CHAPTER 10
INJURY QUANTIFICATION

10.1 INTRODUCTION

The preceding chapters present the results of injury determination for surface water, soils and sediments, wildlife, aquatic biota, and riparian resources. In this chapter, the effects of the releases of hazardous substances are quantified in terms of the reduction from the baseline condition in the quantity and quality of services provided by the injured resources [43 CFR 11.70 (a)]. Injury quantification includes determination of the baseline condition and baseline services of the injured resources, determination of the extent of the injuries and the reduction in services resulting from the injuries, and determination of the recoverability of the injured resources [43 CFR 11.70 (c)].

As noted in Chapter 1, this report necessarily presents an *initial* quantification of injury. The Trustees' claim for damages will be based on calculation of restoration costs and must include consideration and estimation of losses residual to any remediation or response actions undertaken in the Coeur d'Alene basin by the U.S. EPA or other response agencies, final injury quantification cannot be completed until remedial and response actions are determined and the Trustees prepare a restoration plan.

10.2 BASELINE SERVICES

Baseline refers to the conditions that would have existed had the releases of hazardous substances not occurred [43 CFR § 11.14 (e)]. As part of injury quantification, baseline services normally provided by the injured resources must be determined [43 CFR 11.72 (a)]. The injured resources of the Coeur d'Alene River basin, including surface water, soil and sediment, wildlife, aquatic biota, and riparian resources, are ecologically interdependent and provide interdependent services. The baseline services provided collectively by these resources are inseparable at the ecosystem level. This section describes services unique to the injured resources, linkages between the injured resources, and services provided by interacting injured resources.

Individually, **services provided by surface water** include habitat for migratory birds and their supporting ecosystem; habitat for fish and their supporting ecosystem; habitat for benthic macroinvertebrates and aquatic, semiaquatic, and amphibious animals; water, nutrients, and sediments for riparian vegetation and its supporting ecosystem; nutrient cycling; geochemical exchange processes; primary and secondary productivity and transport of energy (food) to downstream and downgradient organisms; growth media for aquatic and wetland plants; a migration corridor; and cultural services.

Bed sediments provide habitat services for all biological resources that are dependent on the aquatic habitats in the basin. In addition, bed sediment services contribute to services provided by surface water, including suspended sediment transport processes, security cover for fish and their supporting ecosystems, primary and secondary productivity, geochemical exchange processes, nutrient cycling and transport, and cultural services.

Floodplain soils and sediments provide habitat for all biological resources that are dependent on riparian or floodplain wetland habitats in the basin. Floodplain soils and sediments provide habitat for migratory birds and mammals; habitat for soil biota; growth media for plants and invertebrates; primary productivity, carbon storage, nitrogen fixing, decomposition, and nutrient cycling; soil organic matter and energy (food) to streams; hydrograph moderation; geochemical exchange processes; and cultural services.

Migratory birds provide prey for carnivorous and omnivorous wildlife, as well as existence values, food, and recreational opportunities for humans, and cultural services.

Fish provide food for other biota, as well as existence values and recreational opportunities for humans and cultural services.

Riparian vegetation provides primary and secondary productivity; food and cover (thermal cover, security cover) for fish, migratory birds, and mammals; feeding and resting areas for fish, migratory birds, and mammals; a migration corridor provided by the riparian zone; habitat for macroinvertebrates; nutrient cycling; soil and bank stabilization and erosion control; hydrograph moderation; and cultural services.

The services listed above are interdependent [43 CFR 11.71 (b)(4)]. For example, floodplain soils and riparian vegetation interact to:

- moderate the hydrograph and reduce peak flows by slowing runoff; increase interception, infiltration, and evapotranspiration of precipitation; reduce water velocity; and store flood waters

- stabilize streambanks by anchoring the soil by plant root structures, dissipate erosive stream energy, control lateral meander migration rates, and maintain channel geometry

- control nonpoint source urban, agricultural, and industrial pollutant discharges to surface waters, and maintain surface and shallow groundwater quality by physical filtering of sediment and attached nutrients, by plant uptake of nutrients or pollutants, and through biotically controlled reactions in soils that release nutrients as gases to the atmosphere

- control sediment delivery rates to downstream aquatic and riparian resources
- intercept and store energy from solar radiation, provide a growth medium for plants, and provide substrate for nutrient cycling and decomposition
- support rich assemblages of plant and animal species; diverse habitat for vegetation, fish, and migratory birds and mammals; and highly productive ecological communities
- provide cover and food for fish and benthic invertebrates, shade the water from solar radiation, contribute to aquatic physical habitat complexity through addition of large woody debris and root masses, and regulate the supply of nutrients to the aquatic ecosystem
- provide critical connectivity between upland and aquatic habitats and a corridor for upstream and downstream dispersal for plant and animal species.

Surface water, floodplain soils and sediments, bed, bank, and suspended sediments, and riparian vegetation together provide habitat for aquatic biota, semi-aquatic biota, and upland biota dependent on access to the river or riparian zone; lateral and longitudinal connectivity between habitats; and the capacity to assimilate disturbances such as seasonal floods and anthropogenic nutrient or other pollutant contamination. The services collectively provided by these resources, plus the wildlife that use the resulting habitats, provide recreational opportunities; existence values for a wild and functional ecosystem; sustainable interacting hydrological, geomorphological, and ecological processes; and rich biodiversity.

The injuries to natural resources described in previous chapters have reduced the services identified above. Together, the injuries have caused ecosystem-level service reductions. In addition, many of the services normally provided by the injured resources and reduced by the injuries are secondary services losses [43 CFR 11.71 (b)(4)]. For example, loss of riparian vegetation and the cascading effects of the associated service losses, such as increased erosion and sedimentation and elimination of nutrient and energy regulation, all affect the viability of aquatic resources.

The high degree of overlap in services affected by the injuries results from the fact that contaminated surface water, soil, and sediment resources are now ubiquitous in the basin, and the services provided by these resources are integral parts of an ecologically interdependent ecosystem. Although there are numerous attributes and services that have been reduced and that could be quantified individually, instead, injuries were quantified based on injuries to resources that provide an intrinsic part of the habitat for aquatic biota, wildlife, and vegetation.

In the Coeur d’Alene River basin, injuries to fish and other aquatic biota, wildlife, and riparian vegetation are *caused* by exposure to hazardous substances to which they are exposed in injured surface water, soils, and sediments. The injured surface water, soils, and sediments therefore have diminished ability to sustain aquatic biota, vegetation, and habitat for wildlife and, therefore, to provide ecosystem services. Injury was quantified as the total area where concentrations of hazardous substances in surface water, soils, and sediment resources exceed baseline and have reduced ability to sustain aquatic biota, vegetation, habitat for wildlife, and the interdependent ecosystem services identified above, relative to baseline [43 CFR 11.71 (h)(4)(i) and (k)(1,2)]. In addition, baseline conditions for riparian vegetation structure and composition were quantified, since restoration of vegetation in the upper basin is crucial to restoration of the Coeur d'Alene River basin ecosystem and services provided collectively by the injured resources.

The following sections present the baseline conditions for soil and sediment, surface water, and riparian vegetation resources.

10.3 SOIL AND SEDIMENT BASELINE

Soils include substrates developed in place from weathering of parent materials and transported substrates, plus incorporated organic materials. Older, undisturbed soils typically exhibit horizon development resulting from addition of organic materials by biota, and translocation and transformation of minerals and organic materials within the profile. Floodplain substrates may include fluvially deposited materials, materials eroded from upland areas, and materials derived from in-place weathering. The description of materials in a floodplain as soils or sediments is largely related to scientific discipline. Sediment is the term most frequently used by geologists, and soil by ecologists and biologists. Regardless of the nomenclature, soils and sediments are closely related spatially and functionally in riverine and riparian ecosystems. Both are influenced by parent material in the uplands, weathering and erosion, fluvial mixing and sorting, deposition and burial, remobilization and redeposition, incorporation of organic materials, and geochemical transformations related to saturation and redox state. Therefore, for baseline determination, floodplain soils and sediments, and bed, bank, and suspended sediments, were assessed collectively. DOI NRDA regulations for both surface water resources (which include sediments) [43 CFR 11.72 (g)] and geologic resources (soils)[43 CFR 11.72 (j)] were used to guide baseline determination.

10.3.1 Historical Data

If available and applicable, historical data for the assessment area or injured resource should be used to establish the baseline [43 CFR 11.72 (c)]. Very little historical data exist that describe baseline soil and sediment conditions in the Coeur d'Alene River basin. The few sources of historical soil and sediment data are discussed below.

Before mining began, Mullan (1863), in a report on the construction of the military road through the Coeur d'Alene River basin, described the lower Coeur d'Alene and St. Joe valleys as one of the largest areas of good land, which, once drained, would provide "forty thousand acres of the finest soil in the world." Mullan described the soil as "six and eight feet deep and as black as coal." Mining and milling began in the Coeur d'Alene District in the 1880s. Discharge of tailings to area creeks and floodplains most likely began shortly thereafter (Chapter 2). Tailings were transported downstream by surface waters and deposited in the floodplains (Chapter 3, Chapter 4, and Chapter 5). In 1903, the first of a series of damage suits against the mines was initiated by residents of the lower valley (Casner, 1991). Early studies by Davenport (1921) and Ellis (1940) reported that large areas of floodplain had been covered by tailings deposits that killed vegetation and reduced the productivity of the lands. Ellis (1940) confirmed that crusts collected from the surface of tailings deposits at Mission Flats, Dudley, Medimont, Black Lake Ditch, and Thompson Flats near Harrison contained 5 to 12% zinc (50,000 to 120,000 ppm), and 0.3 to 0.8% lead (3,000 to 8,000 ppm).

In the 1950s, Kennedy (1960) conducted a study of surface soils in the upper basin to determine the feasibility of soil sampling for mineral exploration. He calculated "normal" soil background of 21 mg/kg lead, 100 mg/kg zinc, and 24 mg/kg copper in soils from nonmineralized areas, and background concentrations of 40 mg/kg lead, 76 mg/kg zinc, and 45 mg/kg copper in stream sediments. His analysis showed elevated lead concentrations near outcropping veins, but the quality of the analytical methods used was poor. In the 1970s, numerous theses, agency reports, and published papers describing tailings distribution and the effects of heavy metals from tailings and smelter emissions on environmental quality were published (e.g., Galbraith, 1971; Galbraith et al., 1972; Rabe and Flaherty 1974; Maxfield et al., 1974; Carter, 1977; Ragaini et al., 1977; Reece et al., 1978; Keely, 1979). The first large-scale soil sampling study was conducted by the USGS in the 1970s (Gott and Cathrall, 1980), and in 1981, the U.S. Soil Conservation Service released the Soil Survey of Kootenai County (U.S. SCS, 1981).

Since there is a large gap between the time that mining began in the basin and the time when the first soil and sediment samples were collected, historical data cannot be used to determine baseline conditions for soils and sediments. If historical data are not available or do not meet the guidelines in the DOI regulations, then baseline must be defined using field data from a reference area [43 CFR 11.72(d)].

10.3.2 Reference Areas

Identification of baseline conditions of soils and sediments in a basin with both mineralized and nonmineralized parent material must include consideration of the natural weathering of ore outcrops and alluvial soil development that would have occurred if the basin had not been mined. Therefore, reference areas should be selected based on their similarity to the assessment area and lack of exposure to the discharge or release [43 CFR 11.72 (d)(1)], and they should reflect the influence of natural weathering of mineralized deposits and processes that result from historical and ongoing nonmining related human activities. For soil and sediment resources, guidance for both surface water resources and geologic resources applies:

- A reference area should consist of a stream, river reach of similar size, or standing body of water that is as near to the assessment area as practical and if practical, that is upstream or upcurrent from the injured resource, such that channel characteristics, sediment characteristics, and streamflow characteristics are similar to the injured resource and the water and sediment of the reference area have not been exposed to the discharge or release [43 CFR 11.72 (g)(3)(i-ii)].

- The reference area soil or geologic material should be similar to exposed soil or geologic material in the assessment area and not exposed to the discharge or release [43 CFR 11.72 (j)(3)(i)].

Baseline should take into account both natural processes and processes resulting from anthropogenic activities. To address these attributes, data from multiple reference areas were analyzed collectively to identify baseline conditions that are representative of natural processes in a mineralized basin in the absence of mining, as well as nonmining anthropogenic processes expected to contribute to baseline conditions from the time mining began in the basin until the present.

Reference areas for determination of baseline soil and sediment conditions included:

- reaches of Canyon Creek, Ninemile Creek upstream of the East Fork Ninemile Creek confluence, and Little North Fork Coeur d'Alene River floodplains presumed to be upstream of major mining-related influences

- upland areas of the Coeur d'Alene Mining District

- the lower Coeur d'Alene River basin floodplain, using sediments from deep cores

- the St. Joe River basin floodplain

- Coeur d'Alene Lake, using sediments from deep cores.

Reference Reaches Upstream of Major Mining-Related Influences

Reaches of Canyon Creek, Ninemile Creek upstream of the East Fork Ninemile Creek confluence, and the Little North Fork Coeur d'Alene River were sampled as reference areas for the riparian resources injury assessment (Chapter 9). Canyon Creek, Ninemile Creek, and the Little North Fork Coeur d'Alene River reference reaches were selected based on their location upstream or upgradient of major mining related disturbances. Both Canyon and Ninemile Creek reference reaches are in areas of similar quaternary alluvial fill in the valley and Belt Supergroup geology in the uplands; both streams are high-gradient, low-order streams similar to lower

Canyon and East Fork and lower Ninemile Creek and other tributaries of the South Fork subbasin; and both are bordered closely by roads. The Little North Fork Coeur d'Alene River was selected as a reference for the South Fork Coeur d'Alene River based on similar stream size and presence of a road closely bordering the stream. Since these three areas are upgradient of assessment areas in the Coeur d'Alene River basin, it is appropriate to consider inputs from such areas as natural contributors to sediment composition in downstream reaches of the basin. In addition, each of these reaches had public lands that were accessible for sampling.

Three floodplain soil samples from upper Canyon Creek, 3 from Ninemile Creek, and 17 from the Little North Fork Coeur d'Alene River (all 0-15 cm depth) were collected and included in the analysis of baseline soil and sediment concentrations (locations shown in Chapter 9, Figure 9-3). These surface samples integrate effects of nonmining anthropogenic activities such as emissions from leaded gasoline earlier this century that could conceivably influence the concentrations of hazardous substances in floodplain soils.

The sample sites were selected using a systematic-random sampling design so that samples represent an unbiased estimate of the spatial variability of these reference reaches [43 CFR 11.72 (g)(4)(i)]. Methods used to collect and analyze reference data were the same as methods used to collect and analyze assessment data [43 CFR 11.72 (d)(5)]. Sampling design, sample site selection procedures, and sample collection and analysis procedures are described in Chapter 9.

Upland Areas of the Coeur d'Alene Mining District

Upland areas of the Coeur d'Alene Mining District were sampled extensively in the 1970s by the USGS as part of mineral exploration activities (Gott and Cathrall, 1980). An objective of the Gott and Cathrall study was to determine whether surface soil and rock concentrations could be used to identify minable deposits, so soil and rock samples were collected below the 15 cm depth in an attempt to limit sample contamination by metals deposited from smelter emissions. Sampling was conducted within an area of approximately 300 square miles of upland terrain, predominately in the South Fork Coeur d'Alene River subbasin. The resulting data constitute the most spatially comprehensive set of upland area soil and rock data available for the basin.

In the steep uplands of the upper Coeur d'Alene River basin, soils of the valley floor are influenced by mass soil movement processes from tributaries and adjacent hillsides (Gregory et al., 1991). Since weathering of upland rock and soils, including weathering of mineralized outcrops, and subsequent erosion and transport to floodplains and downstream reaches is the predominant pathway by which floodplain soils and sediments might naturally contain elevated concentrations of hazardous substances, use of this data set is appropriate for considering potential inputs from both mineralized and nonmineralized upland parent material.

Lower Coeur d'Alene River Basin Floodplain

Subsurface sediments of the lower Coeur d'Alene River basin floodplain between Cataldo and Harrison were sampled in 1997 as part of the Bunker Hill Basinwide Remedial Investigation (URSG and CH2M Hill, 1998). Cores up to 25 feet in depth were collected along transects crossing the river and floodplain of the lower basin. Sample locations included both floodplain soils and submerged sediments in the main river channel and in lateral lakes (see Figure 5-2, Chapter 5). Cores were subdivided into a series of samples for analysis of hazardous substances and other constituents.

Initial inspection of the data showed clear evidence of a horizon of elevated concentrations of hazardous substances in the upper portion of most cores, and a lower horizon of low concentrations of hazardous substances. Previous studies (Horowitz et al., 1993; S. Box, USGS, Spokane, WA, unpublished core data[1]) and historical accounts of tailings releases from mills, transport of tailings downstream, and deposition on floodplains, beds, and banks of the lower river (Ellis, 1940; Casner, 1991; Long, 1998) suggested that the upper sediments containing elevated concentrations of hazardous substances were deposited after mining began in the basin, and that the lower sediments were deposited before mining began in the basin. Therefore, the core data from lower horizons provide estimates of premining concentrations of hazardous substances in sediments of the lower basin.

Since the sediments of the lower basin would have included inputs from natural weathering of veins in the upper basin that might have been exposed at the ground surface before mining began, these sediments provide an estimate of baseline conditions expected in a basin containing ore deposits. In addition, the core sediments integrate effects that fluvial transport and sorting by particle size might have naturally on concentrations of hazardous substances in baseline sediments. Methods used to collect and analyze all sections of each core were the same [43 CFR 11.72 (d)(5)].

St. Joe River Basin

The St. Joe River basin was used as a reference area for pathway and injury assessment studies for wildlife resources (Chapter 6) because of its proximity to the Coeur d'Alene River basin, its general morphological and geographical similarity to the Coeur d'Alene River basin, its similarity of wildlife species assemblages and wildlife habitats, and its similarity of recreational management. The St. Joe River flows from the Montana/Idaho border through the St. Joe Mountains, and discharges to Coeur d'Alene Lake at the southern end of the lake.

1. Data summarized in URSG and CH2M Hill, 1998.

Among the data collected from the St. Joe River basin are sediments from palustrine and lacustrine wetland complexes known to be used by waterfowl (Campbell et al., 1999); 126 samples were collected from the St. Joe River basin and analyzed for hazardous substances. Surface sediment samples from the St. Joe River basin integrate effects of anthropogenic activities such as inputs from agricultural fertilizers or pesticides that might influence baseline concentrations of hazardous substances in floodplain soils.

The sample sites were selected using a systematic-random sampling design so that samples represent an unbiased estimate of the spatial variability of these reference reaches [43 CFR 11.72 (g)(4)(i)]. Methods used to collect and analyze reference data were the same as methods used to collect and analyze assessment data [43 CFR 11.72 (d)(5)].

Bed Sediments of Coeur d'Alene Lake

Horowitz et al. (1993, 1995) sampled bed sediments throughout Coeur d'Alene Lake. Twelve core samples were collected from the 97 to 141 cm depth in the Coeur d'Alene River delta, the main stem of the lake, and in the backs of several bays perpendicular to the main body of the lake. Based on metals concentrations in the sediments, an assessment of deposition rates using cesium dating (^{137}Cs), and visual observations of an upper zone of striated sediments over a homogeneous lower zone, Horowitz et al. (1993, 1995) reconstructed the geochemical history of the lake from just before mining began through 1993. They concluded that deposition of trace element-rich sediment in the lake began in about 1910 and that the deepest portions of some of the core samples represent sediments deposited before mining began in the Coeur d'Alene River basin (Horowitz et al., 1993, 1995). Data from the lower portion of cores determined to represent premining conditions were used for comparison to reference data sets identified above.

10.3.3 Data Analysis

Data from four of the data sets described above were used to describe the chemical condition of baseline soils and sediments [43 CFR 11.72 (j)(4)(i)]. To evaluate those data in an integrative analysis, preliminary analyses were performed to ensure that the data were used appropriately in statistical analyses.

Riparian resources reference area data. During the riparian resources floodplain soil sampling, evidence of past disturbance to the sample sites in the presumptive unexposed reference reach of Canyon Creek was noted (RCG/Hagler Bailly, 1994). Results of the soil chemistry analyses subsequently confirmed that metals concentrations are elevated in the areas that appeared to have been disturbed, though to a lesser degree than downstream sites. The samples were retained as part of the baseline determination data set (and as part of the reference data set for determination of injury to riparian vegetation, Chapter 9) as a very conservative estimate of floodplain soil concentrations of hazardous substances.

Gott and Cathrall (1980) data. Gott and Cathrall (1980) used an opportunistic sampling plan to search for patterns of ore forming metals in soil and weathered rock that might reveal mineralized rock below the ground surface. Most sample sites were located at 100 to 160 m intervals along unpaved roads and ridge lines, but certain areas were sampled more intensively. Rock samples were collected wherever they were encountered along a traverse. Since the sampling design was not intended to provide an unbiased description of upland soils and rocks of the Coeur d'Alene Mining District, the resulting data set is not evenly weighted across the sampling area. Before data analysis, original records of metals concentrations from individual soil or rock samples were spatially averaged by aggregation into 0.5 km^2 hexagonal cells. This procedure was conducted to reduce the influence of statistical biases that could result from the nonrandom sampling procedures, including selection bias and spatial autocorrelation of samples collected in selected clusters or transects selected based on geographic features such as roads or ridge lines. The data set derived in this manner approximates a complete census of the surveyed region (as opposed to a statistical sample). The values of interest are mean metal concentrations in sampling units of size 0.5 km^2.

The hexagonal grid system was established as a geographic information system (GIS) layer on a regional map of the Coeur d'Alene River basin, without regard to any particular features of the data set. Data records from replicate samples collected at the same coordinates were averaged, then all data records located within each grid cell were averaged. This procedure was performed for cadmium, lead, and zinc analyzed by quantitative methods (Gott and Cathrall, 1980); "semiquantitative analytes" reported by Gott and Cathrall (1980) were not used in the determination of baseline. The practical effect of the hexagonal grid averaging is to relocate sample coordinates collected at unique locations in the grid cell to the center of the grid cell and to treat the samples as replicates. The average spatial bias introduced by this procedure is approximately 290 m, a distance that is small with respect to the total size of the study area and likely degree of precision of the original coordinate records. Hexagonal grid averaging reduced the effective number of records of soil samples from 7,621 to 1,005 (the number of samples per cell ranged from 1 to 101; median = 5). The effective number of records of rock samples was reduced from 2,950 to 734 (the number of samples per cell ranged from 1 to 21; median = 3).

As part of the determination of baseline conditions, subsets of the Gott and Cathrall data were examined separately to determine chemical characteristics of samples collected within mineral belts of the Coeur d'Alene District (Hobbs and Fryklund, 1968) and over the North and South Gem and Dago Peak Stocks (Gott and Cathrall, 1980). This additional analysis was conducted based on the presumption that soils and rocks collected in these areas might have higher naturally occurring concentrations of cadmium, lead, and zinc than soils and rocks collected elsewhere in the upper basin. This analysis addressed the potential areal variability that may be introduced by the spatially nonuniform distribution of mineralized material [43 CFR 11.72 (j)(4)(i)]. For this analysis, individual samples were categorized as within a mineral belt or stock using GIS before aggregation into grid cells.

URSG and CH2M Hill (1998). The sediment cores were used to provide information about hazardous substance concentrations in lower basin sediments deposited before mining began in the basin. Most of the sediment concentration core profiles showed that cadmium, lead, and zinc concentrations are substantially elevated in the upper portion of the core, peak at an intermediate depth, and markedly decrease below a certain depth. Based on previous analyses and interpretations of depositional patterns in the lower Coeur d'Alene River basin and Coeur d'Alene Lake (Horowitz et al., 1993; S. Box, USGS, Spokane, WA, unpublished core data) and on summaries of the history of mining operations and tailings releases in the basin (Ellis, 1940; Casner, 1991; Long, 1998), the concentration pattern was interpreted as an upper horizon of tailings-enriched sediments deposited after mining began in the basin, and a lower horizon of sediments deposited before mining began in the basin.

To eliminate bias in selecting sections of a core that represent the lower horizon, an individual core section was categorized as "lower horizon" if it satisfied three objective rules:

1. The core section must be part of a whole core that produced three or more subsamples.

2. Samples from the core section must have lead concentration less than 10% of the maximum concentration measured in the core.

3. The sample or samples with lead concentrations less than 10% of the maximum concentration measured in the core must occur deeper in the core than the peak concentration.

Not all cores contained subsamples that met these criteria. Most of the cores that failed to meet these criteria contained low metals concentrations throughout and/or no distinct metal enrichment horizon. Cores that contained relatively low metal concentrations throughout were typically located in an erosional (nondepositional) section of river bank (S. Box, USGS, Spokane, WA, pers. comm., 1999). Cores that contained elevated concentrations of metals but no distinct metal enrichment horizon were located near Cataldo, where historical dredging probably disrupted depositional patterns, or were short cores that may have failed to penetrate into the lower horizon. The data inclusion criteria were intended to isolate soil samples that did not contain elevated metals concentrations attributable to mine waste, but the procedures do not provide certainty that this goal was met. Any bias that remained is likely to have caused overestimation of baseline metal concentrations because of the possibility that retained soil samples contained mine wastes.

For use in baseline analyses, concentrations of metals from subsamples within each lower horizon core section were averaged to define a mean concentration of cadmium, lead, and zinc for each core site.

10.3.4 Results

For all the data sets, analytical chemistry results that were qualified as below detection limit were assigned a value selected randomly from the range between zero and the minimum value of all nonqualified samples. Concentrations in the quantiles of interest were much greater than detection limits. All statistical analyses were conducted using $\log_{10}$ transformations of the data. Results were back-transformed and are presented on the natural scale.

Statistical correlation among cadmium, lead, and zinc concentrations was examined as a first step. Correlations between these metals are statistically significant and strongly positive (Table 10-1). Multivariate relationships between metals were examined using principal component ordination. The results of the ordination confirm that the covariance among metals is so strong that, with respect to the description of baseline conditions and determination of significant difference from assessment areas, lead alone is a sufficient surrogate for the other metals and their relative concentrations in soil or sediment. Therefore, baseline conditions are described primarily in terms of the univariate distribution of lead concentration, and secondarily on the univariate distributions of cadmium and zinc.

Table 10-1
Correlation of Metals Concentration among Soil/Sediment Samples

	Lead			**Zinc**		
	n	**Pearson's r**	**p value**	**n**	**Pearson's r**	**p value**
Reference Samples						
Zinc	1,108	0.68	<0.001			
Cadmium	1,107	0.52	<0.001	1147	0.47	<0.001
Assessment Samples						
Zinc	77	0.76	<0.001			
Cadmium	76	0.54	<0.001	89	0.64	<0.0001

Lead concentrations were lowest in sediments from the St. Joe River basin, with a geometric mean (and 95% upper confidence limit on the mean, UCL) of 15.4 (16.6) mg/kg (Table 10-2) and upper 95th percentile of 25.3 mg/kg. Lead concentrations in floodplain soil samples from the Little North Fork Coeur d'Alene River were similar. The geometric mean (UCL) was 15.8 (19.0) mg/kg, and the upper 95th percentile was 27.5 mg/kg. Canyon Creek reference samples were considerably higher: the geometric mean (UCL) was 753 (1,750) mg/kg, and the upper 95th percentile was 1,030 mg/kg. Inclusion of Canyon Creek samples that are known to have been exposed to mine wastes but to a lesser degree than downstream areas contributes to the higher metal concentrations in these samples relative to the St. Joe River basin and Little North Fork Coeur d'Alene River samples.

