Bank sediment (6-12 kt/y) as percent of sediment deposited on floodplain			**3% to 6%**	
Total transport, Rose Lk.+ Harrison gauges, as pct. of lead-rich sed. deposited on floodlain				50%
Baseline deposition rates, Coeur d'Alene (CdA) Lake[c]				
Sand to silt deposited on CdA River delta toe		160		
Silt to mud deposited in CdA Lake, beyond the delta toe		40		
Annual deposition of metal-enriched sediment in CdA Lake		**200**		
Bank sed eroded as percent of lead-rich sed deposited in CdA Lake			**3% to 6%**	
Riverine sususpended sed as percent of lead-rich sed deposited in CdA Lake				
Total of lead-rich sediment deposited on floodplain and in CdA Lake		**390**		
Bank sed eroded, as pct. of lead-rich sed deposited: floodplain + CdA Lake			**1.5% to 3%**	
Total transport, Rose Lk. and Harrison, as pct. of lead-rich sed. deposited in CdA Lake				48%
Total transport, RL and H, as pct. of lead-rich sed. Deposited: floodplain and CdA Lake				24%

a. Based on 1999 measurements, Woods (2001) modeled sediment transport as a function of discharge (USEPA, 2001). This model was applied to estimate sediment transport as a function of discharge for water years 1992 to 1998. Summary statistics for these estimates (converted from short tons to metric kilotons) are presented above.

b. Decadal average tonnages of lead-rich sediment deposited on the floodplain during the baseline interval (table 13) were converted to kt/y.

c. Means of baseline sediment-deposition rates for the toe of the CdA River delta and the distal lake axis (table 2) are converted to annual rates, which are multiplied by corresponding areas to calculate volumes of sediment deposited annually. The CdA River delta extends to core holes 6 and 8 of Horowitz (1995), and covers an area of about 12.5 km^2. Horowitz (1995) reported that 85 percent of the 128 km^2 of the lakebed (106 km^2) is covered by metal-enriched sediments. Of that, about 18 km^2 overlaps the delta and the lower floodplain. The area of contaminated lake-bottom is therefore about 91 km^2. To convert volume to tonnage, we multiplied by densities of 1.4 t/m^3 for the delta, and 1.07 t/m^3 for distal lake-bottom sediments (from Bookstrom and others, 2001).