Table 10-2
Concentrations of Lead (mg/kg) in Reference Soils and Sediments, Mineralized Upland Soils and Rocks, and Mine-Waste Exposed Soils and Sediments

	Sample Size	Geometric Mean	Upper 95% CL	95th Percentile
Reference Data Sets				
St. Joe River basin[a]	126	15.4	16.6	25.3
Little North Fork[b]	17	15.8	19.0	27.5
Canyon Creek reference[b]	3	753	1,750	1,030
Ninemile Creek reference[b]	3	145	543	292
Upland soils[c]	964	45.5	47.8	190
Upland rocks[c]	632	19.0	21.3	131
Alluvium cores[d]	10	87.8	181	343
Pooled Reference	1,755	30.7	32.4	175
Mineralized Upland Soils				
Upland soils over stocks[c]	40	50.0	64.5	208
Upland soils over mineral belts[c]	210	49.3	55.4	195
Upland rocks over stocks[c]	127	20.8	28.7	405
Upland rocks over mineral belts[c]	36	13.7	20.5	47.3
Mine-Waste Exposed Soils/Sediments				
South Fork Coeur d'Alene basin[b]	29	9,690	13,000	22,100
Canyon Creek assessment[b]	6	13,700	31,000	39,800
Ninemile Creek assessment[b]	5	23,800	44,200	48,900
Lateral lakes palustrine/lacustrine wetlands[a]	555	1,880	2,110	7,650
Lateral lakes floodplain[e]	185	885	1,110	5,000
Lateral lakes floodplain[b]	44	999	1,610	6,000

a. Campbell et al., 1999.
b. Chapter 9, this report.
c. Gott and Cathrall, 1980.
d. URSG and CH2M Hill, 1998.
e. Horowitz, 1995.

Lead concentrations in alluvial core sediments from the lower Coeur d'Alene River basin were higher than those in Coeur d'Alene River basin upland soils and Coeur d'Alene River basin and St. Joe River basin surface floodplain soils and sediments, but considerably lower than those in Canyon and Ninemile Creek reference soils (Table 10-2). The geometric mean (UCL) of the lower horizon cores was 87.8 (181) mg/kg, and the upper 95th percentile was 343 mg/kg. The higher lead concentrations in the sediment cores may reflect natural metal enrichment relative to upland soils as a result of differential fluvial transport of fine particles with higher associated metal concentrations from a mineralized headwaters. They may also result from geochemical migration of metals from upper to lower layers, or cross contamination of core materials during the core drilling, retrieval, or subsampling. In several instances, the peak concentration in a core was so great that a value of less than 10% was still substantially elevated relative to concentrations in most other defined lower horizons. However, to avoid bias in identification of the lower horizon section, these substantially elevated portions were retained despite the fact that there might be good reason to eliminate them from the baseline data set, and that they may bias the baseline estimates upward (i.e., overestimated metal concentrations).

In general, concentrations of lead and other metals were greater in upland soils than in upland rocks. Mean and upper 95th percentile lead concentrations in upland soil and rock samples collected over mineral belts and stocks were only slightly higher than in the whole population of upland soil and rock samples (Table 10-2). The absence of an appreciable increase in lead concentrations even in soils and rocks from mineralized areas indicates that natural mineralization is unlikely to explain the measured concentrations in floodplain soils and sediments throughout the basin. For comparison, soil samples from mine-waste exposed assessment areas are presented in Table 10-2. These concentrations are up to two orders of magnitude higher than reference concentrations.

An overall characterization of lead concentrations derived from pooling of the reference data sets is a geometric mean (UCL) of 30.7 (32.4) mg/kg and an upper 95th percentile of 175 mg/kg. The geometric mean is a concentration typical of lead concentrations throughout the basin. The upper 95th percentile concentration is one that is likely to occur infrequently in the basin (in approximately 5% of the basin).

Patterns for cadmium and zinc are similar, with higher concentrations of cadmium and zinc in Canyon Creek and Ninemile Creek reference soils than in St. Joe River basin and Little North Fork Coeur d’Alene River soils (Tables 10-3 and 10-4). Concentrations of cadmium and zinc were not as elevated in the core samples relative to other reference datasets as were concentrations of lead. For both cadmium and zinc, concentrations in mine-waste exposed assessment soils greatly exceed concentrations in reference soils. As for lead, mean and upper 95th percentile cadmium and zinc concentrations in upland soil and rock samples collected over mineral belts and stocks were only slightly higher than in the whole population of upland soil and rock samples.

An overall characterization of cadmium concentrations derived from pooling of the reference data sets is a geometric mean (UCL) of 0.61 (0.64) mg/kg and an upper 95th percentile of 2.86 mg/kg, and for zinc, a geometric mean (UCL) of 63.3 (66.4) mg/kg and an upper 95th percentile of 263 mg/kg.

Table 10-3
Concentrations of Cadmium (mg/kg) in Reference Soils and Sediments, Mineralized Upland Soils and Rocks, and Mine-Waste Exposed Soils and Sediments

	Sample Size	Geometric Mean	Upper 95% CL	95th Percentile
Reference Data Sets				
St. Joe River basin[a]	126	0.53	0.63	1.40
Little North Fork[b]	17	0.61	1.0	1.36
Canyon Creek reference[b]	3	3.31	14.0	6.19
Ninemile Creek reference[b]	3	2.77	5.58	3.65
Upland soils[c]	1,002	0.83	0.89	3.83
Upland rocks[c]	727	0.41	0.44	1.38
Alluvium cores[d]	10	0.29	0.63	0.88
Pooled Reference	1,888	0.61	0.64	2.86
Mineralized Upland Soils				
Upland soils over stocks[c]	40	1.15	1.44	4.33
Upland soils over mineral belts[c]	240	0.79	0.89	3.13
Upland rocks over stocks[c]	191	0.49	0.55	1.60
Upland rocks over mineral belts[c]	34	0.31	0.44	0.73
Mine-Waste Exposed Soils/Sediments				
South Fork Coeur d'Alene basin[b]	29	35.1	43.9	68.6
Canyon Creek assessment[b]	6	15.8	42.5	44.6
Ninemile Creek assessment[b]	5	4.58	41.8	12.5
Lateral lakes palustrine/lacustrine wetlands[a]	555	12.8	14.1	46.0
Lateral lakes floodplain[e]	185	5.07	6.25	30.8
Lateral lakes floodplain[b]	44	6.40	9.48	27.4

a. Campbell et al., 1999.
b. Chapter 9, this report.
c. Gott and Cathrall, 1980.
d. URSG and CH2M Hill, 1998.
e. Horowitz, 1995.

Table 10-4
Concentrations of Zinc (mg/kg) in Reference Soils and Sediments, Mineralized Upland Soils and Rocks, and Mine-Waste Exposed Soils and Sediments

	Sample Size	Geometric Mean	Upper 95% CL	95th Percentile
Reference Data Sets				
St. Joe River basin[a]	126	51.5	56.1	104
Little North Fork[b]	17	58.5	66.4	87.4
Canyon Creek reference[b]	3	630	1,280	885
Ninemile Creek reference[b]	3	294	700	467
Upland soils[c]	1,005	101	105	296
Upland rocks[c]	728	33.7	36.8	169
Alluvium cores[d]	10	122	176	236
Pooled Reference	1,892	63.3	66.4	263
Mineralized Upland Soils				
Upland soils over stocks[c]	40	128	164	628
Upland soils over mineral belts[c]	244	121	132	412
Upland rocks over stocks[c]	195	36.0	42.7	204
Upland rocks over mineral belts[c]	36	40.0	50.2	103
Mine-Waste Exposed Soils/Sediments				
South Fork Coeur d'Alene basin[b]	29	4,780	5,900	8,890
Canyon Creek assessment[b]	6	2,600	7,470	7,400
Ninemile Creek assessment[b]	5	2,480	3,580	3,480
Lateral lakes palustrine/lacustrine wetlands[a]	555	1,375	1,510	4,840
Lateral lakes floodplain[e]	185	701	845	4,500
Lateral lakes floodplain[b]	44	612	903	3,100

a. Cambell et al., 1999.
b. Chapter 9, this report.
c. Gott and Cathrall, 1980.
d. URSG and CH2M Hill, 1998.
e. Horowitz, 1995.

10.3.5 Comparison to Literature and Assessment Values

Concentrations in samples collected at the reference areas were compared to concentrations reported in the scientific or management literature for similar resources to determine whether the data represent a normal range of conditions [43 CFR 11.72 (d)(6)]. Table 10-5 presents mean concentrations of cadmium, lead, and zinc reported in background (uncontaminated) soils of various types from a number of countries. Worldwide mean concentrations of cadmium, lead, and zinc are 0.53 mg cadmium/kg, 32 mg lead/kg, and 64 mg zinc/kg (Kabata-Pendias and Pendias, 1992). The concentrations reported for reference data in Tables 10-2 to 10-4 are generally similar to mean concentrations reported in Table 10-5, except that mean concentrations of lead and zinc in the Canyon and Ninemile Creek reference and lower basin alluvium core samples are somewhat higher than the data from the literature.

Data collected at reference areas should also be compared to data collected at the assessment areas to confirm statistically significant differences [43 CFR 11.72 (g)(6) and (j)(4)(iii)]. Concentrations of hazardous substances were consistently greater in assessment soils than in reference soils (Chapter 5 and Chapter 9):

- Concentrations of arsenic, cadmium, manganese, lead, and zinc in sediment samples collected from the lower Coeur d’Alene River basin were all significantly greater than samples collected from the St. Joe River basin (Mann Whitney $p < 0.001$) (Chapter 5; Campbell et al., 1999).

- Concentrations of arsenic, cadmium, copper, lead, and zinc in South Fork Coeur d’Alene River soils were significantly greater than those in Little North Fork soils (Mann-Whitney $p < 0.05$) (Chapter 9).

- Concentrations of copper, lead, and zinc in Ninemile Creek assessment soils were significantly greater than those in reference soils, and concentrations of arsenic, copper, and lead in Canyon Creek assessment soils were significantly greater than those in reference soils (Mann-Whitney $p < 0.05$). In addition, cadmium concentrations in assessment samples from Ninemile Creek and cadmium and zinc concentrations in assessment samples from Canyon Creek were substantially elevated. Although the differences were not statistically significant at $p < 0.05$, these concentrations in assessment samples were considerably elevated relative to reference samples, baseline concentrations, and worldwide mean concentrations.

- Pooled comparison of all upper basin assessment soils with upper basin reference soils showed significant differences between pooled reference and pooled assessment for arsenic, cadmium, copper, lead, and zinc (Mann Whitney $p < 0.001$).

Table 10-5
Mean Background Cadmium, Lead, and Zinc Concentrations in Surface Soils of Various Countries

Country	Cadmium (mg/kg)					Lead (mg/kg)					Zinc (mg/kg)				
	Sandy Soil	**Silty Soil**	**Loamy/ Clay**	**Fluvial Soil**	**Various Soils**	**Sandy Soil**	**Silty Soil**	**Loamy/ Clay**	**Fluvial Soil**	**Various Soils**	**Sandy Soil**	**Silty Soil**	**Loamy/ Clay**	**Fluvial Soil**	**Various Soils**
Australia	—	—	—	—	—	57	—	—	19	—	—	—	—	—	—
Austria	—	—	—	0.37	0.29	—	—	—	—	29	—	—	—	—	—
Bulgaria	—	—	—	—	0.29	—	—	—	—	—	—	—	—	62	65
Canada	0.43	—	0.64	—	0.56	10	—	17	—	20	—	—	17	—	57
Denmark	—	—	—	—	0.26	—	—	—	—	—	—	—	—	—	31
Great Britain	—	—	—	1	1.0	—	—	—	63	29	—	—	70	125	80
Italy	—	—	—	—	0.44	—	—	—	—	26	—	—	—	—	68
Japan	—	—	—	—	0.44	—	—	—	—	35	—	—	—	—	86
Madagascar	—	—	—	—	—	37	—	48	—	—	—	—	—	—	—
New Zealand	—	—	—	—	—	—	—	—	—	—	42	61	79	60	59
Poland	0.07	0.20	0.26	0.30	0.41	16	26	25	39	18	24	47	68	85	47
Romania	0.9	—	0.9	—	—	—	—	21	—	—	61	73	75	—	61
United States	0.21	—	0.27	—	—	17	19	22	—	26	40	59	67	—	74
USSR[a]	0.32	—	—	—	0.06	20	—	40	—	8	31	48	35	42	78
West Germany[a]	—	—	—	—	0.80	—	—	—	—	—	—	—	—	—	—
World Mean					**0.53**					**32**					**64**

a. Former nations.

Source: Tables 61, 67, 107 in Kabata-Pendias and Pendias (1992), and sources cited therein.

10.3.6 Influence of Vein Outcrops and Mining Waste

Historical data on metal concentrations in soils near veins suggest metal concentrations near some veins are elevated (Kennedy, 1960). An analysis was conducted to assess the degree to which the elevated metal concentrations near veins might affect soil metal concentrations in the District. Since the Kennedy data are semiquantitative (precision of ±50%),[2] they cannot be used quantitatively. However, with an understanding of the uncertainty involved, the semiquantitative data can be used to indicate the degree to which metal concentrations may be elevated near veins in the Coeur d'Alene District.

Estimates of the areal contribution of elevated metal concentrations near outcropping and projected veins in Canyon Creek were used to evaluate whether naturally elevated metal concentrations near veins substantially affect background soil concentrations at the scale of the drainage. In this analysis, the following data and information were used:

- the location, linear extent, composition, and surface expression of veins as depicted in the Hobbs et al. (1965) maps
- the location, linear extent, and surface expression of ore bodies and veins as depicted in vertical longitudinal projections and cross-sections in Crosby (1959)
- the surface expression of ore bodies as depicted in Hobbs and Fryklund (1968)
- the extent and composition of surface soils affected by veins as contained in figures and tables in Kennedy (1960)
- the composition of surface soils as contained in data from Gott and Cathrall (1980).

Veins known to contain base metals (veins marked with an "A"on the Hobbs et al. maps) and veins associated with mines that were known to produce metals were included in the evaluation. Thirteen such veins exist in the Canyon Creek drainage. Using information from Crosby (1959), Hobbs et al. (1965), Hobbs and Fryklund (1968), and Kennedy (1960), portions or entire lengths of 10 of the 13 veins either outcrop or affect soil metal concentrations in Canyon Creek (Figure 10-1). One of the veins shown in Figure 10-1, the Copper King, was not a lead or zinc vein, and was not used in the analysis. Of the remaining nine veins, one, the Standard-Mammoth, was not shown to be outcropping by Crosby, Hobbs, or Kennedy. However, because soil concentrations of lead, and to a lesser extent, zinc, were elevated for approximately 250 feet along the projected vein (Kennedy, 1960), a distance of 250 feet was chosen as the "outcrop" length for the Standard-Mammoth vein. The detection of elevated surface soil concentrations over a vein that was close to the surface (within approximately 50 feet) but not outcropping

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2. For lead and zinc, 70-100% of the semiquantitative results agreed within ±50% with the quantitative data (Kennedy, 1960). This implies that up to 30% of the samples do not fall within the ±50% range. There is no way to determine which of the samples fall outside of that range.

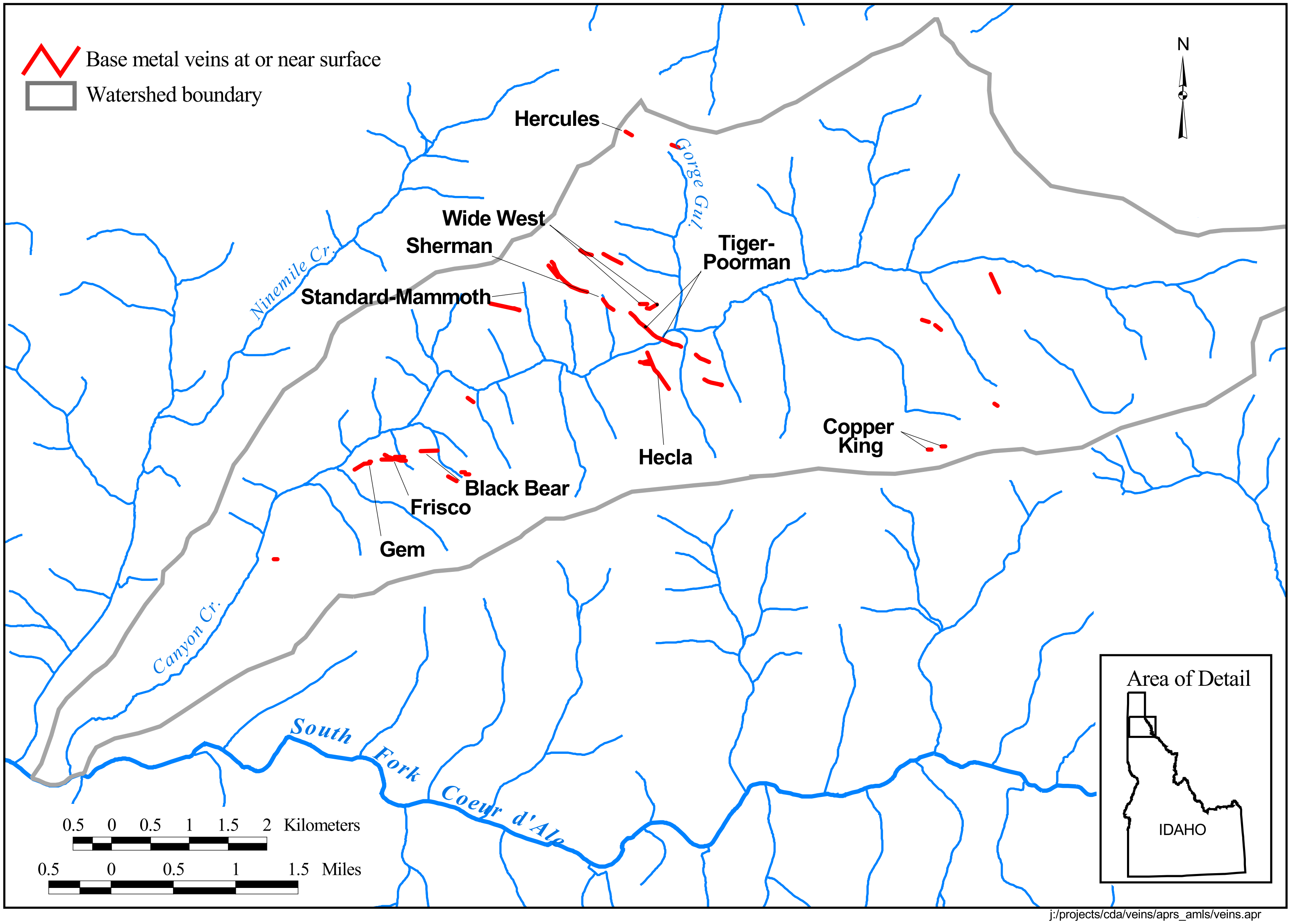

Figure 10-1. Locations of surface or near surface veins known to contain base metals in the Canyon Creek drainage basin.

demonstrates that some subsurface veins affect soil metal concentrations. Some of the elevated concentrations measured by Gott and Cathrall in the District are also likely to be related to this phenomenon.

The area of the Canyon Creek drainage basin was delineated using Interior Columbia Basin Ecosystem Management Project (ICBEMP, 1994) data and a topographical GIS overlay, and the locations and lengths of the nine lead and zinc veins as identified by Hobbs, Crosby, or Kennedy were mapped. For each vein, an average width of 150 m of elevated metal concentrations was assumed, based on the average width of the traverses of the 13 veins containing lead and zinc reported in Kennedy (1960).[3]

Using the measured lengths of the veins and the average width of elevated metal concentrations around the vein, the veins and associated areas of elevated metal concentrations in Canyon Creek comprise only 0.4% of the total area of the drainage basin. This value is probably an overestimate of the percentage of the watershed occupied by veins and areas of elevated metal concentrations because the concentrations near several of the veins returned to near background levels within distances shorter than 75 m from the vein outcrop or projection. However, using a 150-m width for all of the veins ensures that the analysis does not underestimate the potential contribution of the veins to soil chemistry in the Canyon Creek drainage.

A weighted average of the samples collected at the surface in each of the four Kennedy traverses in Canyon Creek (all of which contained lead and zinc, Table 10-6) was used as the average concentration for the nine veins in Canyon Creek. Sample concentrations were averaged within a traverse, and the traverse averages, weighted by the actual length of the traverse, were averaged. The weighted average concentration of lead near veins in Canyon Creek was 836 ppm (Table 10-6).

Gott and Cathrall data from within the Canyon Creek drainage basin were assigned to hexagon cells, using methods described previously. Using Gott and Cathrall hexagon data, the estimated average concentration of lead in soils in the Canyon Creek watershed is 125 ppm (Table 10-7). This value corresponds to approximately the 90th percentile of the baseline data set for the Coeur d'Alene Basin as a whole (Table 10-2). Gott and Cathrall did not collect any samples in the upper quarter of the watershed, upgradient of where most of the veins are located. Therefore, the average lead concentration based on the Gott and Cathrall data probably overestimates the actual average soil lead concentration for the watershed. Incorporating the average soil lead concentration near the nine veins in the Canyon Creek drainage increases the average lead concentration in the Canyon Creek watershed soils by only 2.1% to a value of 127 ppm (Table 10-7).

3. The wandering traverse at the Jack Waite vein was divided into three traverses that were roughly perpendicular to the vein. The average length of those three traverses and a fourth separate perpendicular traverse was used as the average width for that vein. A similar approach was taken for the Little Pittsburg, where three separate traverses were conducted.

Table 10-6
Characteristics of Lead-Zinc Veins Studied by Kennedy (1960)

Vein	Drainage	Traverse Length (ft)	Sample Size	Traverse Mean Lead (ppm)	Vein Mean Lead (ppm)
Jack Waite — 1	Tributary Creek/North Fork	663	9	19	—
Jack Waite — 2	Tributary Creek/North Fork	674	11	47	—
Jack Waite — 3	Tributary Creek/North Fork	789	18	115	—
Jack Waite — 4	Tributary Creek/North Fork	320	7	63	61
Hercules	Canyon Creek	550	12	490	490
Custer Peak	Canyon Creek	1,096	11	1,027	1,027
Standard-Mammoth	Canyon Creek	373.3	13	387	387
Frisco	Canyon Creek	484.6	18	1,147	1,147
Star	Grouse Gulch/South Fork	774	10	1,070	1,070
Gold Hunter	Gold Hunter/South Fork	493.8	20	713	713
Vindicator	South Fork/Gentle Annie	160	25	285	285
Sidney	Pine Creek	200	12	373	373
Little Pittsburg — 1	Pine Creek	400	14	7,071	—
Little Pittsburg — 2	Pine Creek	345	12	5,733	—
Little Pittsburg — 3	Pine Creek	15	16	5,466	6,090
"Carbonate" vein	Grouse Gulch/South Fork	100	11	150	150
Liberal King[a]	Pine Creek	nd	nd	nd	nd
Page Curlew	Silver Creek/South Fork	1,093	21	213	213
South Fork Basin Weighted Mean:					586
Canyon Creek Weighted Mean:					836

a. No data (nd) provided in Kennedy (1960).

Table 10-7
Summary of Analysis of the Effect of Highly Mineralized Veins on Baseline Soil Lead Concentrations

Drainage Basin	Exposed Veins			Lead Concentration			
	Total Length[a] (m)	Average Width[b] (m)	Areal Extent (%)	Average near Veins[b] (ppm)	Basin Average without Veins[c] (ppm)	Basin Average with Veins (ppm)	Increase (%)
Canyon Creek	1,407	150	0.4	836	125	127	2.1
South Fork Coeur d'Alene	11,851	150	0.2	586	96.4	97.6	1.2

a. Crosby, 1959; Hobbs et al., 1965; Hobbs and Fryklund, 1968.
b. Kennedy, 1960 and text in this report.
c. Gott and Cathrall, 1980 — hexagons.

A similar analysis was conducted for South Fork Coeur d'Alene River basin. The areal percentage of veins in the South Fork Coeur d'Alene River basin is 0.2% (Table 10-7). Based on Gott and Cathrall hexagon data, the mean lead concentration for the South Fork Coeur d'Alene River basin excluding the veins is 96.4 ppm. The average lead concentration near veins for the entire South Fork Coeur d'Alene basin was calculated using the surface concentrations in all 13 of the veins analyzed by Kennedy that contained lead and zinc (Kennedy, 1960, Table 2). The weighted average concentration of lead over the 13 veins (including the anomalously high concentrations at the Little Pittsburg vein) is 586 ppm. The average concentration of lead in the South Fork Coeur d'Alene basin soils adjusted for the veins is 97.6 ppm, which is an increase of only 1.2% (Table 10-7).

The Gott and Cathrall data are approximately 90% of the data used in the baseline soil and sediment analysis. Approximately 24% of the individual Gott and Cathrall soil and rock lead analyses exceeded the Gott and Cathrall threshold value of 60 mg/kg. Approximately 1.8% of the individual Gott and Cathrall soil and rock lead samples exceeded 586 mg/kg lead, the average concentration of lead measured in the vicinity of veins by Kennedy (1960) for the South Fork Coeur d'Alene basin (Table 10-7). Using the hexagonal averaging method, 37.5% of the soil hexagons and 22% of the rock hexagons exceeded 60 mg/kg, and 1.3% of the soil hexagons and 3.7% of the rock hexagons exceeded 586 mg/kg. Given that only approximately 0.2% of the South Fork Coeur d'Alene River basin contains naturally elevated metal concentrations, the number of high concentrations in the Gott and Cathrall data set indicates that Gott and Cathrall sampling locations included mining-contaminated areas as well as naturally mineralized areas.

The contribution of high concentrations of lead near veins to the overall concentration of lead in surface soils in the upper Coeur d'Alene basin is inconsequential. A similar analysis to determine the vein contribution to zinc concentrations was not conducted because the enrichment of zinc in the veins was much lower than that for lead (Kennedy, 1960, Table 5). In addition, because the contribution of veins to baseline soil lead and zinc concentrations is so minor, applying the ±50% factor related to the semi-quantitative nature of the Kennedy data does not change the result. If the average vein lead concentration for the entire South Fork Coeur d'Alene River basin were twice as high, the basin weighted average would be 98.9 ppm rather than 97.6 ppm. Therefore, after conducting this weighted average analysis, it is clear that the baseline soil metal concentrations presented in Table 10-8 already take into account the contribution of elevated metal concentrations in the vicinity of veins in the Coeur d'Alene basin.

In addition to using samples from highly mineralized areas, the analysis of baseline conditions used samples from areas that have been exposed to mining wastes. The Canyon Creek reference sites showed clear evidence of mine waste contamination (Chapter 9; RCG/Hagler Bailly, 1994), and it is probable that some of the samples collected by Gott and Cathrall (1980) were influenced by metals in smelter deposition despite their attempts to exclude influenced layers. The subsets of Gott and Cathrall (1980) data that characterize soil and rock concentrations over mineral belts and stocks in the district show that mean concentrations of lead, cadmium, and zinc are only slightly higher than the mean concentrations of the whole Gott and Cathrall data set (Tables 10-2 to 10-4).

Table 10-8
Statistical Distribution of Baseline Concentrations in Soils and Sediments of the Coeur d'Alene River Basin

	Lead (mg/kg)	Cadmium (mg/kg)	Zinc (mg/kg)
Baseline, whole basin			
Geometric mean	30	0.61	63
95% UCL	32	0.64	66
95th percentile	175	2.9	263
Baseline, geographic subsets with veins			
Canyon Creek, mean	127	NC	NC
South Fork Coeur d'Alene basin, mean	97.6	NC	NC
Anomalous threshold[a]	60	2	250
Median, subsurface lake bed sediments[b]	33	0.3	118

a. Gott and Cathrall, 1980.
b. Horowitz et al., 1995.

NC — not calculated.

Maps of areas disturbed in some way by mining or mineral processing operations in the basin (Chapter 2) show the wide distribution of areas with some degree of disturbance. Since metal concentrations at many of these sites have not been characterized, Gott and Cathrall (1980) samples that were collected from areas identified as disturbed were conservatively retained in the baseline data set.

10.3.7 Sediment and Soil Baseline Concentrations

The DOI NRDA regulations do not suggest a statistic for characterization of baseline concentrations based on the range of variability determined. Therefore, to determine baseline concentrations for lead, cadmium, and zinc in soils and sediments, distributions of the reference data sets presented in Tables 10-2 to 10-4 were considered. The geometric mean and the upper 95% confidence limit on the geometric mean (UCL) are appropriate descriptors of the typical metal concentrations found in reference soils and sediments (Table 10-8). The 95th percentile is a concentration that is rarely exceeded in the reference areas. Figures 10-2 to 10-4 show histograms of lead, cadmium, and zinc concentrations from the reference data set for the whole basin. The UCL and upper 95th percentile concentrations are identified in the figures by dashed lines. The calculated average concentrations for lead in the Canyon Creek drainage and the South Fork Coeur d'Alene River basin are also presented (Table 10-8).

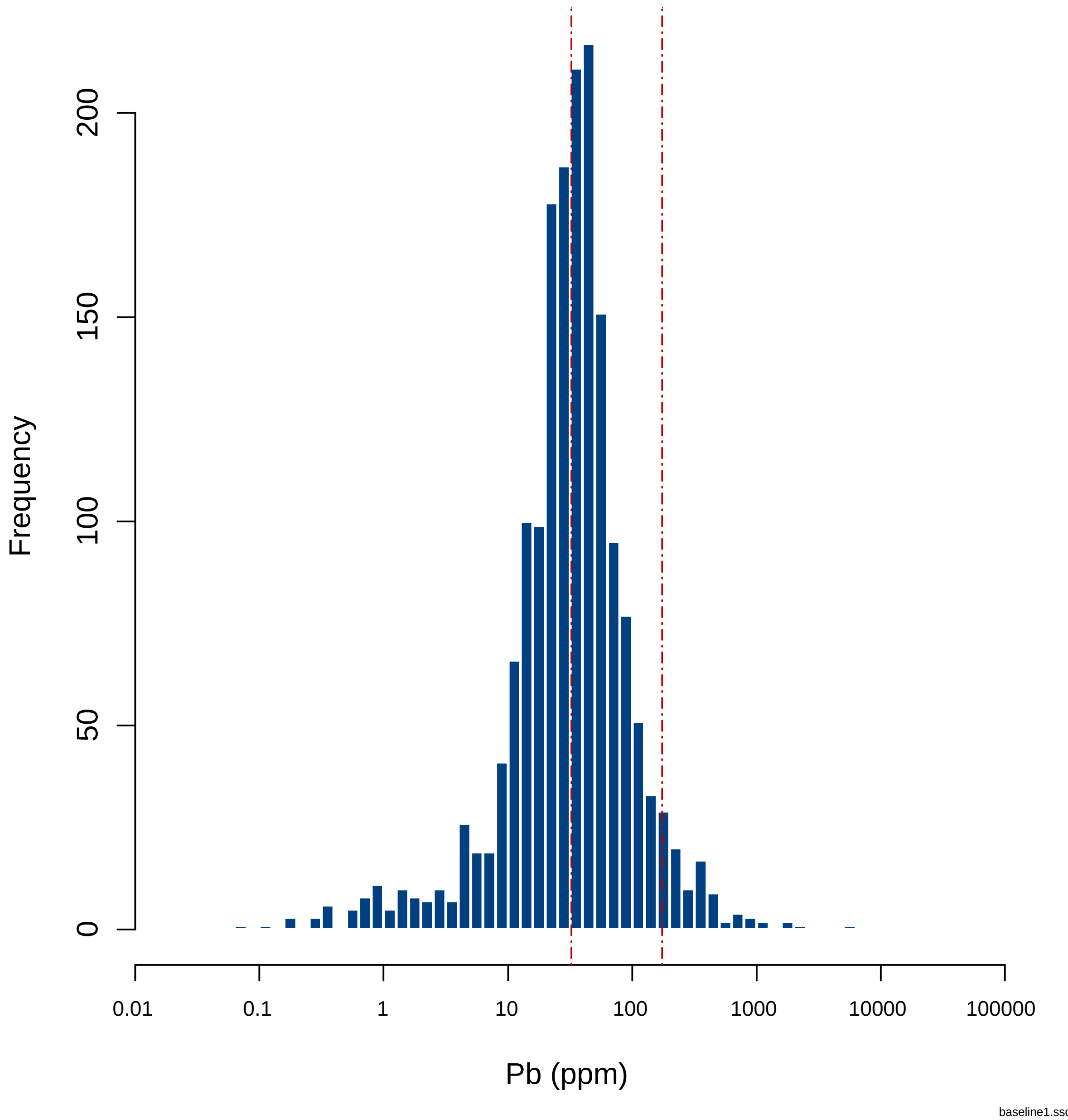

Figure 10-2. Histogram of lead concentrations in reference soils and sediments. Dashed lines identify the upper 95% confidence limit on the geometric mean and the 95th percentile concentrations.

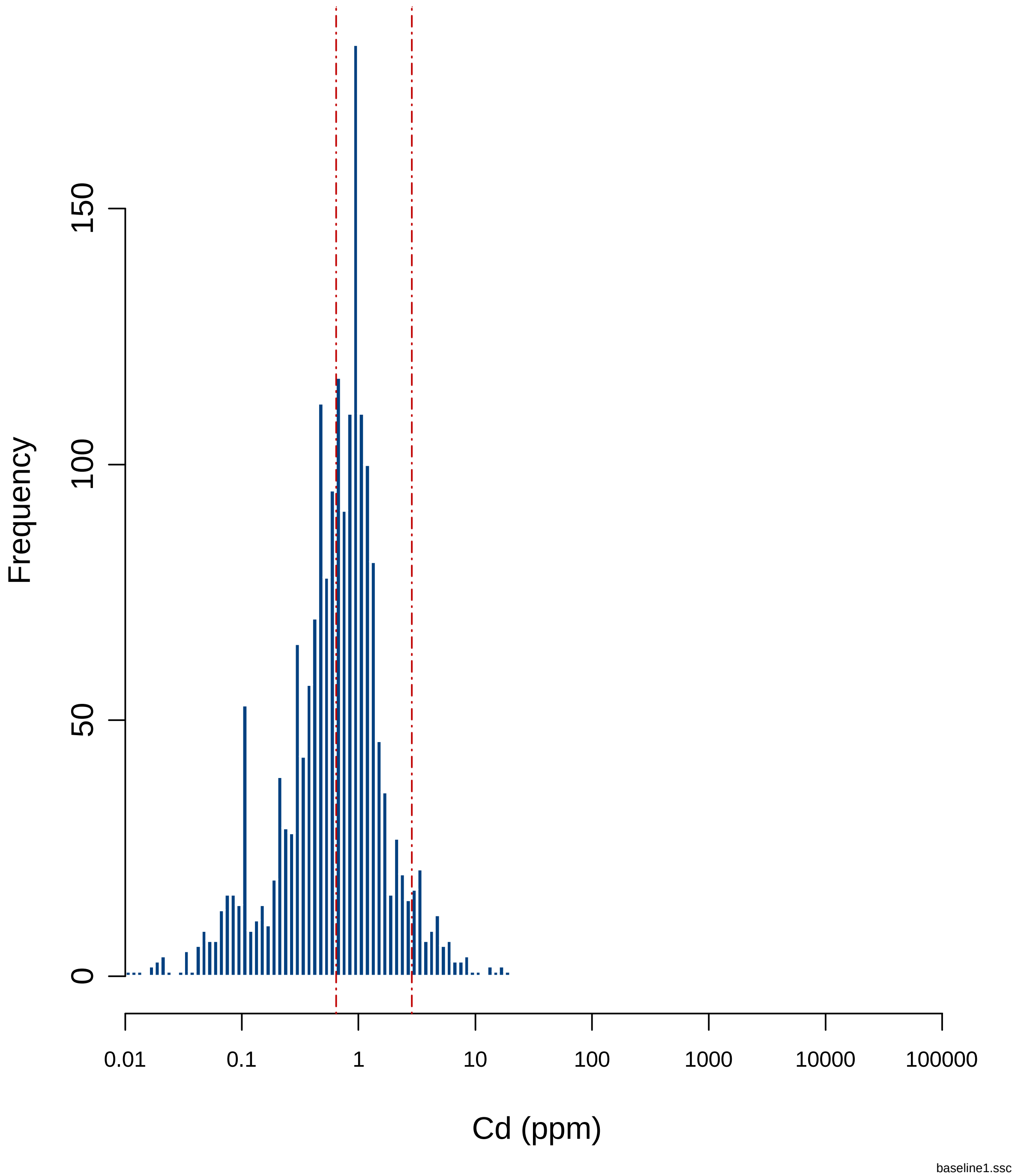

Figure 10-3. Histogram of cadmium concentrations in reference soils and sediments. Dashed lines identify the upper 95% confidence limit on the geometric mean and the 95th percentile concentrations.

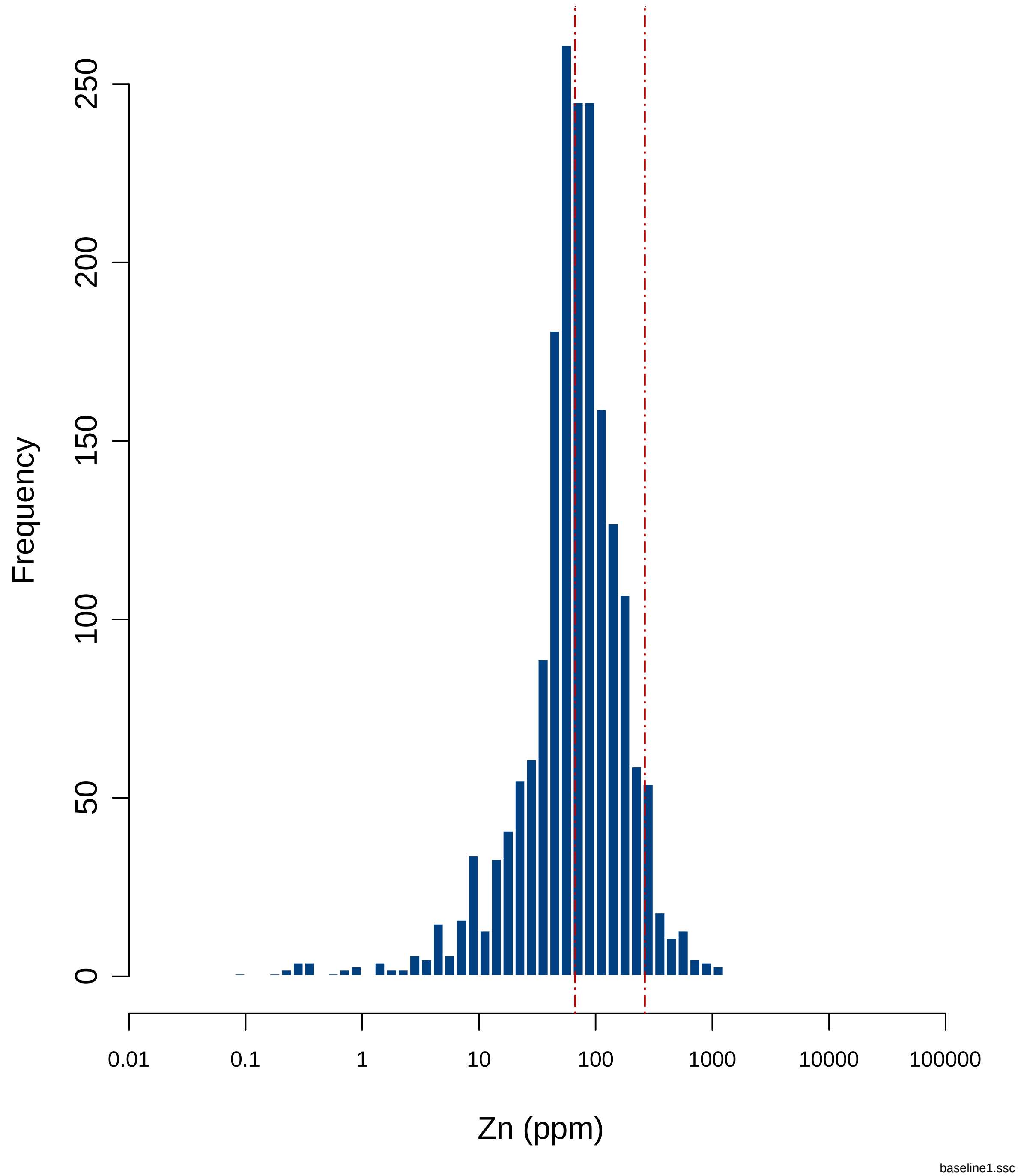

Figure 10-4. Histogram of zinc concentrations in reference soils and sediments. Dashed lines identify the upper 95% confidence limit on the geometric mean and the 95th percentile concentrations.

Gott and Cathrall (1980) reported threshold concentrations in soils and rocks that they considered "anomalously" high. For lead, the anomalously high concentration reported was 60 mg/kg, for cadmium, 2 mg/kg, and for zinc, 250 mg/kg. These concentrations are presented in Table 10-8 as an additional descriptor of the distribution of baseline concentrations in soils and sediments. In addition, Horowitz et al. (1993, 1995) determined concentrations of elements in uncontaminated subsurface sediments of Coeur d'Alene Lake using subsurface samples collected from 12 cores throughout the lake. Median concentrations of lead, cadmium, and zinc in the unenriched subsurface lake bed sediments are presented in Table 10-8 for comparison.

Uncertainty in the precision of these baseline estimates stems from the possibility that some of the reference samples were actually exposed to mining-related releases of the hazardous substances assessed. Uncertainties associated with the core samples stem from the lack of definitive dating information, the possible misinterpretation of the delineation between pre- and post-mining sediment horizons, and the possibility of cross contamination of layers resulting from core sampling or historical dredging.

The most likely effect of the uncertainties is a bias toward overestimation of baseline conditions throughout the basin. There is no realistic source of bias that could cause underestimation in the interpretation. Therefore, this determination of baseline concentrations is more likely than not higher than the true baseline conditions.

10.4 SURFACE WATER BASELINE

This section presents the determination of surface water baseline conditions. As noted previously, baseline is defined in the DOI NRDA regulations as the condition or conditions that would have existed at the assessment area had the release of the hazardous substance under investigation not occurred [43 CFR § 11.14 (e)]. Baseline data should reflect conditions expected at the assessment area had the release of hazardous substances not occurred, taking into account both natural processes and those that are the result of human activities [43 CFR § 11.72 (b)(1)]. When identifying baseline conditions for surface water resources in a mineralized area such as the Coeur d'Alene River basin, "natural processes" include the weathering of ore deposits that would have occurred if mining had never taken place. As such, a number of the streams or sections of streams identified as "control" or "reference" reaches should be in areas with geologic and mineralogic characteristics that are similar to those of the assessment area.

Although the geology of the Coeur d'Alene area is relatively uniform across the basin, there are ore deposits of varying mineralogic and elemental composition within the basin. In addition, there are few confirmed locations with similar mineralization that have not been mined and virtually no reliable historical water quality data, especially for metal concentrations. These conditions complicate the determination and characterization of baseline water quality and necessitate an approach that largely relies on upstream reference locations [43 CFR § 11.72 (g)(3)(i-ii)] in areas with geologic and mineralogic conditions that are similar to those in the downstream assessment areas [43 CFR § 11.72 (j)(3)(i)].

10.4.1 Historical Data

Mining began in the Coeur d'Alene River basin in the 1880s, although different mines and mills began production at different times, as described in Chapter 2. The first mines on the South Fork Coeur d'Alene River upstream of Canyon Creek began production in 1895 (Morning Mine), and the first mine along the reach from Canyon Creek to Elizabeth Park began in 1904 (Sunshine Mine). Mining along Canyon Creek began in 1888 at the Tiger-Poorman Mine (Quivik, 2000), mining along Ninemile Creek began at the Monarch Mine in 1904, and mining along Pine Creek began in 1900 at the Nevada Stewart Mine. Although it is difficult to determine exactly when releases to surface water from mining began, it is certain that hazardous substances were released directly to streams from milling operations that sluiced tailings to creeks (see Section 2.3). The first mill in the basin began operation in 1886 and processed ore from the Bunker Hill Mine (Casner, 1991).

All of the mines were underground mines, so the underground workings related to each mine may have affected more than one drainage basin. Many of the underground workings are probably located below levels that would have directly affected area streams. However, blasting may have created fractures above underground workings, which may have increased the rate of weathering of subsurface materials.

The first water quality sampling of the basin was in 1911 by Kemmerer et al. (1923), who sampled Coeur d'Alene Lake for plankton, water depth, temperature, dissolved CO_2 and oxygen, and turbidity. Kemmerer described the inflow waters from the Coeur d'Alene River as being "muddy" and "so laden with silt that they may be traced far out into the clear water of the lake." Hoskins (1932) also collected samples from Coeur d'Alene Lake, reporting lake water to be at saturation for lead.

In 1932, the U.S. Bureau of Fisheries conducted water quality and fish toxicity sampling of the lake and other parts of the basin (Ellis, 1940). In the Coeur d'Alene River, dissolved oxygen, pH, and dissolved carbon dioxide were found to be "suitable" for fish, but upstream of Cataldo, the South Fork Coeur d'Alene River was heavily laden with mine wastes. Ellis stated that the mine waste had largely eliminated the aquatic vegetation and algae from the Coeur d'Alene River. Ellis (1940) measured a range in pH of mine waters from 6.7 to 7.5 but noted that specific conductance in the Coeur d'Alene River downstream of mine waste discharge increased by approximately 100% relative to upstream of the discharge.

Ellis (1940) also conducted a series of laboratory and in-situ toxicity tests on fish, frogs, turtles, and plankton using lead and zinc ore, waste incrustations (efflorescent crusts) from mine wastes, and other mining-related wastes. The results are described in Chapter 7. In summary, dissolved waste crusts were the most toxic and zinc ore the least, and Ellis found that mine wastes in the Coeur d'Alene River had destroyed the fish and the plants and animals on which the fish relied upon for food.

The first modern water quality samples in the Coeur d'Alene basin were collected in the mid-1960s, approximately 80 years after mining and milling began. The early water quality data were of variable quality. Detection limits often exceeded aquatic life criteria (ALC), digestion methods varied, and hardness, which is necessary to calculate ALC, was often not measured (Ridolfi, 1995).

Because there is such a gap between the beginning of mining and milling in the basin and the analysis of the first water quality samples, there are no historical water quality data representative of the condition of streams before mining. If historical data are not available or do not meet the guidelines in the DOI regulations, baseline must be defined by field data from the reference area [43 CFR § 11.72 (d)].

10.4.2 Reference Area Selection

Reference areas should be selected based on their similarity to the assessment area and lack of exposure to the release [CFR 43 §11.72(d)(1)]. For surface water resources, DOI regulations indicate that reference areas should consist of a "stream or river reach of similar size, that is as near to the assessment area as practical and, if practical, that is upstream or upcurrent from the injured resource, such that the channel characteristics, sediment characteristics, and streamflow characteristics are similar to the injured resource, and the water and sediments of the reference area, because of location, have not been exposed to the release" [43 CFR § 11.72(g)(3)(i)]. The samples from reference streams should be collected using methods similar to those used for injured site collections [43 CFR § 1172 (d)(5)], and the data collected at both reference and assessment area streams should be sufficient to estimate the normal variability in measurements made [43 CFR § 11.72(d)(4)].

As noted above, baseline should take into account both natural processes and those that are the result of human activities. In mineralized areas, ore deposits at or near the surface can be weathered or oxidized naturally by exposure to air and water. The more extensive and deeper the fracture systems in the ore body, the deeper oxidation will occur. The reactions that produce acid mine drainage from mining activity are identical to those that produce acid "rock" drainage from the natural oxidation of sulfide ore bodies. Higher concentrations of metals in streams and groundwater usually result from mining activity, mostly as a result of the increase in surface area from blasting, milling, and removal of waste rock from the ore body. These mining processes increase the amount of sulfide and metal-rich material exposed to oxygen and water relative to an unmined ore body.

The extent to which the reference streams and reaches are similar to assessment reaches was examined in terms of hydrologic, geologic, and mineralogic considerations. The hydrologic considerations included a comparison of discharge, or flow, at assessment and reference locations, and an examination of the variability in concentrations under different hydrologic conditions. The geologic and mineralogic considerations included an examination of the geology, ore deposits, and soil and rock metal concentrations in the reference and assessment drainages.

Similarity of Timing of High and Low Flow

Water quality samples have been collected in both injured and reference stream reaches during both low flow and high flow conditions. High flow generally occurs in May and low flow in October. The precise timing of the peak flow varies with location, depending on aspect, elevation, and other factors, but, the general timing of peak and low flows at locations in the upper basin are similar year to year.

Flow ranges measured in both injured and reference reaches are summarized in Table 10-9 for Ninemile Creek, Canyon Creek, South Fork Coeur d'Alene River and tributaries, including Government Gulch, Milo Creek, and Pine Creek. In general, flows in upstream reference reaches are lower than, but exhibit the same seasonal patterns as, flows in downstream injured reaches.

Variability in Concentrations under Different Hydrologic Conditions

Samples and measurements at both reference and assessment locations should be collected under similar hydrologic conditions, and discharge should be measured at the same time that water and sediment samples are collected [43 CFR §11.72(g)(4)(ii)]. In this way, seasonal and hydrologic effects on the concentrations of hazardous substances and other constituents can be compared in reference and injured streams and reaches.

Baseline data for surface water resources should be sufficient to determine the:

- range of concentrations of hazardous substances in water and sediment
- variability of concentrations of hazardous substances, suspended sediment, and physical properties of water and sediments during different conditions of water discharge/stage
- variability of physical and chemical conditions during different conditions of stage/discharge relating to transport or storage of substances in water and sediments [43 CFR § 11.72 (g)(4)(iii)].

Relationships between hardness and flow, zinc concentrations and flow, and total suspended sediment (TSS) concentrations and flow in assessment and reference reaches were examined to assess the comparability of the assessment and reference reaches under different hydrologic conditions.

At both assessment (injured) and reference locations, hardness and zinc concentrations are highest and most variable during fall and winter low flow, and lowest during peak flow in the spring. Figures 10-5a and b show patterns of hardness and zinc concentrations during high and low flow periods at an injured site on Canyon Creek, and Figures 10-6a and b show the similarity in hardness concentration with flow at both an injured and a reference site in Canyon Creek. These figures show patterns of hardness and zinc concentrations under different hydrologic conditions that are typical for both reference and assessment reaches.

Table 10-9
Range of Flows at Selected Injured and Reference Locations in the South Fork Coeur d'Alene River Basin

Location	Site ID	Flow (cfs)
Injured Reaches		
Ninemile Creek	NM 305 (mouth)	1-87
	NM 298 (mouth East Fork)	1.2-56
Canyon Creek	CC 287 (near mouth)	11-300
South Fork Coeur d'Alene	SF 205 (most upstream)	1.4-146
	SF 233 (downstream Ninemile)	86-720
	SF 270 (Smelterville)	55-1,230
Milo Creek	SF 183 (mouth)	4.9-25
Government Gulch	SF 110 (near mouth)	4.3-24
Moon Creek	SF 262 (mouth)	0.93-112
Pine Creek	PC 305 (mouth)	4.6-2,030
	PC 312 (near mouth East Fork)	15-71
Reference Reaches		
Ninemile Creek	NM 300 (East Fork-mainstem confluence)	0.91-2.3
	NM 289 (most upstream)	0.2-18
Canyon Creek	CC 2 (upstream of O'Neill Gulch)	1.6-420
Milo Creek	SF 185 (Slaughterhouse Gulch)	8.1
Government Gulch	SF 108 (most upstream)	1.9-23
Pine Creek	PC 311 (East Fork-mainstem confluence)	20-136
	PC 309 (mouth Trapper Creek)	2.7-13.8
	PC 325 (headwaters Denver Creek)	0.14
	PC 306 (headwaters East Fork)	0.80-6

Data source: Flow measurements contained in the database compiled for assessment of injury to surface waters. For original sources, see Chapter 4.

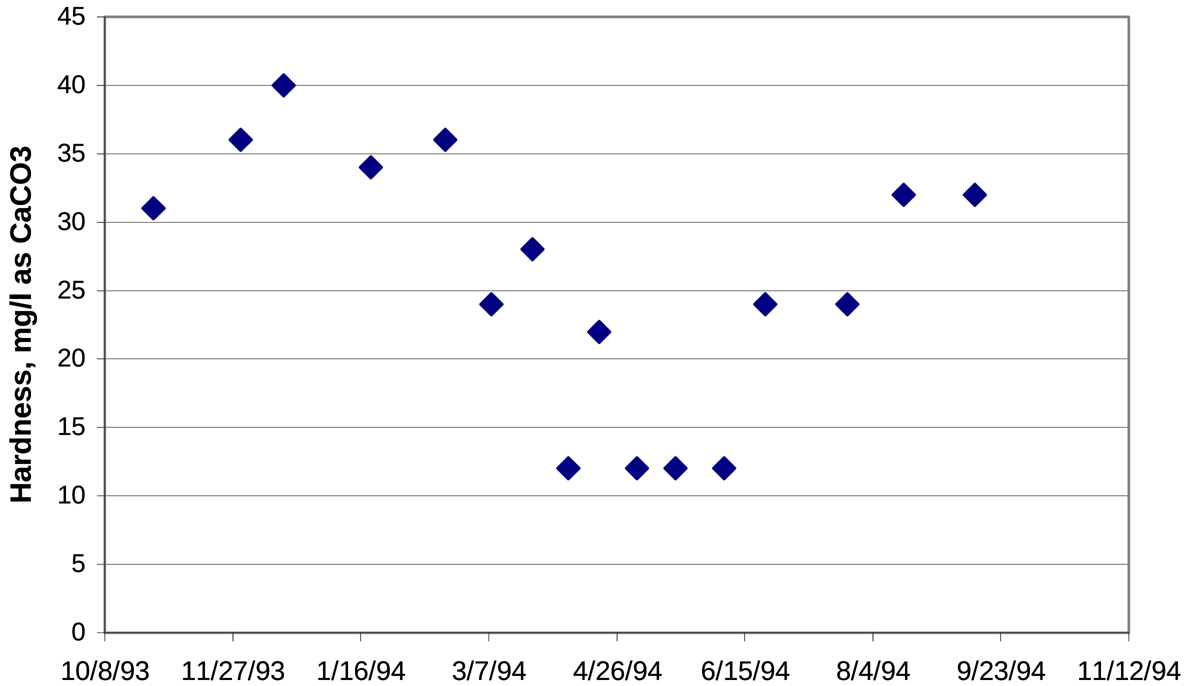

Figure 10-5a. Hardness values measured in Canyon Creek downstream of O'Neill Gulch (site CC 276).

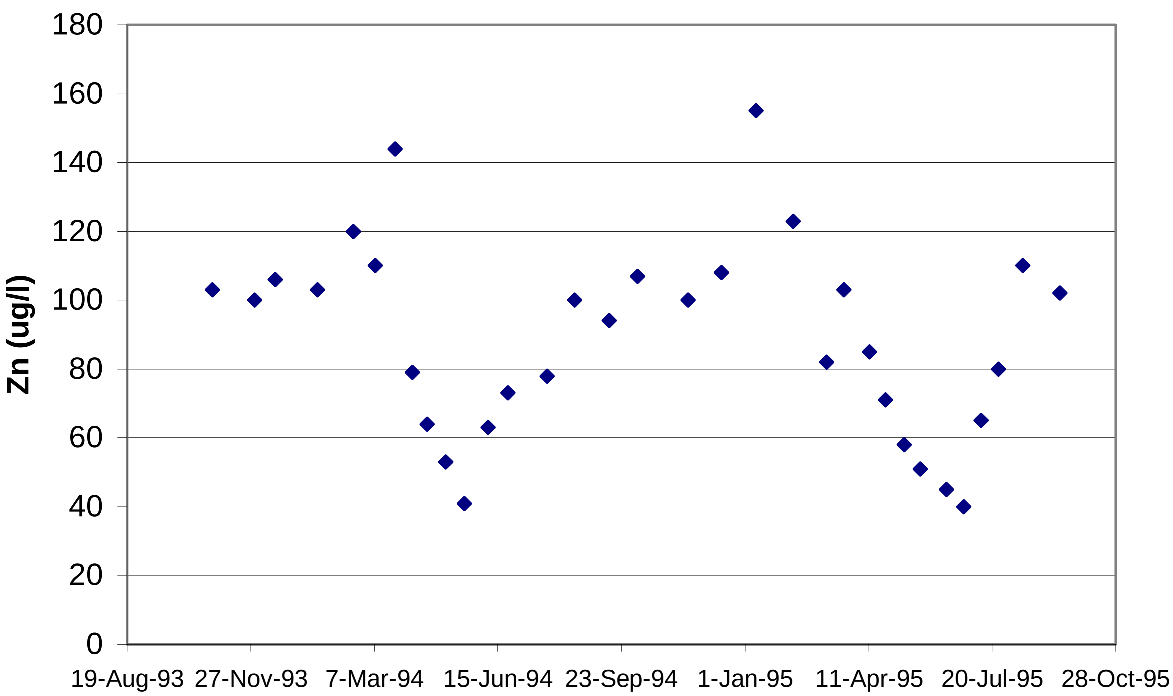

Figure 10-5b. Zinc concentrations in Canyon Creek downstream of O'Neill Gulch, assessment site CC 276.

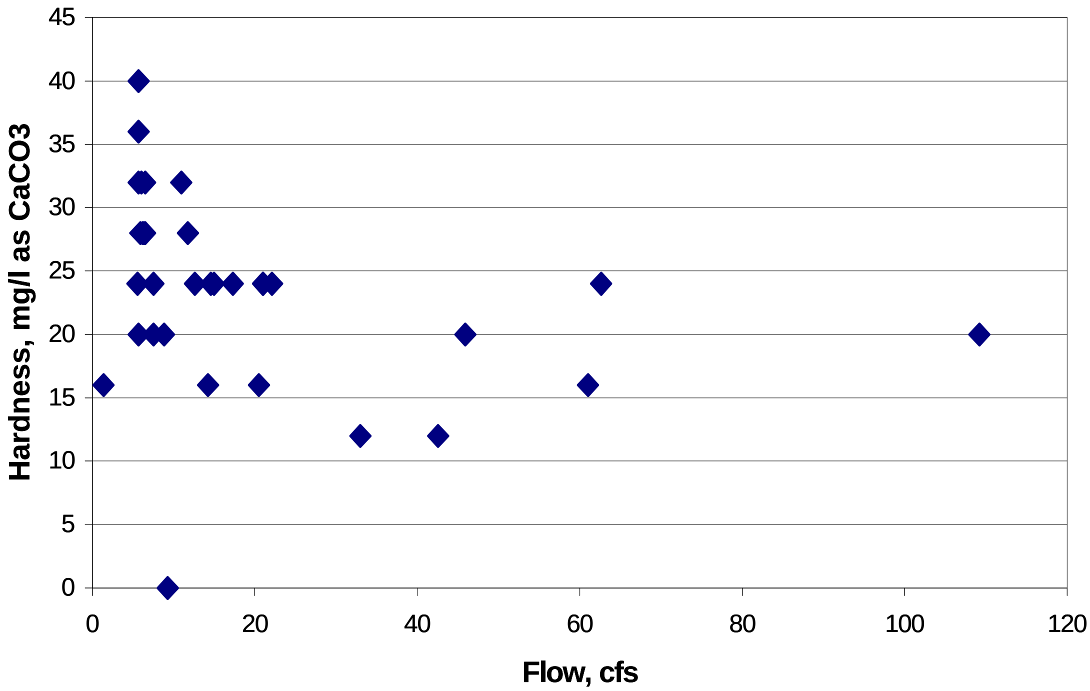

Figure 10-6a. Relationship between flow and hardness in upper South Fork Coeur d'Alene River, assessment site SF 205.

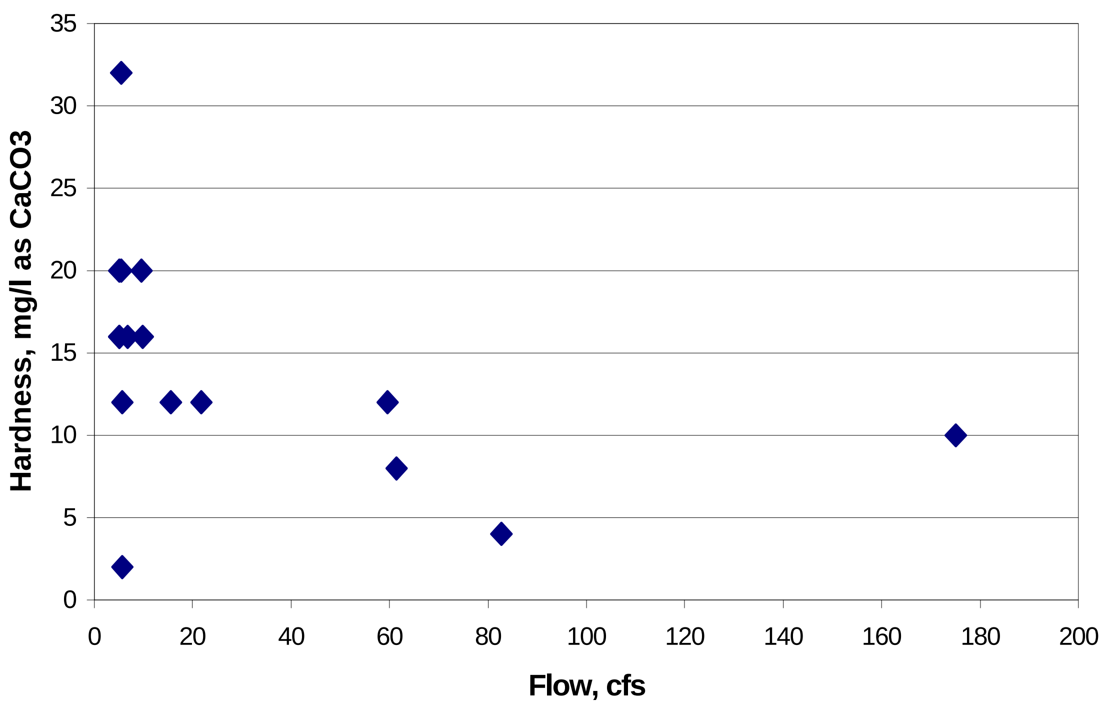

Figure 10-6b. Relationship between flow and hardness in upper Canyon Creek, reference site CC 2.

TSS increases with flow in both assessment and reference reaches, with highest concentrations in the spring at both reference and injured locations. The increase in TSS concentrations at injured locations during high flow is often much greater than the increase at reference locations. For example, at Canyon Creek reference location CC-2 and assessment location CC-276, flows differ by only 1 to 2%, but TSS concentrations at the assessment location are more than twice those at the reference location during high flow. TSS concentrations at the two sites are similar during low flow. The disproportionately higher concentrations of TSS at injured locations are most likely the result of suspension during higher flows of tailings deposits in the beds, banks, and floodplains.

Trends in physical and chemical characteristics of waters from reference and injured stream locations with time and discharge are similar. However, concentrations of metals and TSS are higher at assessment locations than reference locations under similar hydrologic conditions. Samples of hazardous substances and other constituents and measurements of discharge were taken at similar times at both reference and assessment locations. Therefore, the reference locations are similar to the assessment locations for surface water resources in terms of hydrologic considerations.

Geologic, Mineralogic, and Environmental Considerations

Most of the rocks in the Coeur d'Alene Mining District are slightly metamorphosed sedimentary rocks of late pre-Cambrian age belonging to the Belt Supergroup. These rocks are predominantly argillite[4] and quartzite, with lesser amounts of disseminated dolomite and limestone in the upper part of the section. The Belt Supergroup rocks cover a large area, including north and central Idaho, western Montana, southeastern British Columbia, and Alberta. Belt rocks in the Coeur d'Alene area are the host rock for the ore deposits. Igneous monzonite intrusions (a granite-like rock) of Cretaceous age cut through the Belt rocks north of the South Forth Coeur d'Alene River in the Ninemile/Canyon Creek area (Gem Stocks) and the area to the west of Ninemile Creek (Dago Stocks) (Hobbs et al., 1965; Gott and Cathrall, 1980). The geologic map for the district, based on Derkey et al. (1996), is shown in Figures 10-7a and b.

The Belt rocks in the Coeur d'Alene Mining District are cut by a complex series of faults, the largest of which is the 100-mile-long Osburn Fault. This fault follows the valleys of the South Fork Coeur d'Alene River in Idaho and the St. Regis River and parts of the Clark Fork River in Montana (Hobbs et al., 1965). The Osburn Fault is a strike-slip fault with approximately 16 miles of lateral (roughly east-west) displacement. It is widely believed that the ore bodies were originally formed in this "structural knot" and then separated and moved along the Osburn Fault. Therefore, deposits south of the fault just east of Big Creek (Silver Summit, Silver Dollar) were originally located due south of ore deposits on Ninemile Creek (Silver Star, Dayrock). The two main areas of mineralization — Kellogg south of the fault and Mullan-Burke area north of the fault — are separated by approximately 16 miles.

4. Sedimentary rock composed of silt and/or clay with some cleavage approximately parallel to bedding.

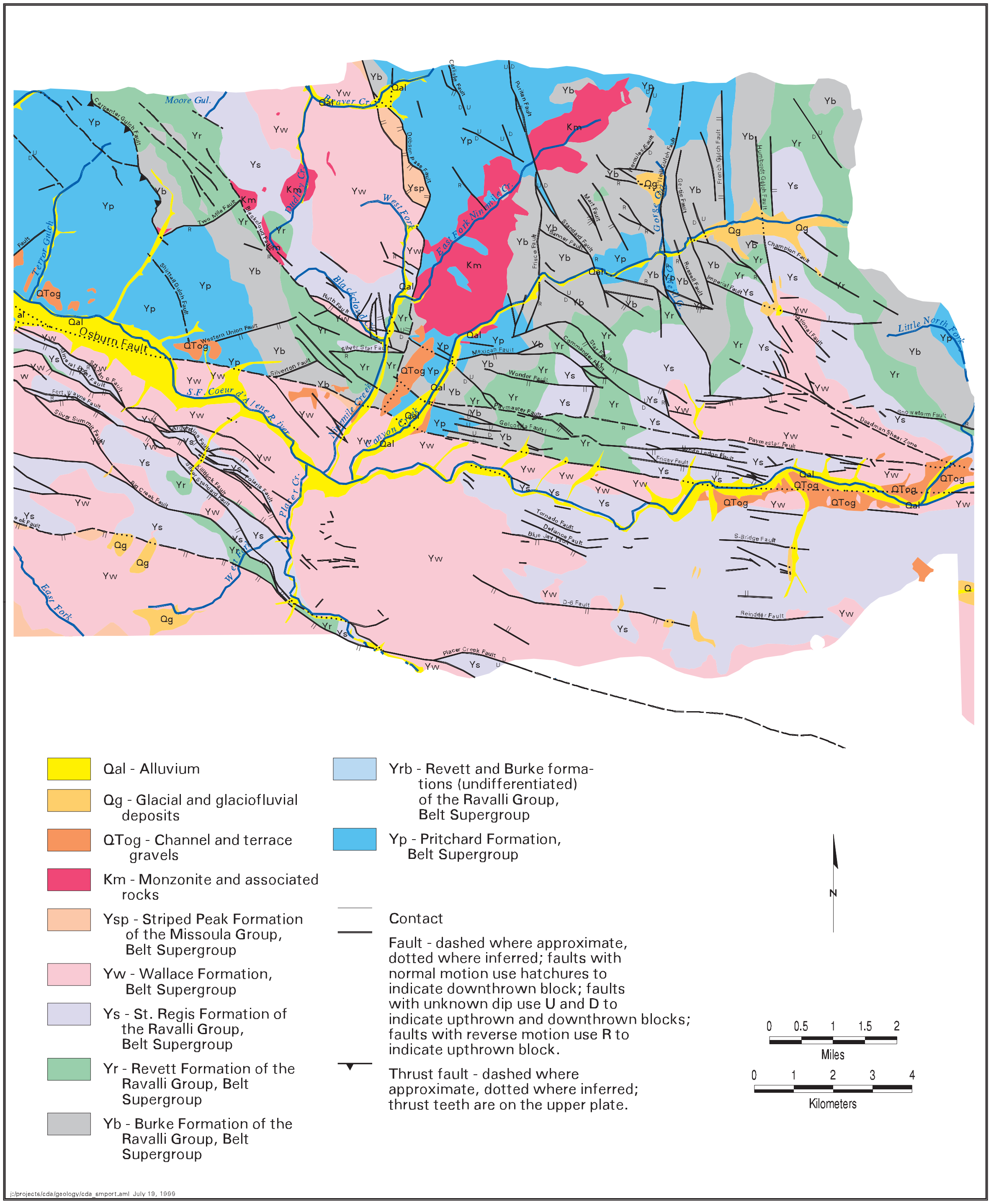

Figure 10-7a. Geologic map of Coeur d'Alene area — eastern section.

Source: Derkey et al., 1996.

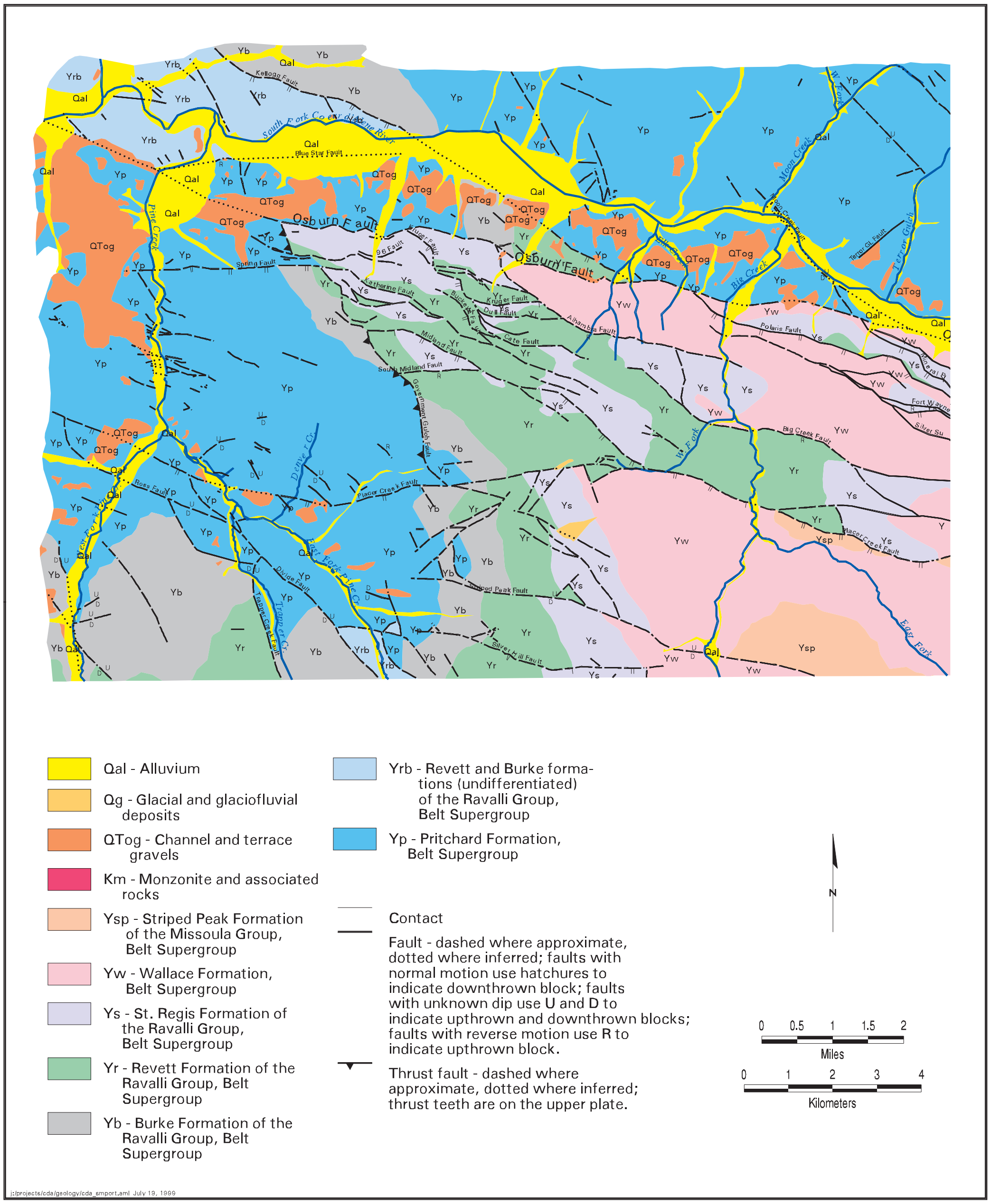

Figure 10-7b. Geologic map of the Coeur d'Alene area — western section.
Source: Derkey et al., 1996.

There are five main geologic formations in the Belt Supergroup of the Coeur d'Alene area (from oldest to youngest): the Prichard Formation, the Burke Formation, the Revett Quartzite, the St. Regis Formation, and the Wallace Formation (Figures 10-7a and b). In the Coeur d'Alene Mining District, the Burke, Revett, and St. Regis formations are often combined into the Ravalli Group (Hobbs et al., 1965). The Prichard Formation is composed of fine-grained argillite with abundant pyrite or pyrrhotite. The Ravalli Group is composed predominantly of siltite and quartzite with argillite at the top. The Wallace Formation includes quartzite, argillite, and lesser amounts of dolomite and limestone. The carbonate-bearing argillite and quartzite set off the Wallace Formation from the others in the Supergroup. Some carbonate is also contained in the underlying and overlying rock units.

Weathering of the three groups of rocks described above (Prichard Formation, Ravalli Group, Wallace Formation) may result in different characteristic chemistries of streams draining these deposits. Streams draining the Prichard Formation may be somewhat iron-rich and acidic. Streams cutting through the Ravalli Group would be of low hardness but not acidic. Streams draining the Wallace Formation would have higher hardnesses and may have higher pH and alkalinity values.

Ore deposits in the Coeur d'Alene Mining District are predominantly in high grade veins consisting of variable amounts of sphalerite (zinc sulfide, ZnS), galena (lead sulfide, PbS), and argentiferous tetrahedrite (an arsenic-antimony sulfide with varying proportions of copper, iron, zinc and/or silver) $[(Cu,Fe,Zn,Ag)_{12}(Sb,As)_4S_{13}]$ (White, 1998). The non-ore minerals in the veins consist mostly of quartz (SiO_2) or siderite (ferrous iron carbonate, $FeCO_3$). The ore bodies can be grouped into northwest-trending areas called mineral belts (Figures 10-8a and b). Veins contain the ore shoot (economic part of the deposit) and gangue (non-economic part of the deposit).

There are three general types of vein deposits in the district: one in the middle Prichard quartzites (zinc-lead orebodies on Pine Creek), another in the Prichard-Burke transition zone (Ninemile Creek and Canyon Creek lead-zinc deposits), and the third in the Revett-St. Regis transition zone (Bunker Hill Mine, Star-Morning Mine, Lucky Friday Mine, and the mines in the Silver Belt) (Bennett and Venkatakrishan, 1982). The discussion of baseline water quality that follows is grouped into these three general categories and areas. Most of the ore production (75%) has come from the Revett Formation; 19% has come from quartzite at the Burke-Prichard boundary; and all current production is from the Revett-St. Regis boundary (White, 1998).

The mineralized veins typically are steeply dipping and very narrow at the surface outcrop or do not outcrop at the surface at all; however, dispersion patterns are still evident in soils and weathered rocks (Gott and Cathrall, 1980). Gott and Cathrall (1980) established "threshold" values or "anomalous" concentrations. Concentrations in rock and soil higher than the threshold values are associated with ore deposits. Many of the mineral belts are delineated by concentrations higher than threshold values.

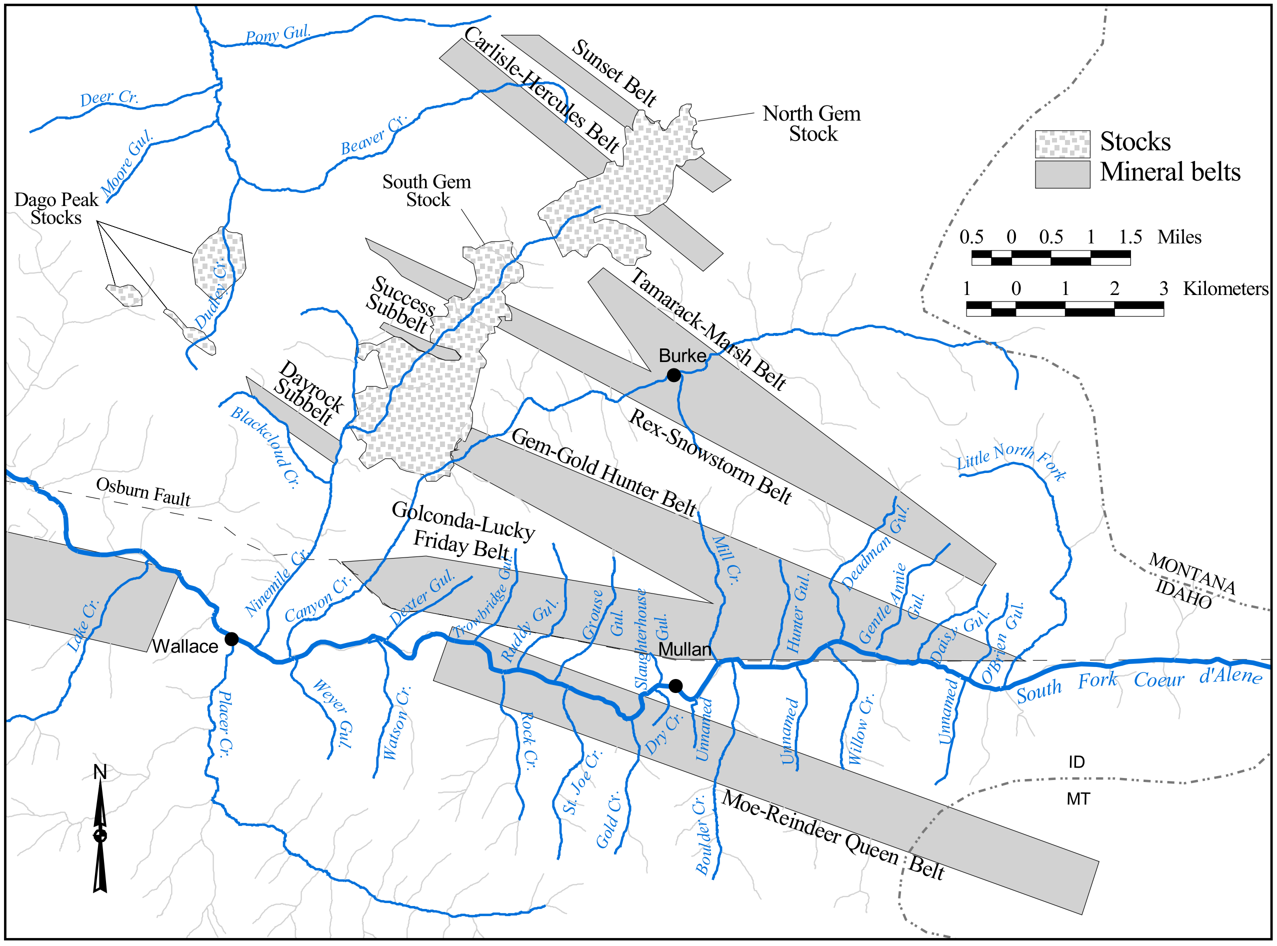

Figure 10-8a. Mineral belts of the Coeur d'Alene River basin — east.

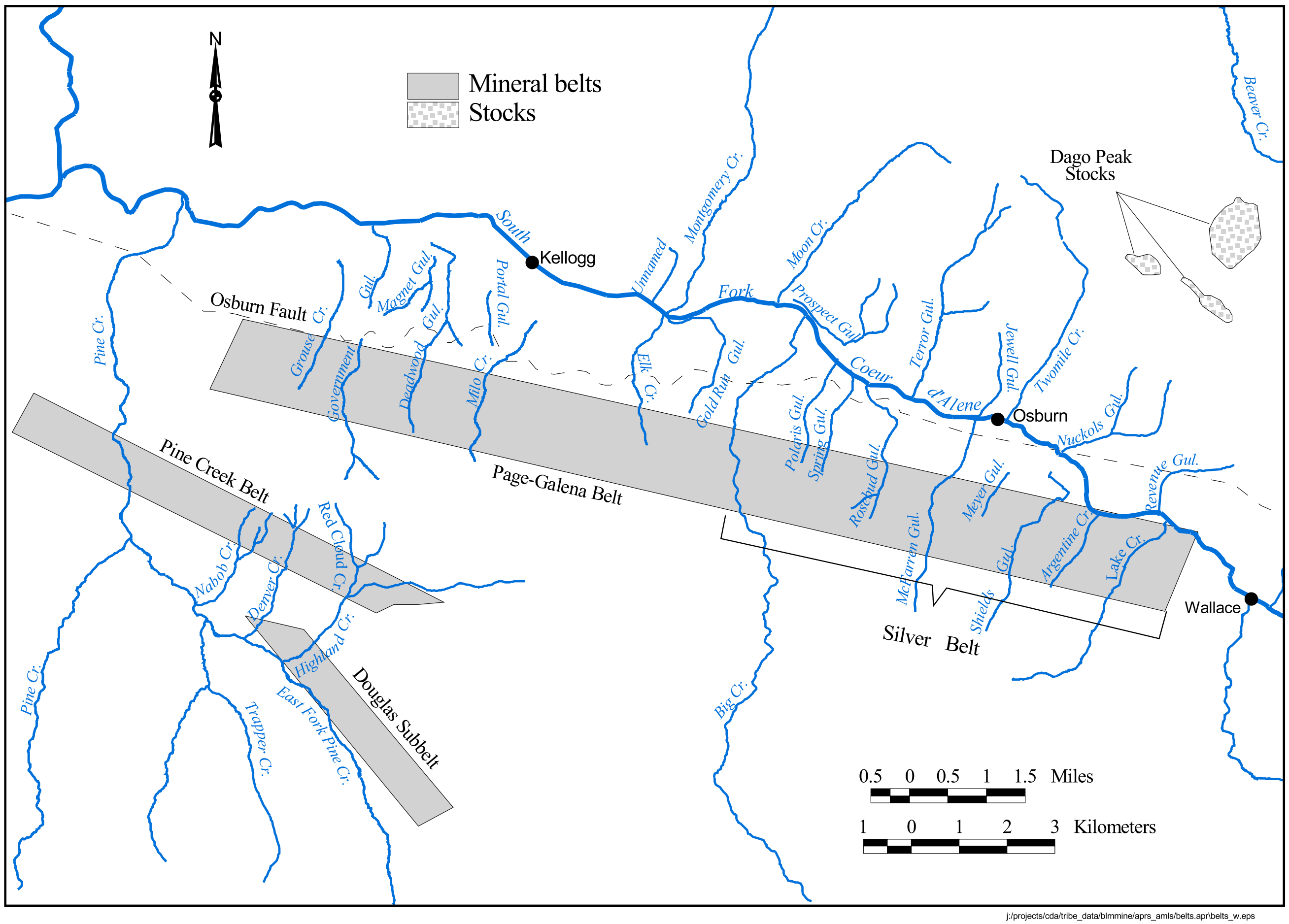

Figure 10-8b. Mineral belts of the Coeur d'Alene River basin — west.

In general, deposits in the northern and western part of the district are relatively shallow and deposits east of the Bunker Hill Mine in the Page-Galena mineral belt are approximately 1,000 ft. deep (Gott and Cathrall, 1980). Dispersion patterns of lead best characterize mineral belts with shallow deposits, including the Gem-Gold Hunter and the Rex-Snowstorm belts in the upper South Fork area. Even where veins do outcrop, they are generally deeply weathered (Keith Long, USGS, pers. comm., 1998), and their outcrops represent only a small fraction of their extent at depth. Hobbs and Fryklund (1968) show cross-sections of some ore shoots along the Gem-Gold Hunter mineral belt, including the Lucky Friday Mine, and along the Page-Galena mineral belt (Figure 10-9). Some veins apex 1,000 ft or more below the surface and give no hint at the surface of their existence (Hobbs and Fryklund, 1968).

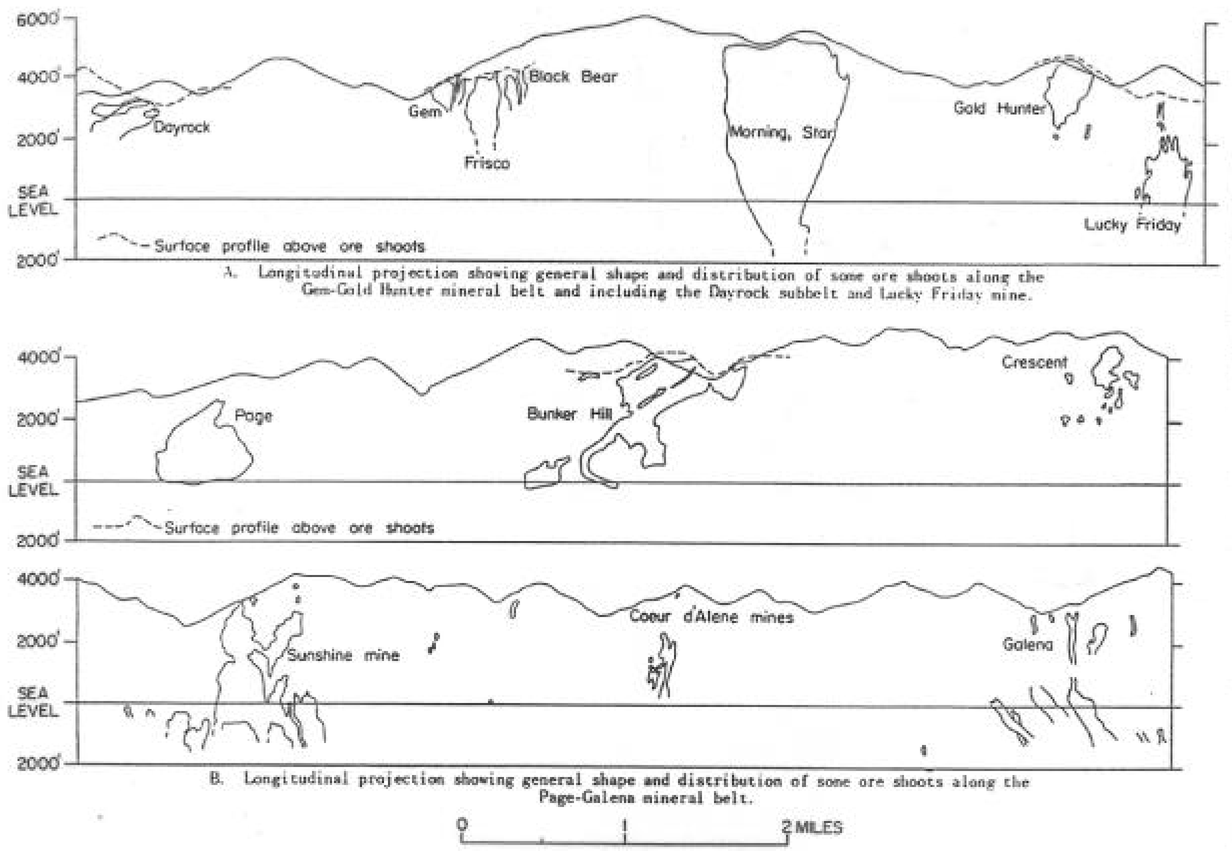

Figure 10-9. Longitudinal projections of some ore shoots in the Coeur d'Alene Mining District.
Source: Hobbs and Fryklund, 1968.

There appears to be carbonate zoning around many of the veins in the district, especially disseminated siderite (ferrous iron carbonate) (White, 1998). The carbonate is most likely derived from the original Belt sediments. The weathering of these disseminated carbonates should produce stream water that contains alkalinity and iron, with lesser amounts of calcium and magnesium. The presence of abundant carbonate material surrounding the veins may limit the concentrations of naturally weathered metals in water by raising the pH and precipitating the metals as hydroxides or carbonates and/or by adsorption, which would be promoted under higher pH conditions. The alkalinity produced from weathering of carbonates surrounding veins is also important in buffering the pH of mine drainage water in the Coeur d'Alene basin.

In addition to carbonate zoning around veins, disseminated galena, sphalerite, pyrite, and arsenopyrite are also found around many of the ore bodies in the district (White, 1998). Distributions are similar to the carbonate zoning patterns (White, 1998). The weathering of the disseminated sulfides around the veins could produce waters that contain elevated concentrations of metals, at least in areas where there is not sufficient dilution from nonmineralized rock.

Pyrite, which is the mineral most commonly responsible for the formation of acid drainage, is a ubiquitous vein mineral but is volumetrically unimportant except for some of the veins in the Pine Creek area, and possibly around the Dago Peak and North Gem stocks. In several veins, including the large Star-Morning vein (2,600 m deep), pyrite is more abundant with depth. This is also true in the Silver Belt mines, in which pyrite and chalcopyrite increase with depth (White, 1998). The removal of ore from depth, milling, and the deposition of tailings directly in the creeks in the basin probably caused past and ongoing violations of water quality criteria in the Coeur d'Alene area.

10.4.3 Identification of Reference Streams and Reaches

Baseline water quality was determined for three areas that generally correspond with the three general types of vein deposits characterized by Bennett and Venkatakrishan (1982):

- Upper South Fork. Streams in the upper portion of the South Fork Coeur d'Alene River basin from the Little North Fork of the South Fork to Placer Creek. These streams drain mineral belts in Ninemile and Canyon creeks and other upper South Fork tributaries (Figure 10-8a).

- Page-Galena Mineral Belt area. Streams along the lower portion of the South Fork draining the Page-Galena and Silver mineral belts and northern tributaries of the South Fork across from these mineral belts (Figure 10-8b).

- Pine Creek drainage. Streams in the Pine Creek basin draining the Pine Creek mineral belts (Figure 10-8b).

Each drainage was evaluated in terms of its geology, mineralization, and environmental considerations, including water quality data and mine waste deposits.[5] The geology and mineralization were determined by examining geologic and mine maps of the district that are presented as plates in Hobbs et al. (1965). These plates contain detailed information on the geology, veins, mine identity and locations, and underground workings for the entire Coeur d'Alene Mining district. The veins in the plates are distinguished as being either surface or subsurface, and as "known to contain base metals (A)," "not known to contain base metals (B)," or, in some cases, the veins are not marked with an A or B. Other sources relied on include geologic maps by Derkey et al. (1996; Figures 10-7a and b), the maps delineating mineral belts (Figures 10-8a and b), and locations of mine waste deposits (Figures 10-10a and b).

Drainages with large producing mines and/or with mill sites were excluded from consideration as reference streams, even if water quality did not violate relevant aquatic life criteria. Figures 2-3 to 2-5 in Chapter 2 were used to determine if a major mine or a mill existed in a drainage. Drainages without large producing mines and/or mill sites were considered to be reference streams even if water quality did violate relevant standards. Drainages were considered to be mineralized if they drain known mineral belts (Figures 10-8a and b), if they have veins known to contain base metals (Hobbs et al., 1965), or if rock or soil samples collected by Gott and Cathrall (1980) in the drainage exceed threshold values. If none of these conditions were met, the drainages were considered to be unmineralized. The water samples were evaluated for exceedence of dissolved cadmium, lead, and zinc chronic criterion values.

Table 10-10 and Figures 10-11a and b identify mineralized and unmineralized streams in the upper South Fork Coeur d'Alene River basin, the Page-Galena and Silver belts, and the Pine Creek drainage. Rocks and soils in the vicinity of Dudley Creek and Moore Gulch contain elevated concentrations of lead and other metals and may represent an unmined ore body. Because this area is similar geologically and mineralogically to Ninemile and Canyon creeks, Dudley Creek and Moore Gulch samples were included in the Upper South Fork area for baseline surface water determination.

5. Supporting geology, mineralization, and environmental information is included in Appendix A to this chapter.

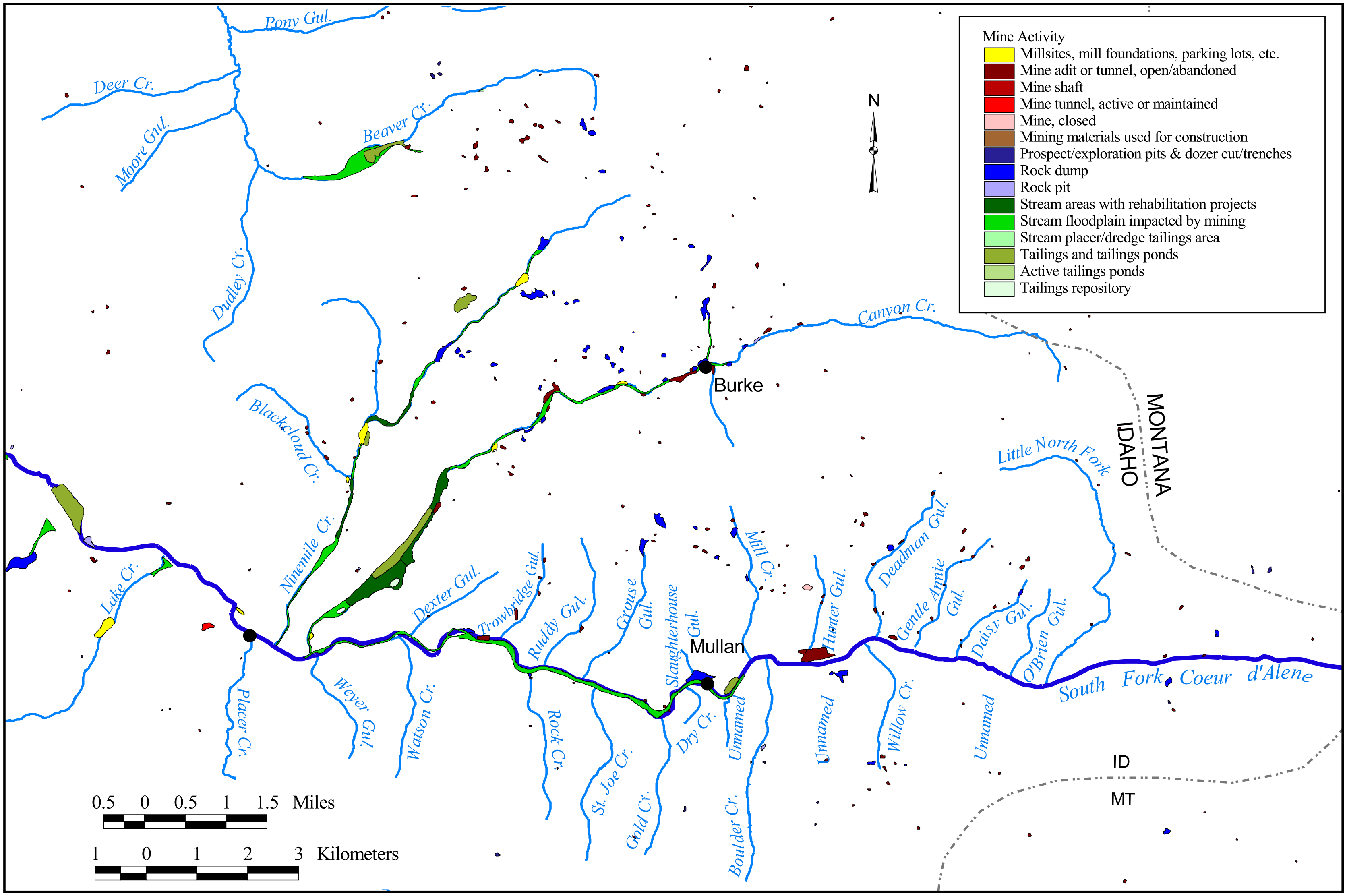

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Figure 10-10a. Location of mine deposits/activity — eastern section.
Source: U.S. BLM, 1999.

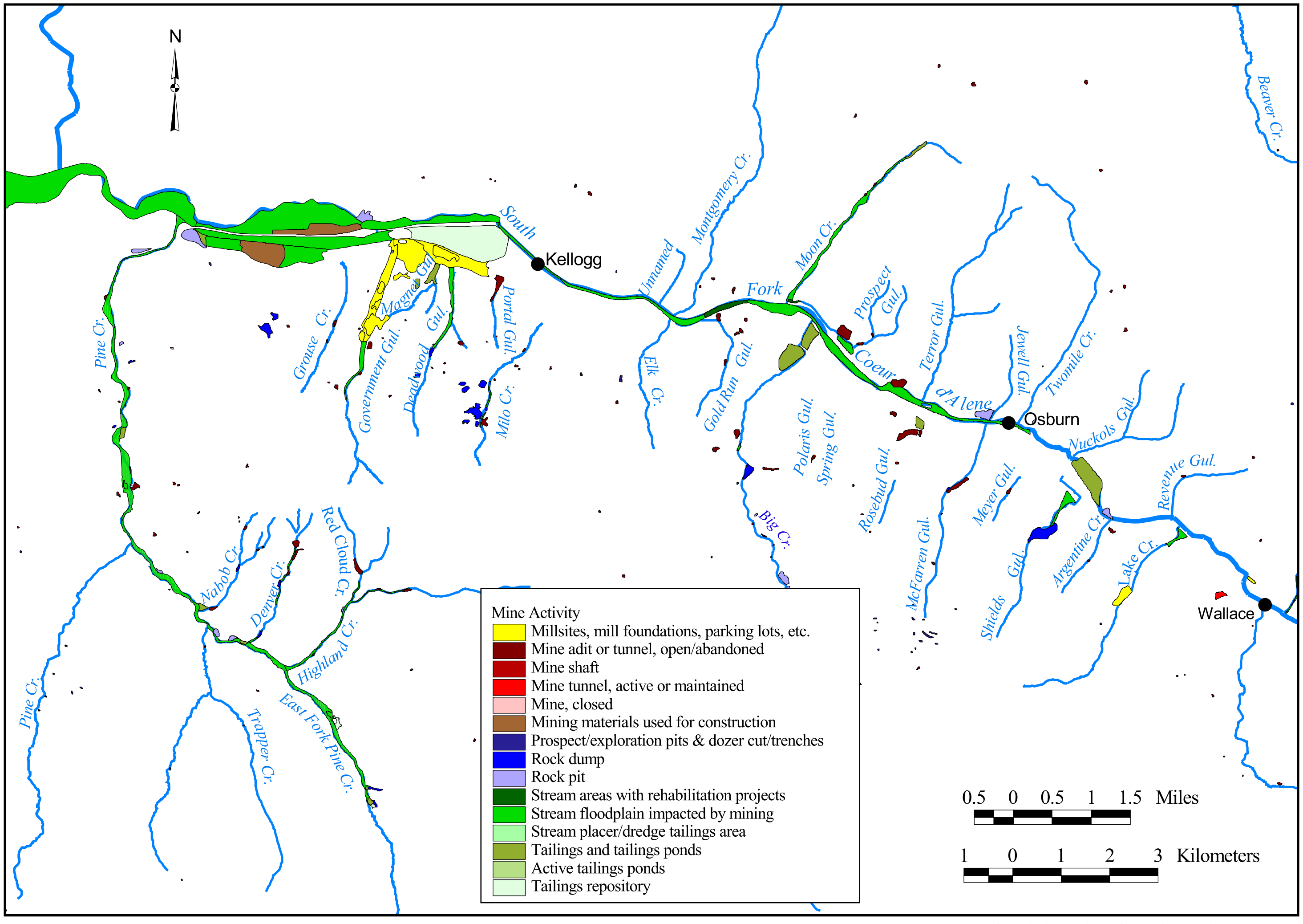

Figure 10-10b. Location of mine deposits/activity — western section.
Source: U.S. BLM, 1999.

Table 10-10
Identification of Reference Streams and Sample Locations Used in Determination of Surface Water Baseline

Location	Site Number
I. Upper South Fork Coeur d'Alene River and Tributaries	
Mineralized	
Little North Fork of the South Fork	SF 202
Gentle Annie Gulch	SF 207
Willow Creek	SF 210
Unnamed creek	SF 211
Unnamed creek	SF 213
Boulder Creek	SF 214
Dry Creek	SF 219
Gold Creek	SF 221
St. Joe Creek	SF 222
Rock Creek	SF 225
Trowbridge Gulch	SF 226
Dexter Gulch	SF 229
Ninemile Creek	NM 289 East Fork headwaters
Ninemile Creek	NM 299 — East Fork — mainstem confluence
Ninemile Creek	NM 300 — East Fork — mainstem confluence
Canyon Creek	CC289 — upstream of O'Neill Gulch
Canyon Creek	CC 272 — upstream of O'Neill Gulch
Canyon Creek	CC 1 — upstream of O'Neill Gulch
Canyon Creek	CC 273 — upstream of O'Neill Gulch
Canyon Creek	CC 274 — upstream of O'Neill Gulch
Canyon Creek	CC 2 — upstream of O'Neill Gulch
Canyon Creek	CC 290 — upstream of O'Neil Gulch
Unnamed Creek	SF 204
Watson Gulch	SF 230
Weyer Gulch	SF 231
Dudley Creek	NF 51
Moore Gulch	NF 52

Table 10-10 (cont.)
Identification of Reference Streams and Sample Locations Used in Determination of Surface Water Baseline

Location	Site Number
II. Page-Galena and Silver Belts	
Mineralized	
Milo Creek	SF 185 — Slaughterhouse Gulch
Government Gulch	SF 108 — Upper Government Gulch
Argentine Gulch	SF 242
Nuckols Gulch	SF 245
Meyer Gulch	SF 246
Twomile Creek	SF 248
Jewel Creek	SF 251
Terror Gulch	SF 252
Spring Gulch	SF 256
Gold Run Gulch	SF 265
Montgomery Gulch	SF 266
Elk Creek	SF 267
Unnamed	SF 269
Unmineralized	
Revenue Gulch	SF 20, 240
III. Pine Creek Drainage	
Mineralized	
Pine Creek	PC 309 — Trapper Creek
Pine Creek	PC 311 — upper mainstem Pine Creek
Denver Creek	PC 325 — upper Denver Creek
Unmineralized	
Pine Creek	PC 306 — upper East Fork (South Fork)

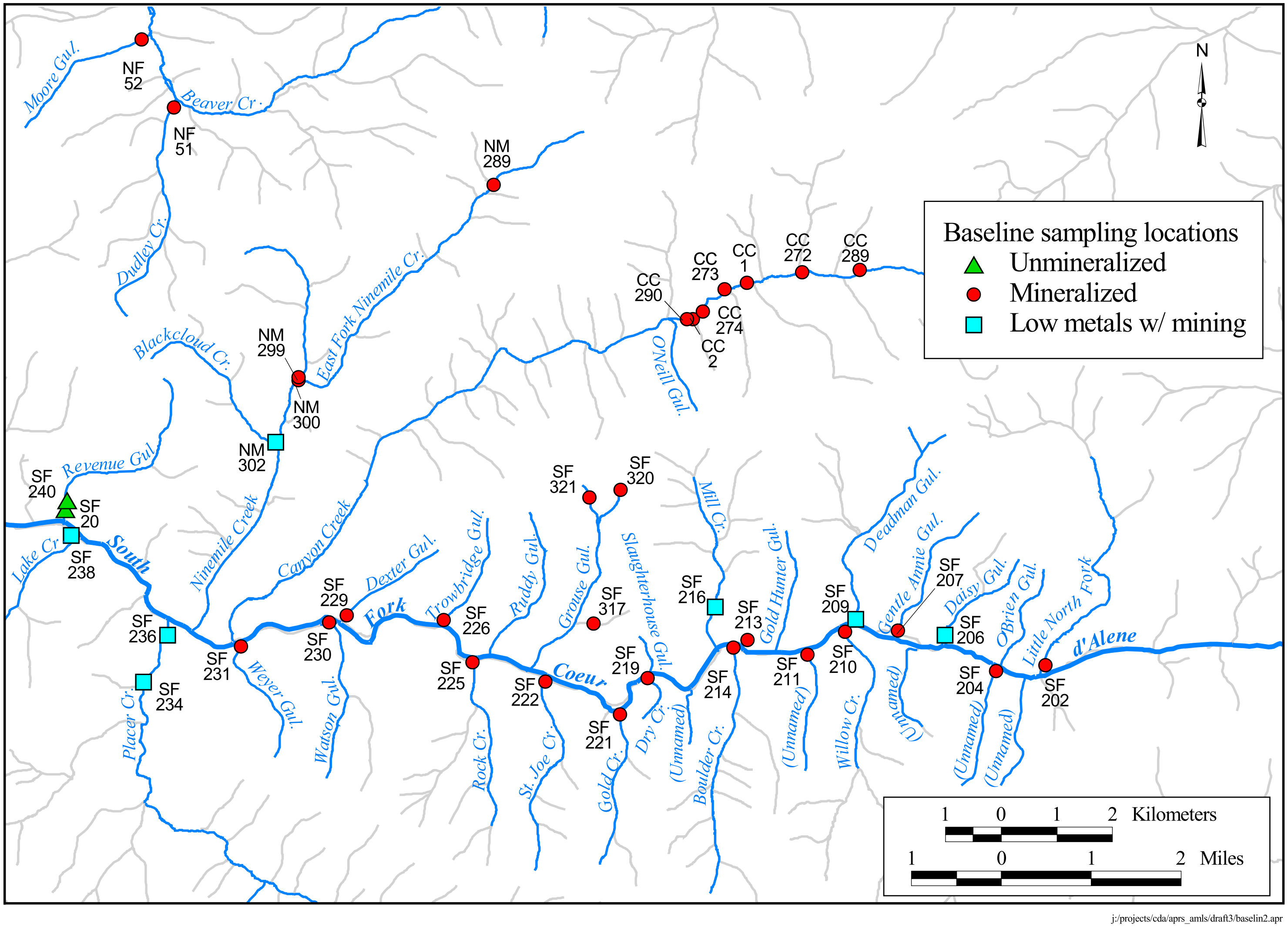

Figure 10-11a. Baseline surface water locations — east.

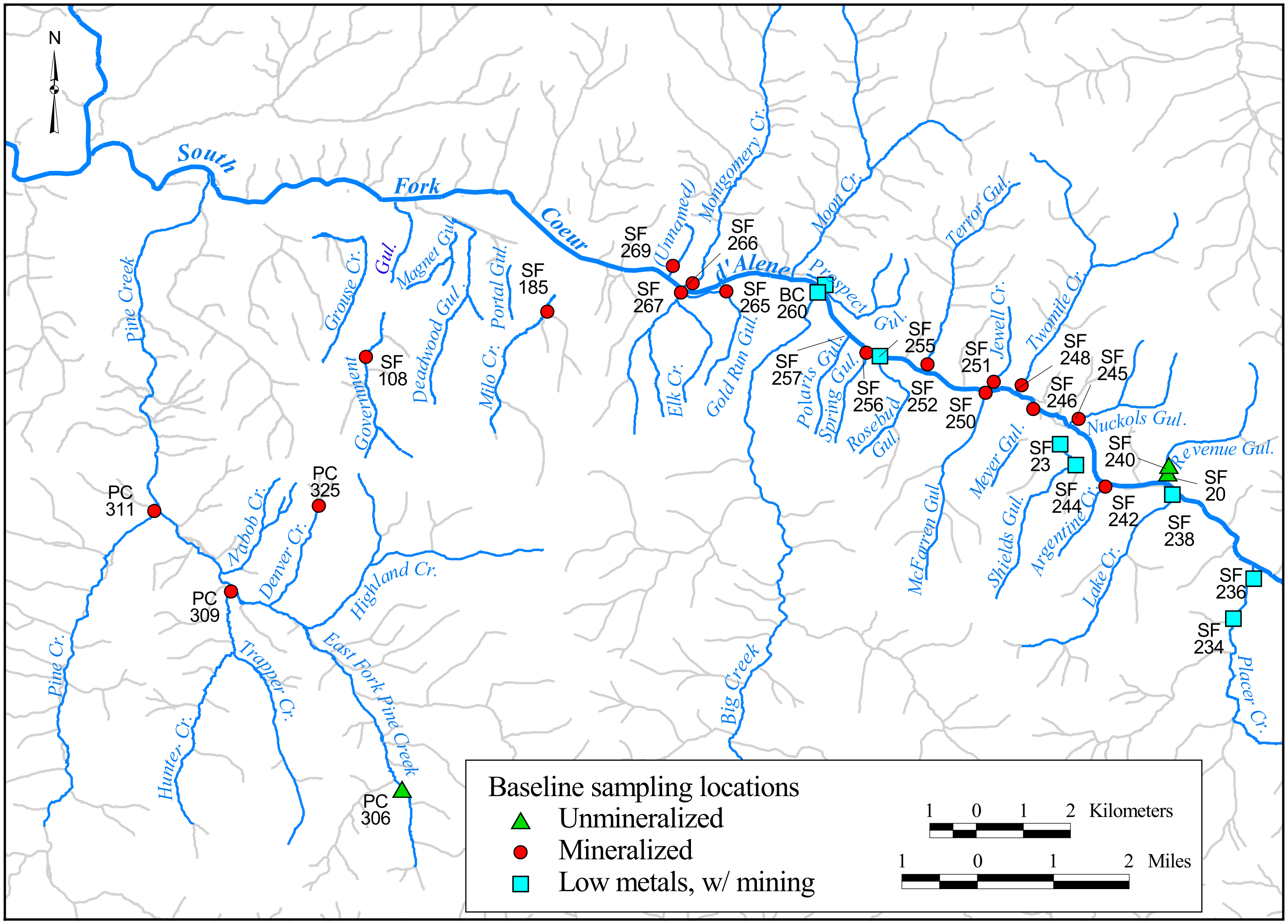

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Figure 10-11b. Baseline surface water locations – west.

Water quality samples from the following locations do not violate aquatic life criteria for dissolved cadmium, lead, and zinc, even though a major mine or mill or other type of significant mining disturbance exists in the drainage. These locations were not used for baseline surface water quality, but the data indicate that water quality was high in these mineralized drainages before mining.

- Deadman Gulch (SF 209)
- Mill Creek (SF 216)
- Placer Creek (SF 234, 236)
- Blackcloud Creek (NM 302)
- Lake Creek (SF 238)
- Shields Gulch (SF 23, 244)
- Rosebud Gulch (SF 255)
- Polaris Gulch (SF 257)
- Big Creek (BC 260).

10.4.4 Extent of Mineralization of Individual Drainages

Some of the tributaries of the South Fork Coeur d'Alene River have veins known to contain base metals that are outcropping or close to the surface (as determined by Crosby, 1959; Hobbs et al., 1965; and Hobbs and Fryklund, 1968). Canyon Creek and Ninemile Creek are the tributaries of the South Fork Coeur d'Alene River that have had the largest number of mines and are also known to have a large number of outcropping veins. The percentage of the Canyon Creek drainage with outcropping veins or veins close to the surface was determined in the section on soil and sediment baseline (Section 10.3.6). For comparison, the percentages of outcropping or near-surface veins in two other drainages with low metal concentrations in streams, Mill Creek and Gentle Annie Gulch, were also determined.

In Mill Creek, the Star-Morning vein, one of the largest in the district, is shown to be outcropping (Crosby, 1959, Section H), and the ore body itself is shown to be very close to the surface for much of its length (Hobbs and Fryklund, 1968). The You Like vein is also in Mill Creek and is shown to be within approximately 50 feet of the surface in Crosby (1959, Section H). In Gentle Annie Gulch, there are four outcropping veins known to contain base metals or to be associated with mines, as shown by Hobbs et al. (1965). Both Mill Creek and Gentle Annie Gulch have very low metal concentrations (water quality criteria were not exceeded in any sample). Gentle Annie Gulch was used as a baseline water quality stream, and Mill Creek was identified as a stream with low metal concentrations even though significant mining activity was conducted in the drainage (Maest et al., 1999). Mill Creek was excluded from consideration as a baseline stream because of the presence of the Morning No. 5 adit, which was the main producing adit for the large Morning mine for a number of years. However, there are no significant tailings deposits in the drainage.

The drainage basins of these watersheds were delineated as described in Section 10.3.6, and the veins containing base metals that were at or near the surface were delineated on maps of the drainages (Figure 10-12). The lengths of the outcropping or near surface veins were measured, and the average width from the Kennedy analysis (150 m) was applied to determine the total area of veins in each drainage. The areal percentages of these drainages covered by metal-containing surface or near-surface veins were 0.9% for Gentle Annie Gulch and 2% for Mill Creek. This compares to a value of 0.4% for Canyon Creek (Section 10.3.6). Therefore, even in drainages with more than twice as much surface area occupied by metal-rich outcropping or near surface veins, metal concentrations in surface water are low in the absence of significant tailings deposits.

This analysis confirms that streams used for determining baseline water quality had areal percentages of highly mineralized material similar to or greater than percentages in Canyon Creek. Surface water in Gentle Annie Gulch and Mill Creek had very low metal concentrations. These results and the demonstration of the minimal effect of highly mineralized veins on soil baseline metals values presented in Section 10.3.6 indicate that, while metal concentrations in veins and ore are very elevated, the geographic extent of the veins themselves relative to the area of the basin is so insignificant that the veins do not substantially affect baseline soil or water metal concentrations.

10.4.5 Determination of Baseline Surface Water Concentrations

Baseline surface water concentrations were determined using concentrations from individual reference locations. Median concentrations and interquartile ranges [43 CFR §11.72 (g)(6)] of dissolved cadmium, lead, and zinc were determined for reference surface water locations in each of three areas of the South Fork Coeur d’Alene River basin — the upper South Fork basin, the Page-Galena mineral belt area, and the Pine Creek drainage. In addition, median and interquartile range values were determined for the South Fork Coeur d’Alene River basin as a whole.

For a given sample location, mean values were determined for dissolved cadmium, lead, and zinc concentrations. For concentrations that were below detection, one-half the detection limit was used. If there was more than one sample location on a tributary, as was the case for Canyon and Ninemile creeks, the mean tributary value was calculated as the mean of the individual sample location means. In this way, tributaries with more than one sample location were not weighted more heavily than those with only one sample site, and sites sampled more frequently did not weight tributary means. The median and interquartile ranges for the three areas and the entire South Fork Coeur d’Alene River basin are presented in Table 10-11. Medians and interquartile ranges are presented for dissolved cadmium, lead, and zinc.

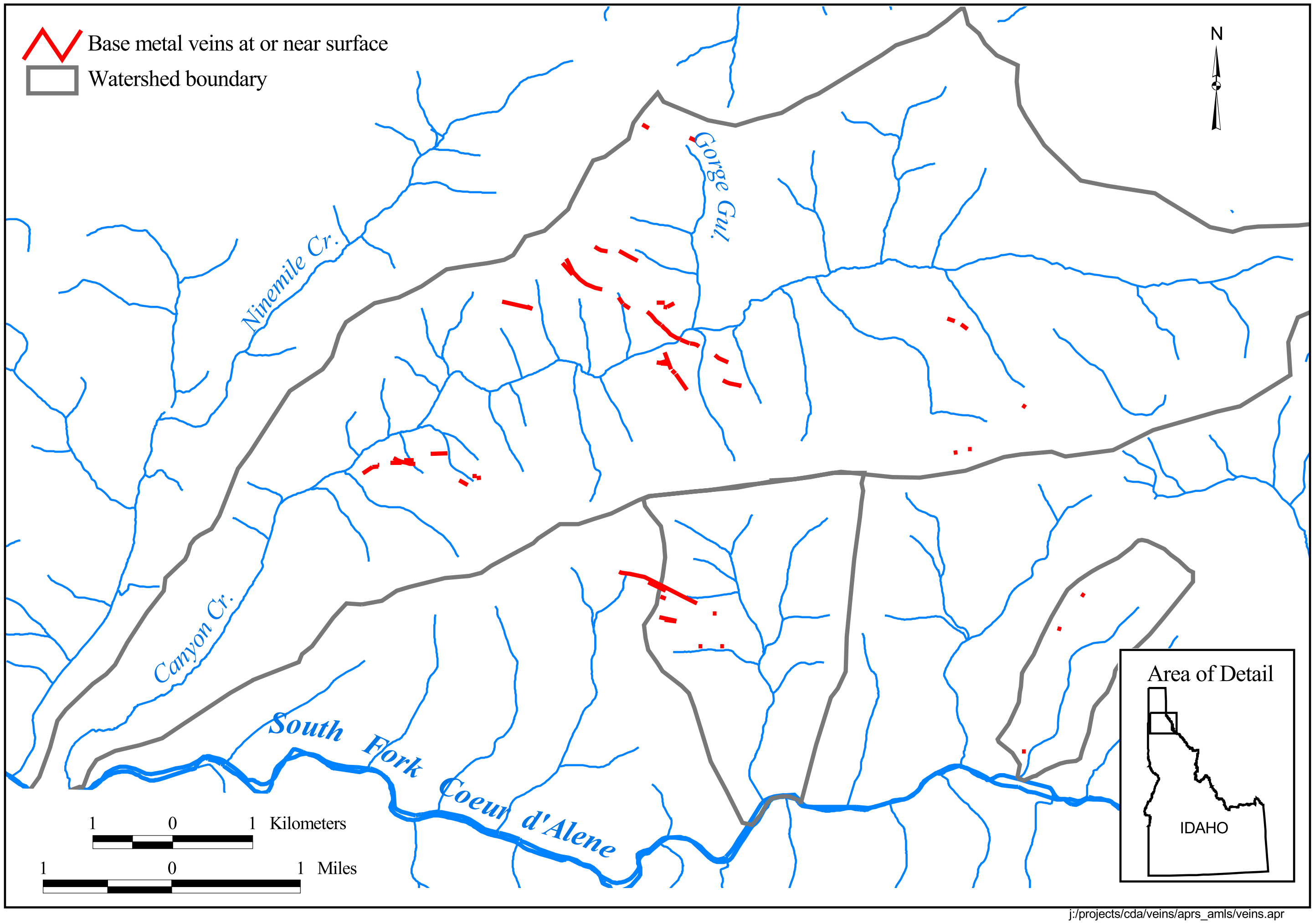

Figure 10-12. Location of surface or near surface veins known to contain base metals in the Canyon Creek, Mill Creek, and Gentle Annie drainage basins.

Table 10-11
Median and Interquartile Ranges for Baseline Surface Water in the South Fork Coeur d'Alene Basin

Area	Statistical Analysis	Cadmium (µg/L)	Lead (µg/L)	Zinc (µg/L)
Upper South Fork	Median	0.06	0.15	5.35
	25th percentile	0.04	0.08	4.50
	75th percentile	0.07	0.25	8.45
Page-Galena Mineral Belt	Median	0.10	0.44	9.04
	25th percentile	0.07	0.21	6.76
	75th percentile	0.16	0.87	20.0
Pine Creek Drainage	Median	0.03	0.11	3.68
	25th percentile	0.02	0.07	2.94
	75th percentile	0.04	0.22	5.24
Entire South Fork CdA Basin	Median	0.06	0.18	6.75
	25th percentile	0.04	0.08	4.60
	75th percentile	0.10	0.52	10.7

Median values for dissolved cadmium, lead, and zinc in the upper South Fork Coeur d'Alene River basin were 0.06, 0.15, and 5.35 µg/L, respectively. Median values for dissolved cadmium, lead, and zinc in the Page-Galena mineral belt area, 0.10, 0.44, and 9.04 µg/L, respectively, were the highest of the three groups. Median values for dissolved cadmium, lead, and zinc in the Pine Creek drainage, 0.03, 0.11, and 3.68 µg/L, respectively, were the lowest. For the South Fork Coeur d'Alene River basin as a whole, medians for the three metals were 0.06, 0.18, and 6.75 µg/L, respectively.

None of the baseline surface water median values exceed relevant ALC values. Chronic ALC values for dissolved cadmium, lead, and zinc at a hardness of 25 mg/L as $CaCO_3$ are 0.80, 0.54, and 36.5 µg/L, respectively. This is the lowest hardness value that can be used to calculate ALC values and yields the lowest, or most environmentally conservative, chronic ALC value. Average hardness values for all three areas (Upper South Fork, etc.) and for the South Fork Coeur d'Alene basin as a whole are at least twice this value. Therefore, baseline water quality values are well below relevant ALC values, and baseline water quality would not have exceeded even chronic ALC values calculated at the lowest possible hardness value.

10.4.6 Comparison of Baseline and Injured Surface Water Concentrations

To establish that differences between surface water conditions of the reference and injured areas are statistically significant, the median and interquartile range of the data were determined and concentration distributions of dissolved cadmium, lead, and zinc in baseline and injured surface water sample locations were compared using the Mann-Whitney test [43 CFR §11.72 (g)(6)].

The median and the interquartile range of dissolved cadmium, lead, and zinc in injured areas were determined for the same three areas for which baseline concentrations were characterized (Upper South Fork, Page-Galena mineral belt area, and Pine Creek drainage). The data used to calculate median and interquartile ranges in injured areas were mean concentrations in the tributaries and the portion of the South Fork Coeur d'Alene River within each of the three baseline characterization areas. For example, a mean concentration was calculated for each tributary in the Upper South Fork area, and a mean concentration was calculated for the South Fork Coeur d'Alene River from the headwaters to Placer Creek, using individual sample location data. For the Page-Galena area, a mean concentration was calculated for each tributary downstream of Placer Creek and upstream of Pine Creek, and a mean concentration was calculated for the South Fork Coeur d'Alene River from downstream of Placer Creek to upstream of Pine Creek. For the Pine Creek drainage, a mean concentration was calculated for Pine Creek and for each of the injured Pine Creek tributaries, and a mean concentration was calculated for the South Fork Coeur d'Alene River from downstream of Pine Creek to the North Fork Coeur d'Alene River confluence. Table 10-12 and Figures 10-13a, b, and c present the median and interquartile ranges of the mean concentrations for each area.

The median and the interquartile range of mean injured concentrations also were determined for the whole South Fork Coeur d'Alene River basin (Table 10-12 and Figures 10-13a, b, and c). For that calculation, the three mean concentrations for the sections of the South Fork Coeur d'Alene River described above were included with the means for all other injured tributaries in the basin.

For each area, and for the South Fork Coeur d'Alene River basin as a whole, baseline and injured concentrations of dissolved cadmium, lead, and zinc were highly significantly different (Mann-Whitney $p < 0.01$, Table 10-12). Even though the Page-Galena Mineral Belt area had the highest median baseline metal concentrations of the three areas, differences between baseline and injured median values were all significantly different at $p < 0.001$.

Median injured concentrations for dissolved cadmium, lead, and zinc in the Upper South Fork area were 1.17, 7.00, and 170 µg/L, respectively. These are the lowest median injured values for cadmium and zinc of the three areas examined. The value for cadmium, 1.17 µg/L, exceeds the dissolved chronic ALC at hardnesses above 25 mg/L as $CaCO_3$; values for lead and zinc are higher than chronic ALC values even at hardnesses above 100 mg/l as $CaCO_3$. In addition, the median zinc concentration exceeds the acute ALC value at relevant hardnesses for the Upper South Fork.

Table 10-12
Summary of Statistical Comparisons of Baseline and Injured Surface Water Locations for Dissolved Metals

Area	Statistical Measure	Cadmium (µg/L)			Lead (µg/L)			Zinc (µg/L)		
		Baseline	Injured	p Value	Baseline	Injured	p Value	Baseline	Injured	p Value
Upper South Fork	Median	.06	1.17	<0.01	.15	7.00	<0.001	5.35	170	<0.01
	25th percentile	.04	0.20		.08	1.83		4.50	37.4	
	75th percentile	.07	8.33		.25	18.6		8.45	1230	
Page-Galena Mineral Belt	Median	.10	8.12	<0.001	.44	10.9	<0.001	9.04	1080	<0.001
	25th percentile	.07	3.65		.21	7.46		6.76	623	
	75th percentile	.16	12.3		.87	50.1		20.0	2950	
Pine Creek Drainage	Median	.03	3.09	<0.01	.11	2.77	<0.01	3.68	1140	<0.01
	25th percentile	.02	0.80		.07	0.89		2.94	209	
	75th percentile	.04	8.55		.22	6.01		5.24	1740	
Entire South Fork CdA Basin	Median	.06	3.75	<0.001	.18	7.17	<0.001	6.75	769	<0.001
	25th percentile	.04	0.88		.08	2.00		4.60	126	
	75th percentile	.10	11.0		.52	17.6		10.7	1750	

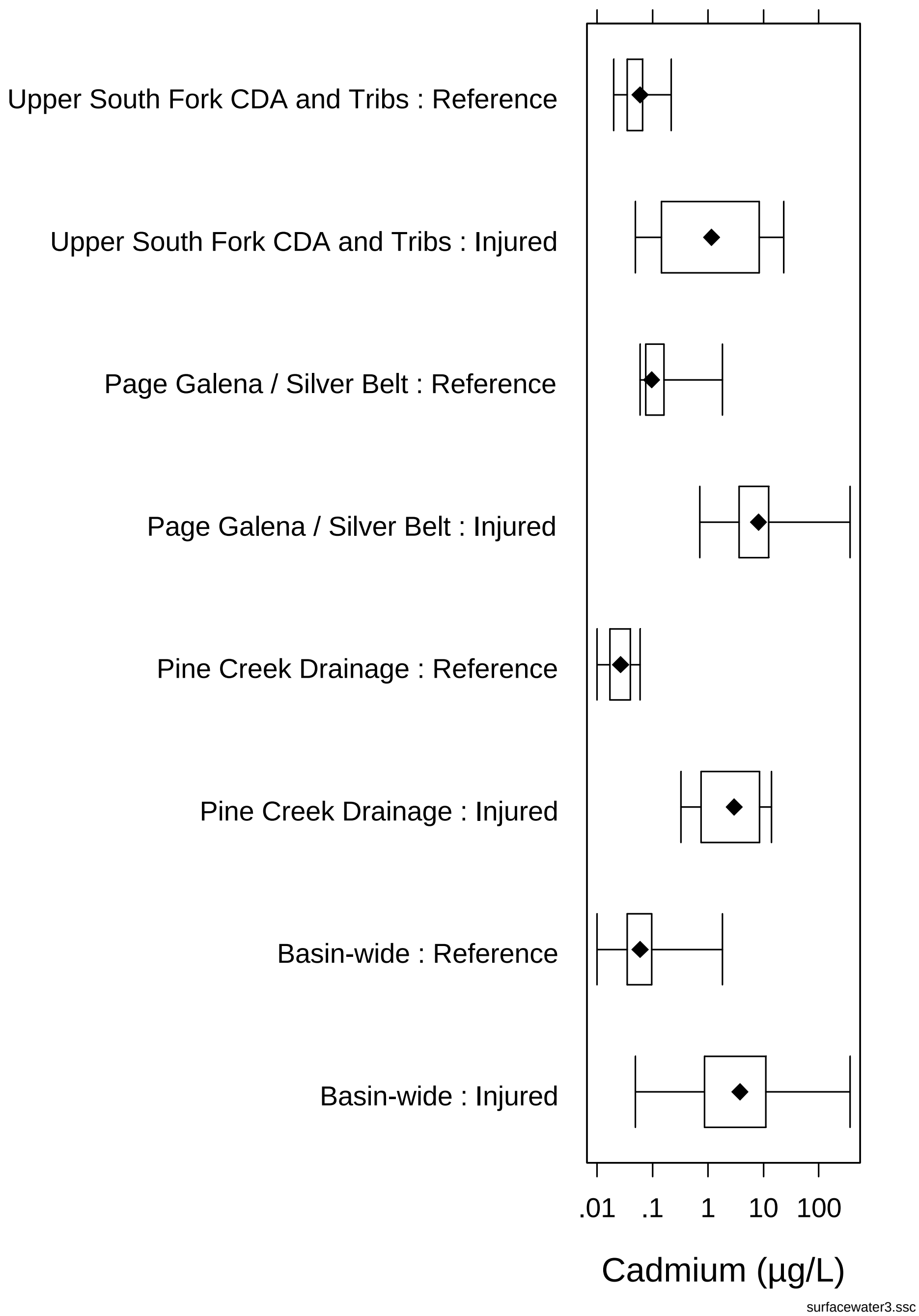

Figure 10-13a. Statistical results for dissolved cadmium for baseline and injured areas in the South Fork Coeur d'Alene River basin. The ends of the whiskers indicate the range, the ends of the boxes indicate the 25th and 75th percentiles, and the diamonds indicate median values.

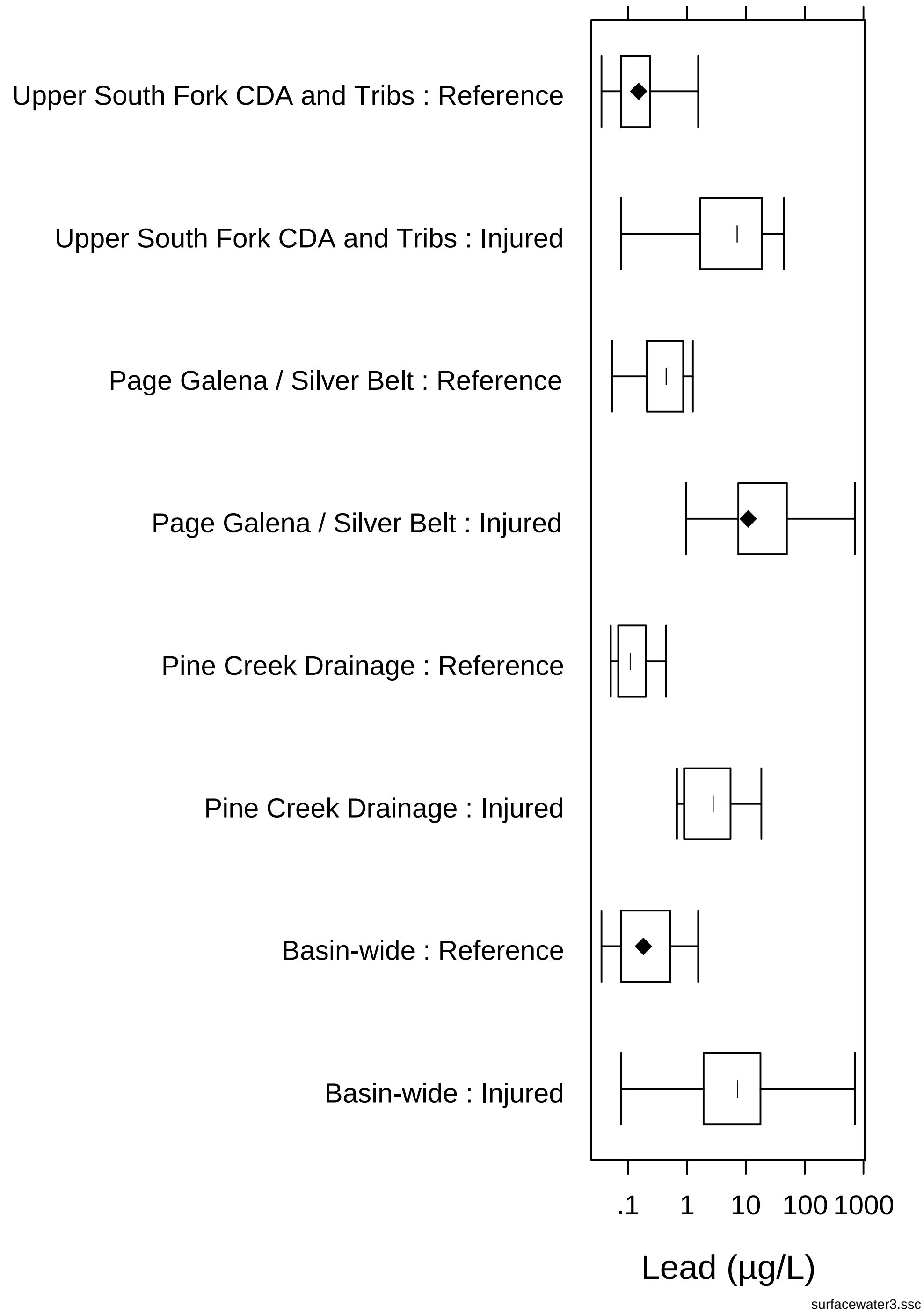

Figure 10-13b. Statistical results for dissolved lead for baseline and injured areas in the South Fork Coeur d'Alene River basin. The ends of the whiskers indicate the range, the ends of the boxes indicate the 25th and 75th percentiles, and the diamonds indicate median values.

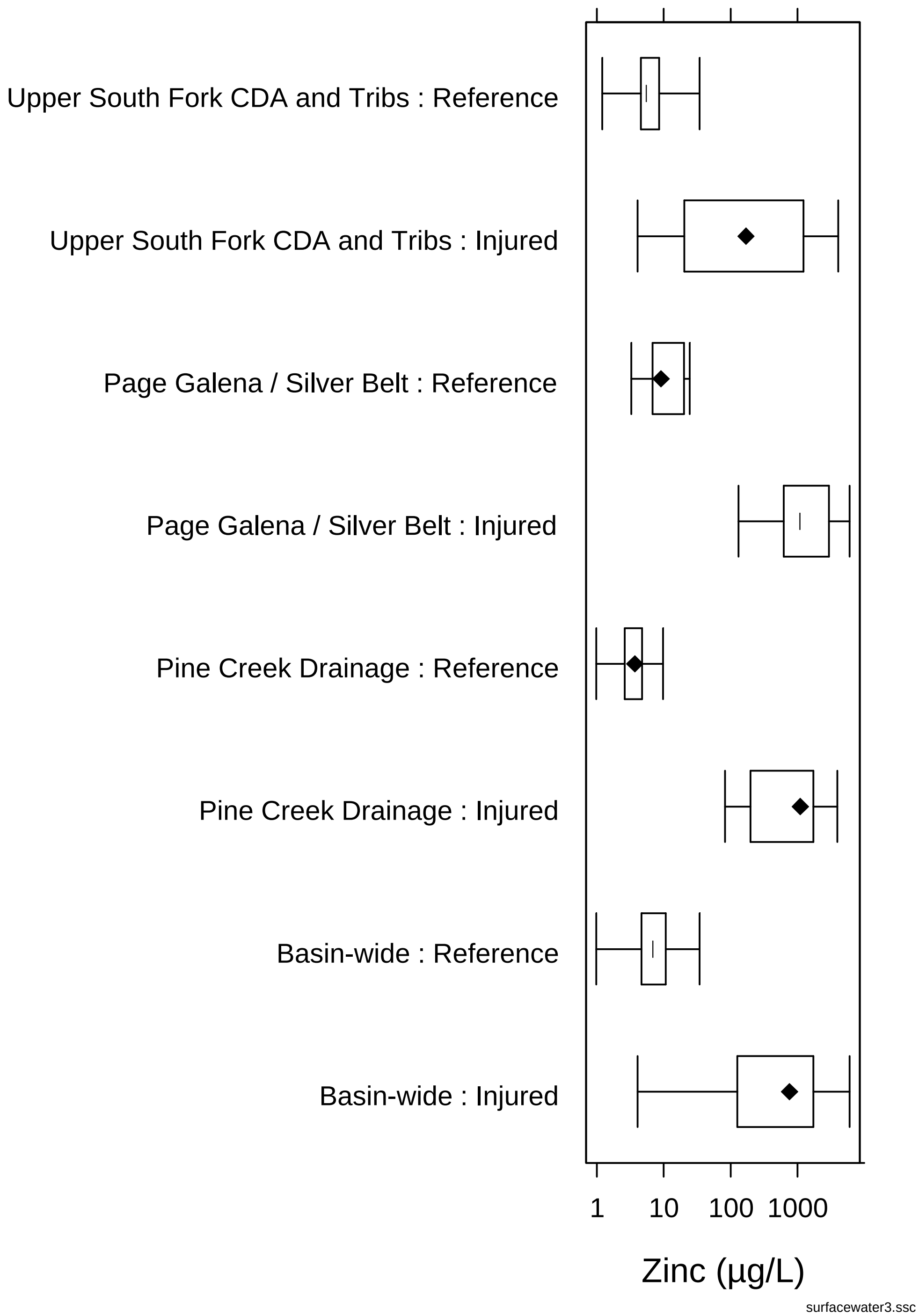

Figure 10-13c. Statistical results for dissolved zinc for baseline and injured areas in the South Fork Coeur d'Alene River basin. The ends of the whiskers indicate the range, the ends of the boxes indicate the 25th and 75th percentiles, and the diamonds indicate median values.

Median injured concentrations for the Page-Galena mineral belt area were 8.12, 10.9, and 1,080 µg/L for cadmium, lead, and zinc, respectively. This area had the highest median injured concentrations for both cadmium and lead. The Page-Galena area also had the highest baseline values for all three metals. The Page-Galena median injured concentrations greatly exceed chronic ALC values at any hardness value. In addition, both the cadmium and zinc median injured concentrations exceed the acute ALC values, even at high hardness values.

Median injured concentrations for dissolved cadmium, lead, and zinc for the Pine Creek area were 3.09, 2.77, and 1140 µg/L, respectively. The median injured lead concentration for the Pine Creek drainage was the lowest of the three areas, while the median injured zinc concentration was the highest of the three areas. These concentrations exceed chronic ALC values, even at hardnesses of 100 mg/L as $CaCO_3$ and higher. In addition, both the cadmium and zinc median injured concentrations exceed acute ALC values at all measured hardness values in the Pine Creek basin.

For the South Fork Coeur d'Alene River basin as a whole, median injured values for dissolved cadmium, lead, and zinc were 3.75, 7.17, and 769 µg/L, respectively. All of these concentrations exceed chronic ALC values, even at hardnesses of 100 mg/l as $CaCO_3$ and higher. In addition, both cadmium and zinc median injured concentrations exceed acute ALC values at measured hardness values in the South Fork Coeur d'Alene River basin.

10.4.7 Surface Water Baseline Conditions Summary and Conclusions

Characterization of surface water baseline conditions included consideration of the natural mineralization of many of the drainages in the Coeur d'Alene River basin and the similarity of reference and injured streams in terms of hydrologic, geologic, and mineralogic considerations. The basin was divided into three areas for surface water baseline, based on similarities in types of ore deposits: 1) the upper South Fork Coeur d'Alene River, including Canyon and Ninemile creeks; 2) streams draining the Page-Galena mineral belt area; and 3) the Pine Creek drainage.

Each tributary drainage basin was considered in terms of its geology, mineralization, and environment, including water quality data and mine waste deposits. Drainages were excluded from consideration as reference areas if they contained mill sites or large producing mines. In some cases, water quality from drainages with mill sites or large mines still met aquatic life criteria, indicating that baseline water quality in many of the areas would have been even more pristine before mining.

Table 10-11 presents the baseline concentrations for each area and for the South Fork Coeur d'Alene River basin as a whole. Baseline water quality concentrations for cadmium, lead, and zinc are well below both acute and chronic ALC values for all three areas and for the South Fork Coeur d'Alene River basin as a whole evan at the lowest possible hardness value. Therefore, baseline concentrations of cadmium, lead, and zinc are low and do not exceed ALC values. This indicates that concentrations of these toxic metals in Coeur d'Alene River basin surface water were low before mining activity began in the basin.

Baseline concentration distributions in the three areas in the South Fork Coeur d'Alene River basin were compared to injured concentration distributions to determine if the distributions were significantly different from one another. For every metal in each of the three areas, and in the South Fork Coeur d'Alene River basin as a whole, dissolved cadmium, lead, and zinc concentrations were all statistically significantly higher in injured areas than in baseline areas.

10.5 RIPARIAN VEGETATION BASELINE

Baseline conditions for riparian vegetation are described in terms of vegetation community attributes measured in reference areas. Riparian vegetation baseline was determined for the upper basin floodplains only. Data presented in Chapter 9 confirm gross modifications of riparian vegetation in the upper basin as a result of toxic metals concentrations in soils.

10.5.1 Historical Data

Historical data describing riparian vegetation before mining began are scarce. Riparian areas are natural travel corridors through the mountains and so were typically settled first and subjected to numerous land uses. Timber adjacent to streams was the first to be harvested, and water corridors were used to transport logs from the forest to the sawmills (Idaho Panhandle National Forests, 1998). Between 1880 and 1965, more than 400 sawmills operated in the Coeur d'Alene River basin (Idaho Panhandle National Forests, 1998). Splash dams and log chutes were constructed in the Little North Fork Coeur d'Alene River and other tributaries of the North Fork Coeur d'Alene River. Logging activity in the basin peaked in 1929, and the last log drive was made in 1943 (Idaho Panhandle National Forests, 1998).

Historical riparian vegetation included large western red cedar, white pine, larch, and cottonwood (Idaho Panhandle National Forests, 1998). Mature riparian forest has been greatly reduced or eliminated along much of the riparian zones of the basin as a result of logging, road construction, agriculture, urban development, and mining (Idaho Panhandle National Forests, 1998). Because there has been substantial anthropogenic modification of riparian vegetation since mining began in the basin, the condition of riparian vegetation before releases to the basin began is inappropriate for determining baseline conditions today. Because historical data are unavailable or not appropriate, baseline was defined using field data from reference areas [43 CFR 11.72(d)].

10.5.2 Reference Areas

Since the assessment area vegetation has been substantially modified, reference areas were selected based on similarity of major nonmining environmental factors that affect plant growth and vegetation community development in the reference areas and that would be expected to control plant growth and vegetation community development in the assessment area. Where possible, reference areas were located upgradient of the assessment area. Where upstream areas were not appropriate, a reference area was identified based on proximity to the assessment area, comparable elevation, and comparable valley orientation. Reference areas for baseline determination in the upper basin were the same reference areas described in Chapter 9 (Section 9.4.1) for riparian resources injury determination.

The reference areas were sampled using standard vegetation sampling techniques [43 CFR 11.71 (l)(4, 6)] to measure baseline habitat quality [43 CFR 11.72 (k)(ii)(A)]. Sampling methods are described in Chapter 9. Field vegetation data characterizing the habitat quality were collected from each of 3 sample sites on upstream Canyon Creek, 3 sample sites on Ninemile Creek upstream of the East Fork Ninemile Creek confluence, and 17 sites on the Little North Fork. The same methods were used in both assessment and reference areas [43 CFR11.72 (d)(5)].

10.5.3 Data Analysis

To determine baseline conditions, vegetation conditions at reference areas (described in Chapter 9) were quantified at the habitat (community) level [43 CFR 11.71 (l); 11.72 (k)(3)(ii)(A)]. Data from the three reference areas were pooled and are described by the following parameters:

- percentage of bare ground
- percentage of cover of vegetation in the herbaceous, shrub, and tree layers
- number of species in the herbaceous, shrub, and tree layers
- number of structural habitat layers.

Table 10-13 presents median, 95 percent confidence interval on the mean, and 25th and 75th percentiles for the above vegetation layers. Table 10-14 presents a comparison of baseline vegetation conditions relative to upper basin assessment area locations (South Fork Coeur d’Alene River, Canyon Creek, and Ninemile Creek). Table 10-14 demonstrates the following differences from baseline conditions at assessment area sites:

- tenfold more bare ground (mean of 58% versus 6%)
- sixfold fewer plant species (mean of 3 versus 18), including fewer shrub species (0.5 versus 4.6), and fewer herbaceous species (1.8 versus 11.6)
- sevenfold less vegetative cover (mean of 19% versus 141%), including reduction in shrub cover (5% versus 61%), and reduction in herbaceous cover (14% versus 50%)
- fewer habitat layers (mean of 1.4 versus 3.8).

These data confirm the substantial reductions in vegetation/habitat services in the upper assessment area relative to baseline conditions.

Table 10-13
Baseline Vegetation Conditions[a]

Measure	N	Mean	Lower 95% CI on Mean	Upper 95% CI on Mean	25th Percentile	Median	75th Percentile
Bare ground (%)	23	5.6	3.1	8.2	0.8	3.0	10.0
Number of herb species (n)[b]	23	11.6	10.0	13.2	8.5	11.0	13.5
Herb cover (%)	23	50.1	40.1	60.2	36.5	48.8	62.6
Number of shrub species (n)	23	4.6	3.6	5.6	3.5	4.0	5.0
Shrub cover (%)	23	61.1	41.9	80.2	34.3	55.5	83.0
Number of tree species (n)	23	0.7	0.3	1.1	0.0	0.0	1.0
Tree cover (%)	23	29.8	11.5	48.1	0.0	0.0	65.0
Total cover (%)[c]	23	141.0	116.8	165.3	94.4	139.4	197.8
Number of species (n)	23	17.7	15.7	19.7	15.0	17.0	21.0
Number of habitat layers	23	3.8	3.3	4.3	3.0	4.0	5.0

a. Source data: See Chapter 9.
b. Excludes moss species.
c. Note: Cover can exceed 100% because of the presence of multiple structural layers.

10.5.4 Comparison to Assessment and Literature Values

Reference area conditions are comparable to published riparian vegetation community descriptions and represent a normal range of conditions [43 CFR 11.72(d)(6)]. For example, in Spion Kop Research Natural Area (RNA) at the confluence of Teepe Creek and the North Fork Coeur d'Alene River, floodplain vegetation consists of an extensive stand of black cottonwood of varying age classes, interspersed with wetland communities occupying old river channels and grass/forb communities occupying dry river terraces (Moseley and Bursik, 1994). The Spion Kop RNA communities are highly structurally diverse, but also show evidence of natural scouring and barren areas caused by fluvial dynamics of erosion, sediment deposition, channel migration, and episodic high flows (Moseley and Bursik, 1994). In approximately 4 km of river floodplain, 145 plant species were identified (Moseley and Bursik, 1994). The high structural and compositional diversity of this upstream RNA is similar to the reference area diversity.

Table 10-14
Comparison of Baseline (reference) Vegetation Conditions Relative to Conditions in the Upper Basin Assessment Area[a]

Measure	Area	n	Mean	Lower 95% CI on Mean	Upper 95% CI on Mean	Standard Error on Mean	Minimum	25th Percentile	Median	75th Percentile	Maximum
Bare ground (%)	assessment	40	58.0	47.0	68.9	5.4	0.0	24.8	63.9	93.2	100.0
	reference	23	5.6	3.1	8.2	1.2	0.0	0.8	3.0	10.0	16.9
Number of herb species (n)[b]	assessment	40	1.8	1.2	2.3	0.3	0	0.0	1.0	2.3	8
	reference	23	11.6	10.0	13.2	0.8	6	8.5	11.0	13.5	18
Herb cover (%)	assessment	40	13.6	7.7	19.6	2.9	0.0	0.0	7.8	20.2	83.0
	reference	23	50.1	40.1	60.2	4.9	9.2	36.5	48.8	62.6	113.1
Number of shrub species (n)	assessment	40	0.5	0.0	0.9	0.2	0	0.0	0.0	0.0	6
	reference	23	4.6	3.6	5.6	0.5	1	3.5	4.0	5.0	9
Shrub cover (%)	assessment	40	5.4	-0.2	11.1	2.8	0.0	0.0	0.0	0.0	77.8
	reference	23	61.1	41.9	80.2	9.3	0.5	34.3	55.5	83.0	190.0
Number of tree species (n)	assessment	40	0.0	0.0	0.1	0.0	0	0.0	0.0	0.0	1
	reference	23	0.7	0.3	1.1	0.2	0	0.0	0.0	1.0	3
Tree cover (%)	assessment	40	0.3	-0.3	0.9	0.3	0.0	0.0	0.0	0.0	12.0
	reference	23	29.8	11.5	48.1	8.9	0.0	0.0	0.0	65.0	117.1
Total cover (%)[c]	assessment	40	19.3	10.5	28.2	4.4	0.0	0.0	10.6	22.6	111.5
	reference	23	141.0	116.8	165.3	11.7	40.7	94.4	139.4	197.8	228.4
Number of species (n)	assessment	40	3.0	2.1	4.0	0.5	0	1.0	2.0	4.0	14
	reference	23	17.7	15.7	19.7	1.0	8	15.0	17.0	21.0	28
Number of habitat layers	assessment	40	1.4	1.1	1.7	0.2	0	1.0	1.0	2.0	4
	reference	23	3.8	3.3	4.3	0.2	1	3.0	4.0	5.0	5

a. Source data: See Chapter 9.
b. Excludes moss species.
c. Cover can exceed 100% because of the presence of multiple structural layers.

To the north of the Coeur d'Alene River basin, the Clark Fork River flows from Montana into Lake Pend Oreille. Habitat surveys were conducted along the river between Thomspon Falls, Montana, and the mouth of the river at Lake Pend Oreille in 1993 and 1994 for Washington Water Power (Northrop, Devine & Tarbell, 1994; Washington Water Power, 1995). The land is predominantly privately owned, and a road and railroad parallel the river throughout the length surveyed. Dominant riparian species include black cottonwood and quaking aspen in the tree canopy, and thinleaf alder, common snowberry, western serviceberry (*Amelanchier alnifolia*), black hawthorn (*Crataegus douglasii*), red-osier dogwood (*Cornus stolonifera*), and willow species (*Salix* spp.) in the shrub midstory (Northrop, Devine & Tarbell, 1994). Average vegetation cover in the 2-5 m height class was 42.3% in 1992 and 31.6% in 1993, and average cover in the 0.5-2 m height class was 34.8% in 1992 and 38.4% in 1993 (Table 10-15). These two height classes are approximately the same as the shrub layer (0.5 to 6 m) defined in this injury assessment (Section 9.4.1). Vegetation cover in the herbaceous layer averaged 85.6% in 1992 and 73.1% in 1993, and in the tree canopy, 7.7% in 1992 and 9.2% in 1993.

Table 10-15
Mean Percent Vegetation Cover by Structural Category in Riparian Habitat of the Lower Clark Fork River, Montana/Idaho

Cover Class	% Cover, 1992 (n = 15)	% Cover, 1993 (n = 32)
Tree canopy cover	7.7	9.2
Tall shrub cover (2-5 m)	42.3	31.6
Low shrub cover (0.5-2 m)	34.8	38.4
Herbaceous cover	85.6	73.1

Sources: Northrop, Devine & Tarbell, 1994; Washington Water Power, 1995.

Riparian zones of Rock Creek, the Bighole River, the Ruby River, and Bison Creek, all in southwest Montana, were surveyed by Boggs (1991). Each of these locations is subjected to agricultural uses and grazing, and each is bordered by a highway or interstate. The Big Hole River is also bordered by a railroad. Riparian zones along these streams supported an average of 60% herbaceous cover, 44% shrub cover, and 18% tree cover (Boggs, 1991). Cover of all vegetation types averages 122% (because of multiple structural layers), and bare ground is insignificant.

The DOI NRDA regulations do not suggest a statistic for characterization of baseline conditions based on the range of variability determined. The intent of the baseline determination is to describe conditions that reflect natural and anthropogenic influences but not influences from releases of hazardous substances from mining operations. The reference area data were collected from reaches that have been exposed to a lesser degree to urbanization, in addition to less exposure to disturbance from mining operations. However, the Little North Fork Coeur d'Alene River is exposed to greater recreational pressure and greater historical disturbance related to logging (Idaho Panhandle National Forests, 1998). Both Canyon and Ninemile creeks are bordered by roads, and the upper Canyon Creek reference area had been occupied historically by some type of urban construction. In addition, the Canyon Creek sites showed clear evidence of mine waste contamination and an exposure-response effect on vegetation. Regardless, Canyon Creek vegetation data were retained in the baseline data since they represent a conservative estimate of riparian vegetation quality. Vegetation communities from the reference areas are not pristine, but do represent conditions of lesser urban encroachment. However, the sampling protocol excluded urban areas, so the comparisons were in areas that should be quite similar, absent releases of hazardous substances.

The reference area data also most likely represent a range of site types reflecting elevational gradients, hydrologic gradients, valley shape, width, and orientation, and successional stages of patches of vegetation within the areas sampled. Over elevational and longitudinal hydrologic gradients, a natural change in species composition is expected, and gradients in species composition and structure with lateral distance from the stream are expected (Hansen et al., 1990; Naiman and Décamps, 1997). However, since the reference area data were collected using a randomized, unbiased sampling design in which all areas within the floodplain on publicly owned land had the same probability of being sampled, the data reflect an unbiased sample of existing vegetation across existing gradients.

Given that the baseline data represent a range of anthropogenic disturbance and a range of natural variability, a range of values from the 25th to 75th percentile was selected as an appropriate descriptor of baseline conditions (Table 10-13).

10.6 EXTENT OF INJURY

The Trustees quantified injury and the associated service reductions as the total area where surface water and soils/sediment resources exceed baseline and have reduced ability to sustain aquatic biota, vegetation, and habitat for wildlife relative to baseline [43 CFR 11.71 (h)(4)(i) and (k)(1-2)]. This approach recognizes the multiple primary and secondary service losses.

10.6.1 Surface Water

The area where surface water exceeds baseline includes areas downstream of sampling stations at which dissolved concentrations of cadmium, lead, or zinc exceed water quality criteria for the protection of aquatic biota. Injured surface waters include:

- South Fork and mainstem Coeur d'Alene rivers from downstream of Daisy Gulch to the mouth at Coeur d'Alene Lake

- Coeur d'Alene Lake

- Grouse Gulch from the Star Mine waste rock dumps to the mouth
- Canyon Creek from approximately Burke to the mouth
- Gorge Gulch downstream of the Hercules No. 3 adit
- East Fork and mainstem Ninemile Creek from the Interstate-Callahan Mine to the mouth
- Moon Creek from the Charles Dickens Mine/Mill to the mouth
- Milo Gulch from the Sullivan Adits to the mouth
- Portal Gulch from the North Bunker Hill West Mine to the mouth
- Government Gulch from the Senator Stewart Mine to the mouth
- Deadwood/Bunker Creek from the Ontario Mill to the mouth
- East Fork and mainstem Pine Creek from the Constitution Upper Mill to the mouth
- Highland Creek from the Highland Surprise Mine/Mill and the Sidney (Red Cloud) Mine/Mill to the mouth
- lower Denver Creek
- lower Nabob Creek.

Table 10-16 presents river kilometers (miles) of injured surface waters in rivers and streams. In addition, surface waters of the lateral lakes and wetlands are injured and the surface water of Coeur d'Alene Lake is injured.

10.6.2 Floodplain Soils and Sediments — Upper Basin

The extent of injury to floodplain soils and sediments in the upper basin was quantified as the area in floodplain in which hazardous substance concentrations exceed baseline and have reduced ability to sustain vegetation and habitat for wildlife relative to baseline conditions [43 CFR 11.71 (h)(4)(i) and (k)(1,2)]. The quantification method was selected based on known sources and pathways of hazardous substances, sampling of floodplain soil and vegetation conducted for the riparian resources injury assessment and as part of previous and subsequent studies, and relationships between hazardous substance concentrations and vegetation cover.

Table 10-16
Quantification of Injured Surface Water in Rivers and Streams

Injured Surface Water	km	Miles
South Fork and mainstem Coeur d'Alene rivers	107	67
Grouse Gulch	4.0	2.3
Canyon Creek	11.3	7.0
Gorge Gulch	2.5	1.6
Ninemile Creek	11.6	7.2
Moon Creek	5.0	3.1
Milo Gulch	2.7	1.7
Portal Gulch	0.9	0.5
Government Gulch	4.1	2.5
Deadwood/Bunker Creek	4.7	2.9
East Fork and mainstem Pine Creek	16.8	10.4
Highland Creek	5.2	3.2
Denver Creek	5.3	3.3
Nabob Creek	0.5	0.3
Total	**181**	**113**

Data presented in Chapters 2 and 3 confirm that geological and surface water resources downgradient of mining related sources contain elevated concentrations of hazardous substances, and that these resources serve as transport and exposure pathways of hazardous substances. The riparian resources injury determination studies show statistically significant differences between concentrations of hazardous substances in assessment and reference area floodplain soils, and between riparian vegetation cover in assessment and reference areas (Chapter 9). Vegetation cover and vegetation structural complexity are significantly negatively correlated with concentrations of hazardous substances, and the quality and quantity of riparian wildlife habitat are defined largely by vegetation cover and structural characteristics. Based on the known patterns of hazardous substance release, transport, resource contamination, and hazardous substance toxicity and toxic effects at the vegetation community level, vegetation cover mapping was used as a conservative indicator of soils with reduced ability to sustain vegetation and habitat for biota relative to baseline.

In an effort independent from the injury assessment, U.S. BLM mapped existing vegetation cover in the Coeur d'Alene River basin using 7.5 minute orthophoto quadrangle maps for the Coeur d'Alene River basin produced by the USGS. Forestry mapping techniques were used to delineate vegetation cover classes by the extent of tree canopy cover (U.S. BLM, 1999). Polygons of cover classes delineated from orthophoto quadrangles were field verified. Cover class categories included:

Category 1. Barren areas, where little to no ground cover exists and where soil conditions prevent the survival of few native species.

Category 2. Areas containing tree canopy cover less than 10% and trees of diameter less than 4.9 inches.

Category 3. Areas of tree canopy cover from 10 to 50%.

Category 4. Areas of tree canopy cover greater than 51%.

For injury quantification, the vegetation cover class map was overlaid on a map of the floodplain and a map of urban areas. Urban areas included roads, railroads, structures, and developed lands surrounding roads, railroads, and structures. Urban areas were delineated using digital orthophoto quadrangles and quarter quadrangles of the South Fork Coeur d'Alene River basin (U.S. BLM, undated; USGS, 1992). The areal extent of nonurban areas within the floodplain where the vegetation cover was classified as barren or supporting less than 10% tree canopy cover was quantified.

Figure 10-14 presents the devegetated or sparsely vegetated nonurban portions of the floodplain of the South Fork Coeur d'Alene River basin. Tailings ponds in the floodplain that are currently maintained (the Lucky Friday tailings ponds on the South Fork Coeur d'Alene River, the Sunshine Tailings on Big Creek, the Star ponds on Canyon Creek, and the CIA) were delineated separately. The area of maintained tailings ponds was not included in the estimate of injured acreage. The total areas of injured riparian resources in the upper basin are presented in Table 10-17.

Of the 40 upper basin assessment sites sampled as part of the riparian resource injury determination, 75% fell within nonurban floodplain, barren area polygons (Category 1). The remaining 25% fell within polygons in the nonurban floodplain that were identified as containing less than 10% tree canopy cover and trees of diameter less than 4.9 inches (Category 2).

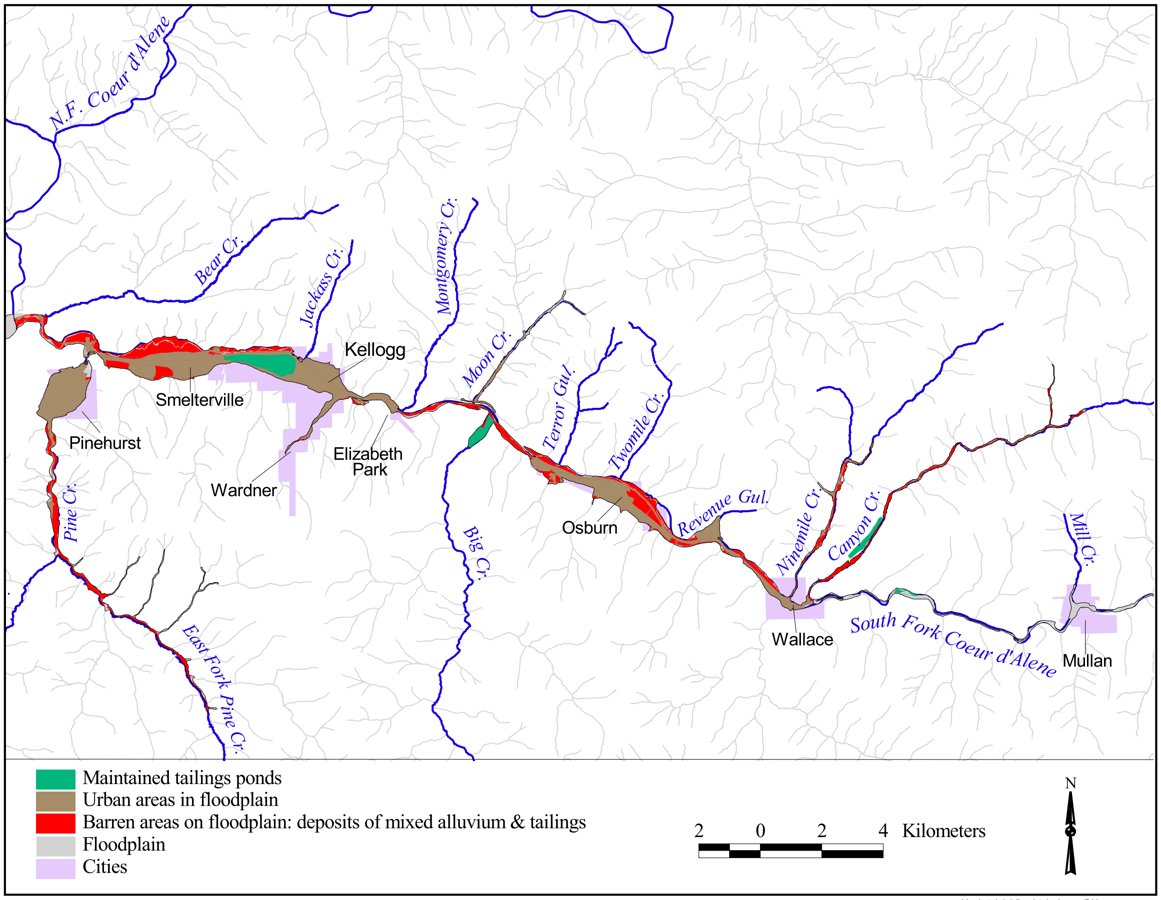

Figure 10-14. Devegetated or sparsely vegetated nonurban portions of the South Fork Coeur d'Alene River basin.

Table 10-17
South Fork Coeur d'Alene River, Canyon, Ninemile, Moon, and Pine Creeks: Areal Extent of Floodplain Soils with Reduced Ability to Sustain Vegetation and Habitat for Biota Relative to Baseline

	Acres (ha)
A. Total floodplain area assessed	4,949 (2,003)
B. Nonurban areas in floodplain assessment area	1,850 (749)
C. Barren or sparsely vegetated nonurban floodplain	1,522 (616)
D. Maintained tailings ponds	390 (158)
Proportion of the available resource that is injured (C/B)	>80%

Based on data collected for the riparian resources injury determination, the mean cover of bare ground at sites categorized as barren (Category 3) was 51%. The remainder of the vegetation cover at sites classified as barren was predominantly sparse grasses and moss. The mean cover of bare ground at the sites classified as containing less than 10% tree canopy cover and trees of diameter less than 4.9 inches (Category 4) was 66%. These sites actually had more bare ground on average compared to the sites classified as barren, but some also contained sparse cover of vegetation in the shrub layer, including the noxious weed spotted knapweed at two sites, tansy at two sites, and willow at two sites.

The total area of barren or substantially devegetated floodplains along the South Fork Coeur d'Alene River downstream of the Canyon Creek confluence, Canyon Creek, Ninemile Creek, Moon Creek, and Pine Creek is 1,522 acres (616 ha). This barren or sparsely devegetated area comprises greater than 80% of the available nonurban floodplain. In addition to this injured acreage, even segments of river bank that were excluded as urban should be capable of supporting vegetative overhang on the river banks.

Floodplains of the upper basin underlying urban development, which were not included in the riparian resources injury claim, also contain contaminated soils and sediments that may serve as a pathway of injury to surface water, via leaching by groundwater.

10.6.3 Floodplain Soils and Sediments — Lower Basin

The extent of injury to soils and sediments of the lower basin was quantified as the area in floodplain in which hazardous substance concentrations exceed baseline concentrations and have reduced ability to provide suitable (nontoxic) habitat for wildlife relative to baseline [43 CFR 11.71 (h)(4)(i) and (k)(1-2)]. Information presented in Chapter 6 confirms that sediments of the lower basin contain elevated concentrations of lead and other hazardous substances, that wildlife ingest contaminated sediments, and that the lead in the sediments is bioavailable and toxic to wildlife. Ingestion of lead-contaminated sediments causes injury to wildlife.

To characterize the spatial distribution of contaminated sediments in the lower basin, kriging models using 840 samples were constructed (Kern, 1999). Data used in the kriging analyses included surficial sediment samples collected by Bender (1991), Rabbi (1994), Hagler Bailly (1995), Hoffman (1995), Horowitz (1995), Union Pacific Railroad (1997), Campbell et al. (1999), and USGS (unpublished data). A set of covariate parameters that take into account the discrete nature of certain geologic, hydrologic, anthropogenic, and habitat features were identified and multiple regression analyses were used to test for association between these variables and sediment lead concentrations. Significantly correlated variables were used in the kriging analyses so that the resulting maps of lead concentration in sediments account for physical features of the landscape that affect the distribution of contamination (Figures 10-15 a and b). Variables retained in the final model included wetland unit (Campbell et al., 1999), an index of hydrological function and ecological habitat classification based on Bookstrom et al. (1999), and proximity to the Union Pacific Railroad.

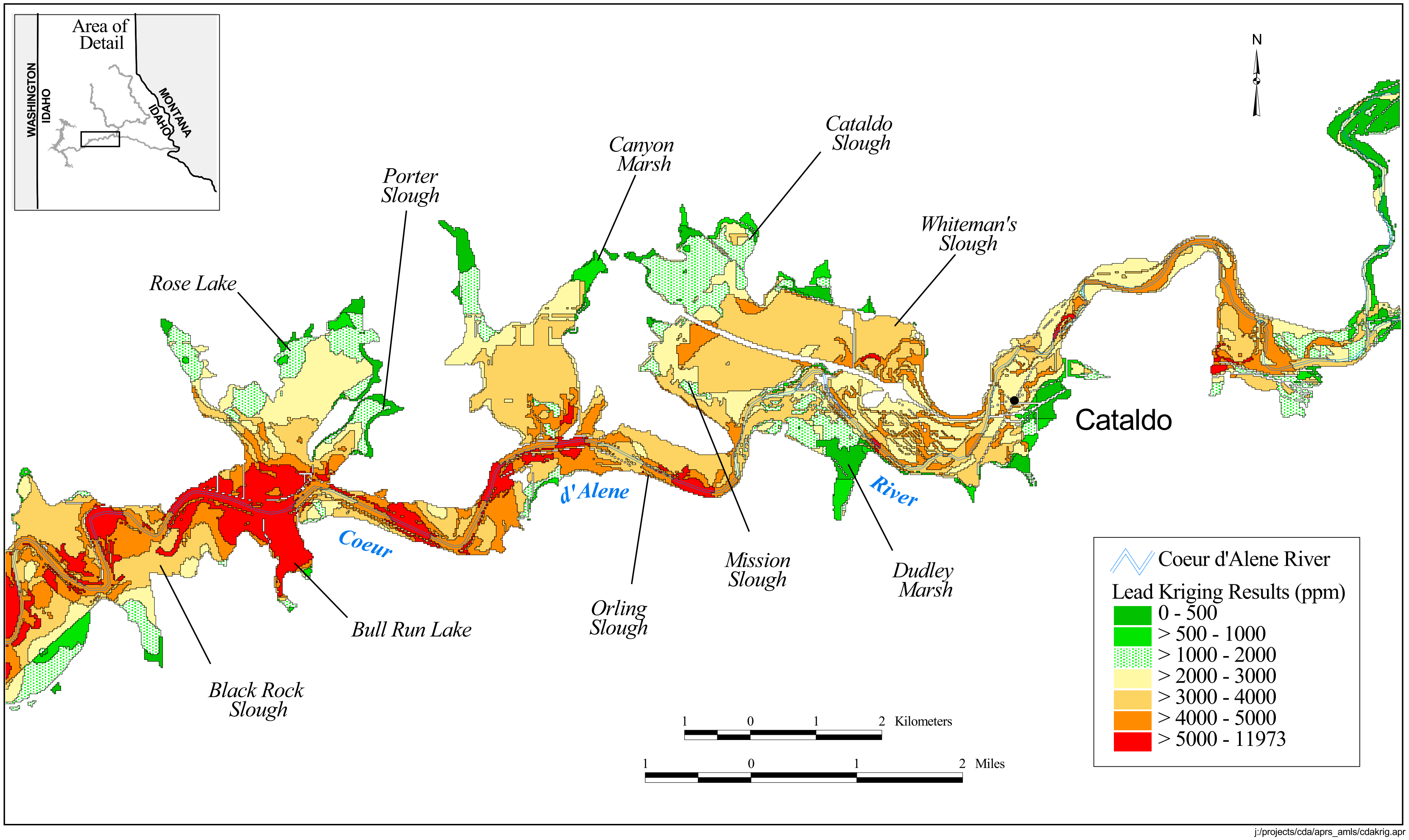

Figure 10-15a. Distribution of lead concentrations in surface sediments of the lower Coeur d'Alene River basin — eastern half.
Data source: Kern, 1999.

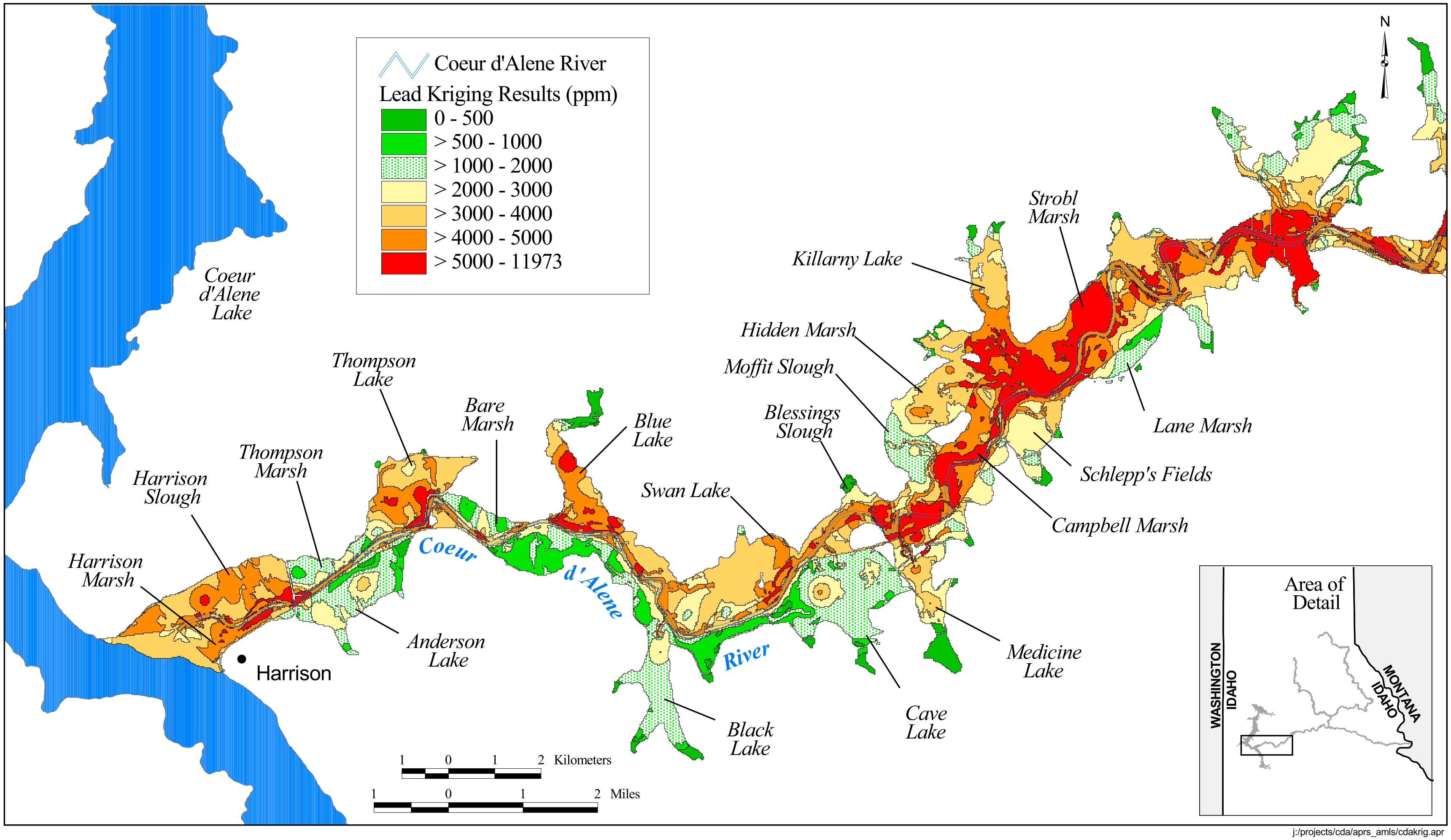

Figure 10-15b. Distribution of lead concentrations in surface sediments of the lower Coeur d'Alene River basin — western half.
Data source: Kern, 1999.

Modeled predictions of lead concentration in surficial sediments were used to estimate the area of contaminated sediments that exceeded four threshold concentrations. The first threshold, 30 ppm lead, is the geometric mean baseline concentration. The second threshold, 175 ppm lead, is the upper 95th percentile of baseline concentrations (Table 10-8). The third, 530 ppm lead, is a lowest observed effect level for waterfowl (Beyer and Audet, 1999). The fourth, 1,800 ppm lead, is a lethal effect level for waterfowl (Beyer and Audet, 1999). Area was calculated as the number of 25 meter pixels in the floodplain with predicted lead concentrations exceeding a given threshold. Results are expressed in acres (0.1544 acres per pixel). Estimates of acreages and percentages of the lower Coeur d'Alene River basin floodplain that exceed the four threshold values are presented in Table 10-18. The distributions of sediments exceeding the 175 ppm, 530 ppm, and 1,800 ppm thresholds are shown in Figures 10-16, 10-17, and 10-18.

Table 10-18
Estimated Area of Sediments Containing Greater than 175 ppm Lead in the Lower Coeur d'Alene River Floodplain

Lead Threshold (ppm)		Acres Exceeding Threshold	Acres Less than Threshold	Floodplain that Exceeds Threshold (%)
Lethal threshold:	1,800	15,368	3,838	80
Lowest observed effect level:	530	18,298	908	95
90th percentile of baseline:	175	18,558	648	97
Geometric mean baseline:	30	18,608	598	97

Sources: Kern, 1999; pers. comm. B. Jackson, Coeur d'Alene Tribe, August 22, 2000.

10.7 RESOURCE RECOVERABILITY

In the Coeur d'Alene River basin, injuries to fish and other aquatic biota, wildlife, and riparian vegetation are caused by exposure to hazardous substances in injured surface water, soils, and sediments. The injured surface water, soils, and sediments of the Coeur d'Alene River basin that should provide habitat for aquatic biota, wildlife, and vegetation instead simultaneously serve as sources, transport pathways, and exposure pathways of toxic concentrations of hazardous substances to these resources. Information presented in Chapter 2 confirms that sources of hazardous substances to the Coeur d'Alene River basin are ongoing, occur throughout the basin, and release hazardous substances to surface water/groundwater, soils, and sediments. Sources include adits and original waste rock and tailings piles in the upper basin, but also hundreds of millions of tons of tailings and mixed alluvium and tailings that are located in the floodplains, beds, and banks of the South Fork and mainstem Coeur d'Alene River and tributaries, the lateral lakes area, and Coeur d'Alene Lake.

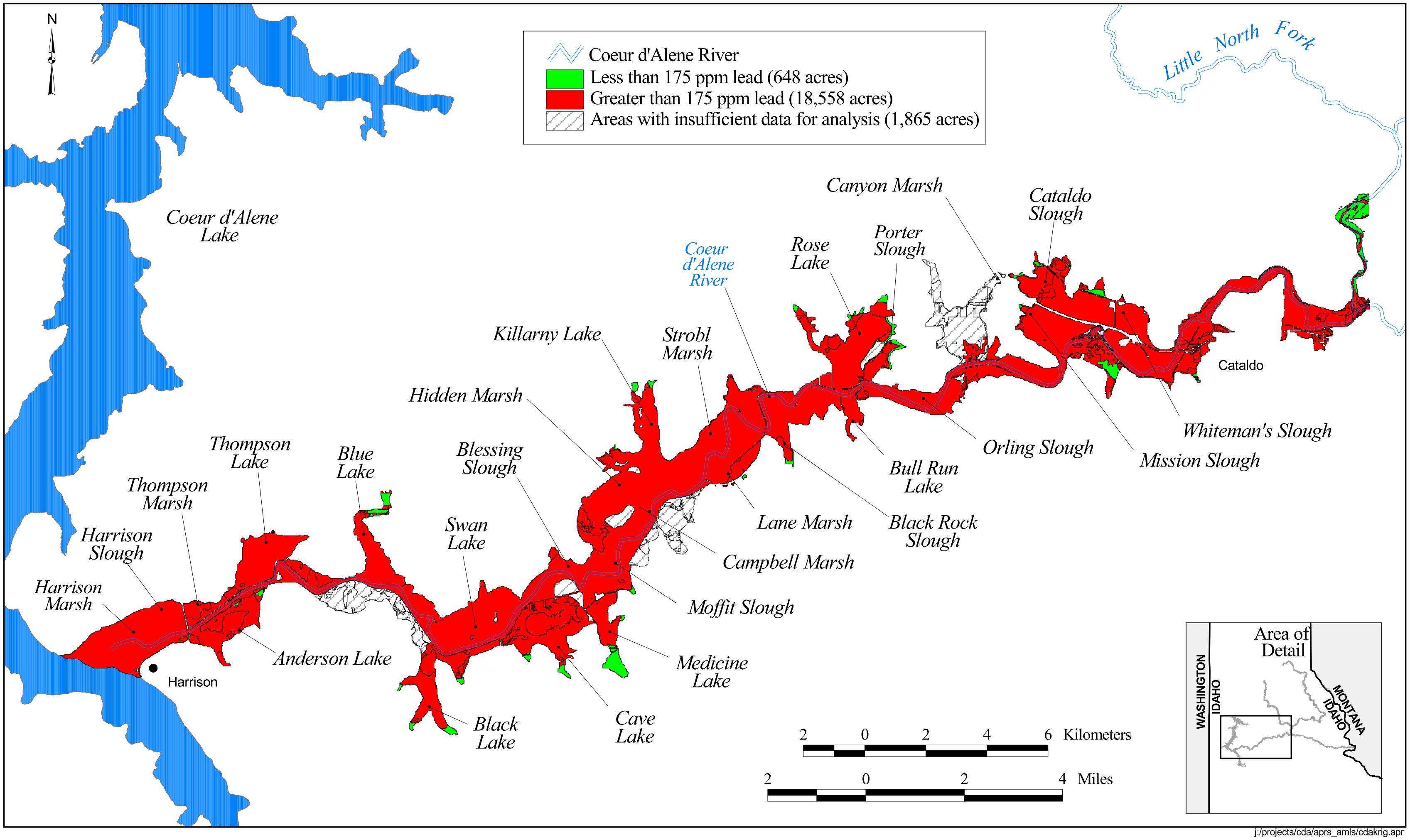

Figure 10-16. Distribution of sediments containing lead at concentrations greater than 175 ppm (90th percentile of baseline).
Data source: Kern, 1999.

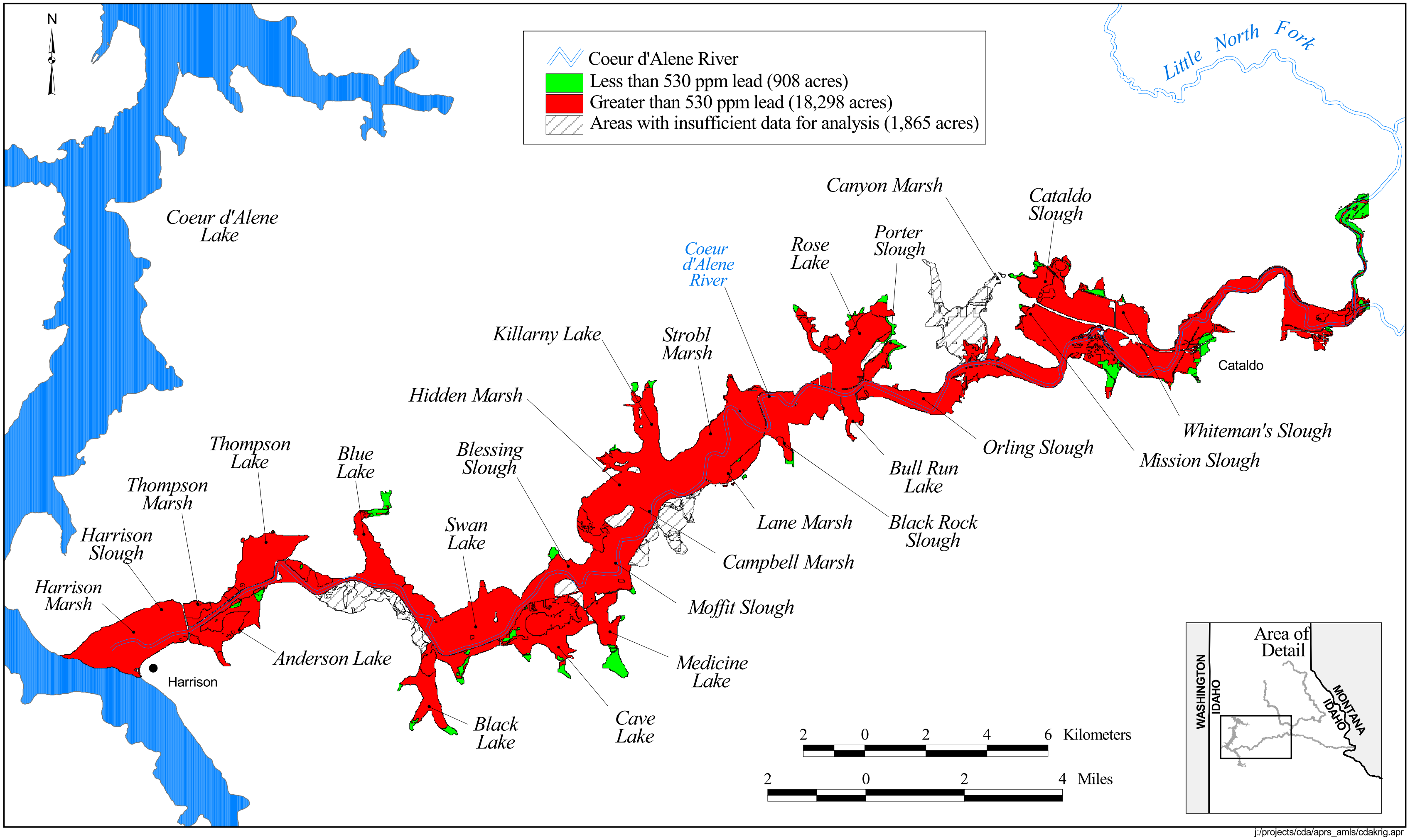

Figure 10-17. Distribution of sediments containing lead at concentrations greater than 530 ppm (lowest observed effect level).
Data source: Kern, 1999.

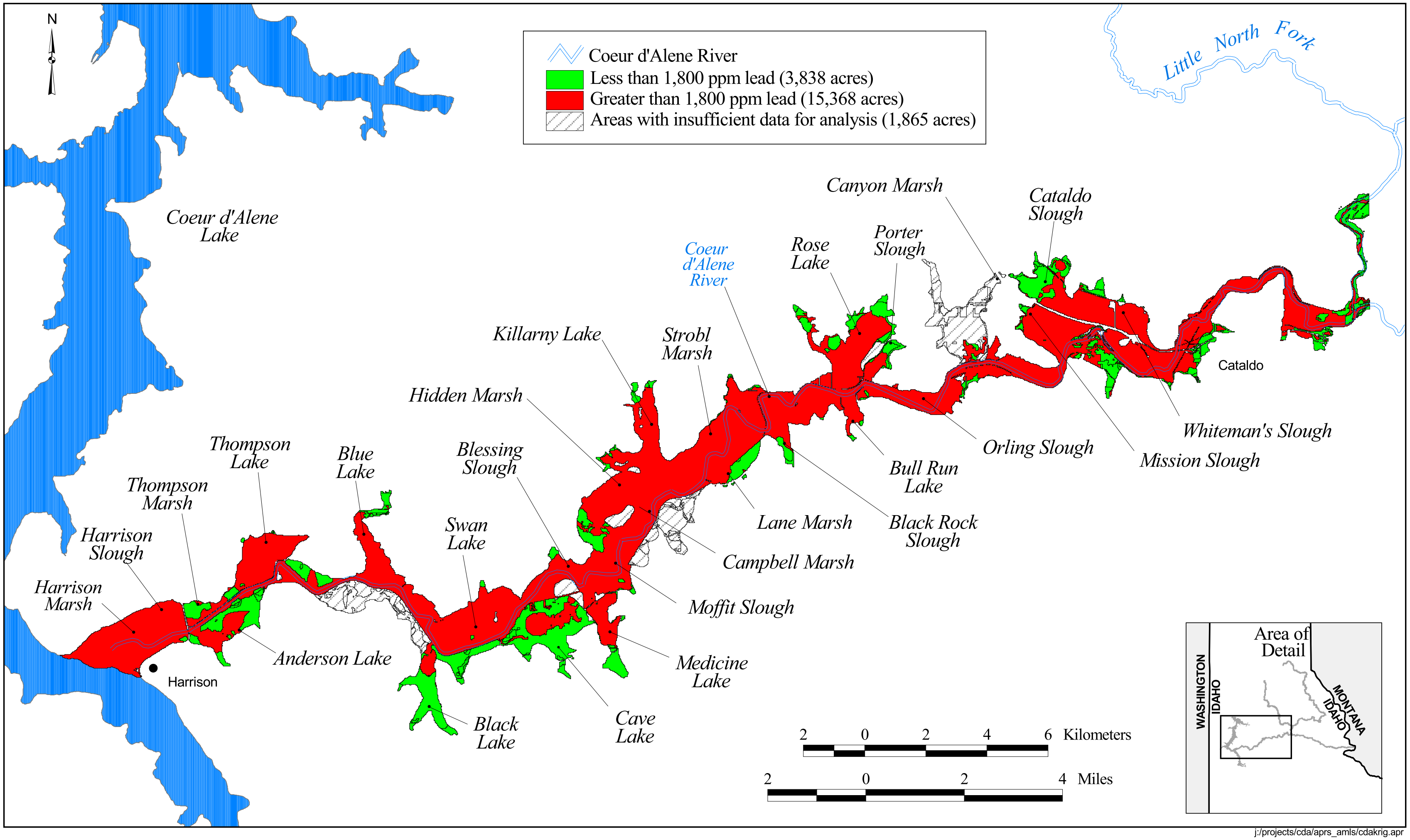

Figure 10-18. Distribution of sediments containing lead at concentrations greater than 1,800 ppm (lethal threshold level).
Data source: Kern, 1999.

The pathways by which hazardous substances are transported in the basin involve natural processes, which will continue to redistribute wastes, thereby exposing natural resources to elevated concentrations of hazardous substances for the foreseeable future. These pathways include surface water pathways (e.g., adit drainage; runoff, erosion, and scouring; suspended and bed sediment transport; dissolved substances transport; and flooding and sediment deposition); groundwater pathways (including infiltration and leaching of hazardous substances from floodplain tailings and mixed alluvium and tailings, and discharge of contaminated groundwater to streams); and sediment pathways (including suspended, bed, bank, and floodplain sediment transport by surface water). Resources will not recover fully until the sources and pathways by which resources are exposed, and injured by, are eliminated. The time required for natural recovery to baseline conditions, given the mass of wastes still in place, is anticipated to be on the order of hundreds of years.

10.7.1 Recoverability of Surface Water Resources

Natural recoverability of surface water resources was assessed in two ways: by evaluating temporal trends in concentrations of cadmium, lead, and zinc in injured reaches, and by examining patterns and magnitudes of ALC exceedences during the last three decades. Concentrations of cadmium, lead, and zinc in surface waters downstream of mining and mineral processing facilities have decreased since the height of mining in the Coeur d’Alene district, mostly as a result of the containment of tailings in the late 1960s. However, overall, existing data do not show clear trends of water quality improvement in the last 20 years.

Three locations in the South Fork Coeur d’Alene River have been sampled intensively during the past approximately 20 years. Total zinc concentrations in the South Fork Coeur d’Alene River near Osburn were measured monthly between July 1978 and December 1990 (MFG, 1991) and approximately monthly from October 1993 to September 1995 by IDEQ. Samples have been collected at the same site less frequently between 1991 and 1998 (in 1991 by MFG and in 1997-1998 by URSG and CH2M Hill). Mean annual concentrations and minimum and maximum concentrations measured at this site between 1978 and 1998 show no clear trend of water quality improvement.

Metal concentrations in the South Fork Coeur d’Alene River near Kellogg and the Bunker Hill complex were monitored between 1972 and 1986 by U.S. EPA (Hornig et al., 1988). Low flow total metal concentrations have decreased since 1979, probably as a result of the cessation of uncontrolled tailings discharge from upstream mines in 1968, waste water effluent controls initiated at the Bunker Hill Complex in 1974, closure and remediation of mineral processing facilities at the Bunker Hill Complex during the 1980s and 1990s, and channel stabilization and lining efforts (Dames & Moore, 1991). However, since the late 1980s, total zinc concentrations upstream and downstream of the Bunker Hill complex have not systematically decreased, nor has the difference between zinc concentration upstream of the site and downstream of the site decreased.

Exceedences of ALC were examined to determine whether water quality is improving at the same three sites on the South Fork Coeur d'Alene River (near Osburn and upstream and downstream of the Bunker Hill complex), in the reach of the South Fork Coeur d'Alene River between Canyon Creek and Milo Creek (SFCDR-3), and at sites near the mouths of Canyon Creek and Ninemile Creek. Acute zinc ALC values were compared to measured zinc concentrations to obtain a magnitude of exceedence (ratio of measured concentration to the ALC; values greater than 1 indicate an exceedence of the ALC). Only zinc concentrations measured during low flow (August through December) were used. If no hardness value was available for calculating the ALC, the mean of all the low-flow hardness values for a given location was used.

In the South Fork Coeur d'Alene River near Osburn and both upstream and downstream of the Bunker Hill complex, and at sites near the mouths of Canyon Creek and Ninemile Creek, all dissolved zinc concentrations measured between 1991 and 1998 during low flow exceeded the acute ALC values. Figure 10-19 shows the magnitude of dissolved zinc exceedences in the South Fork Coeur d'Alene River upstream of the Bunker Hill Complex (at Elizabeth Park), downstream of the complex (at Pinehurst), and at the mouths of Canyon and Ninemile creeks during low flow, 1991 through 1998. Most of the measured concentrations in the South Fork Coeur d'Alene River exceeded the ALC by 10 to 20 times. At Elizabeth Park, both the minimum and maximum exceedences were measured in the late 1990s. In Canyon Creek, exceedences were always greater than 20, and the maximum value measured in both Canyon and Ninemile creeks was near 90 times the ALC. In Ninemile Creek, that maximum value was measured in 1995. No clear trends in improving water quality are apparent from these data.

In reach SFCDR-4 (see Table 4-4 for reach descriptions), all dissolved zinc concentrations measured between the early 1970s and 1998 exceeded the acute and chronic ALC, and most, even into the late 1990s, exceeded the ALC by greater than 10 times (Figure 10-20). Therefore, even at the lowest measured concentrations, surface water resources of the South Fork Coeur d'Alene River remain injured. Again, within the whole reach, no pattern of decreasing magnitude of exceedence with time is evident.

None of the existing concentration or magnitude of exceedence of ALC data indicate declining hazardous substance concentrations with time during the past two decades. There is no clear evidence that maximum, minimum, or mean zinc concentrations have declined, and almost all of the concentrations measured in the South Fork Coeur d'Alene River downstream of Canyon Creek, and all of the concentrations measured at the mouths of Canyon and Ninemile creeks, exceeded acute zinc ALC values at all times that samples were collected over the last 20 to 30 years. Although patterns of recovery may be obscured by variability in flow and climate, the data overall do not indicate that water quality is improving.

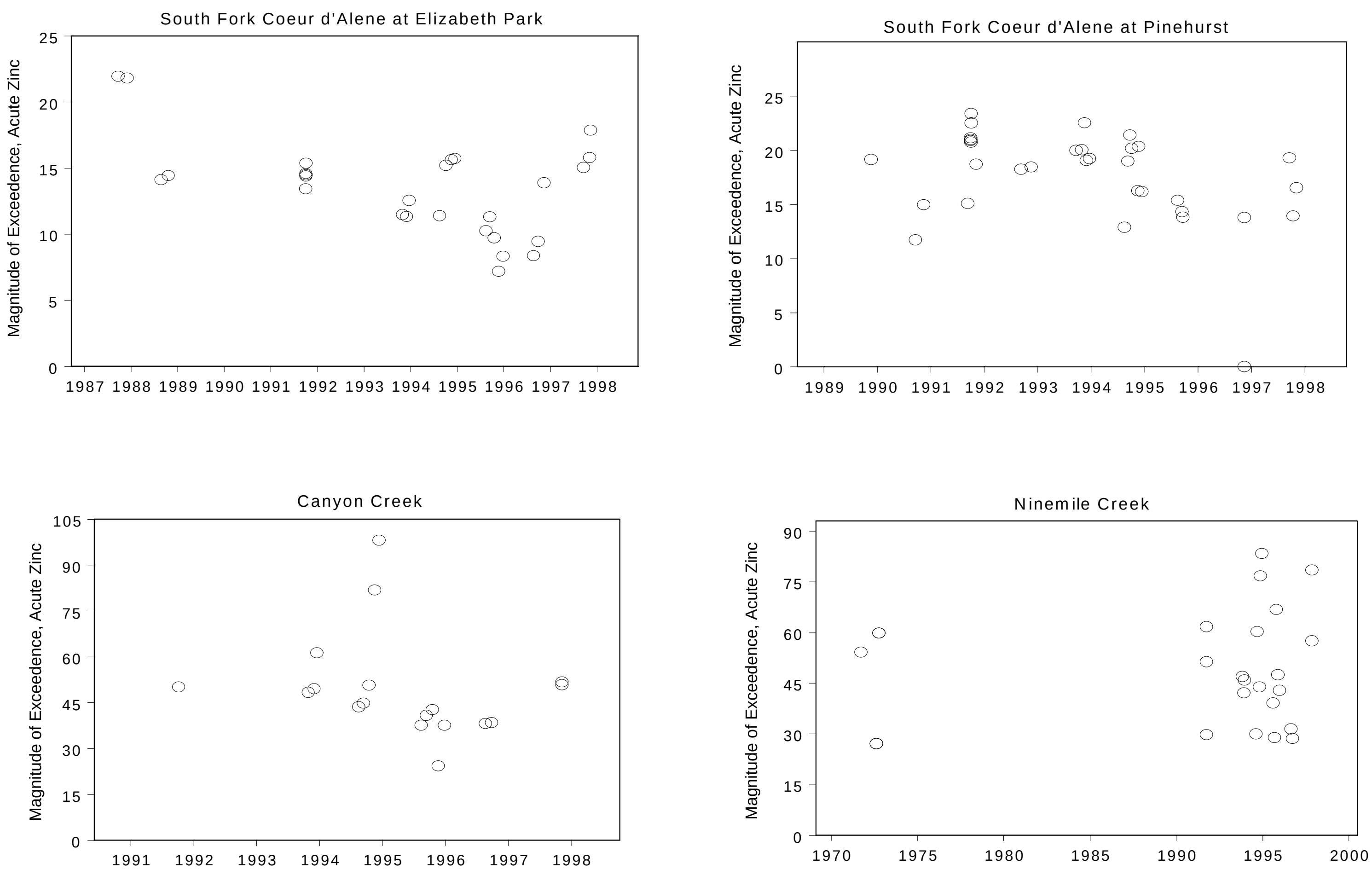

Figure 10-19. Dissolved zinc, acute ALC exceedences during low flow in: the South Fork Coeur d'Alene River at Elizabeth Park; the South Fork Coeur d'Alene River at Pinehurst; Canyon Creek near the mouth; and Ninemile Creek near the mouth. Magnitude of exceedence is the measure concentration divided by the ALC. Values greater than 1 indicate the degree of the exceedence. A value less than 1 would indicate that the ALC was not exceeded.

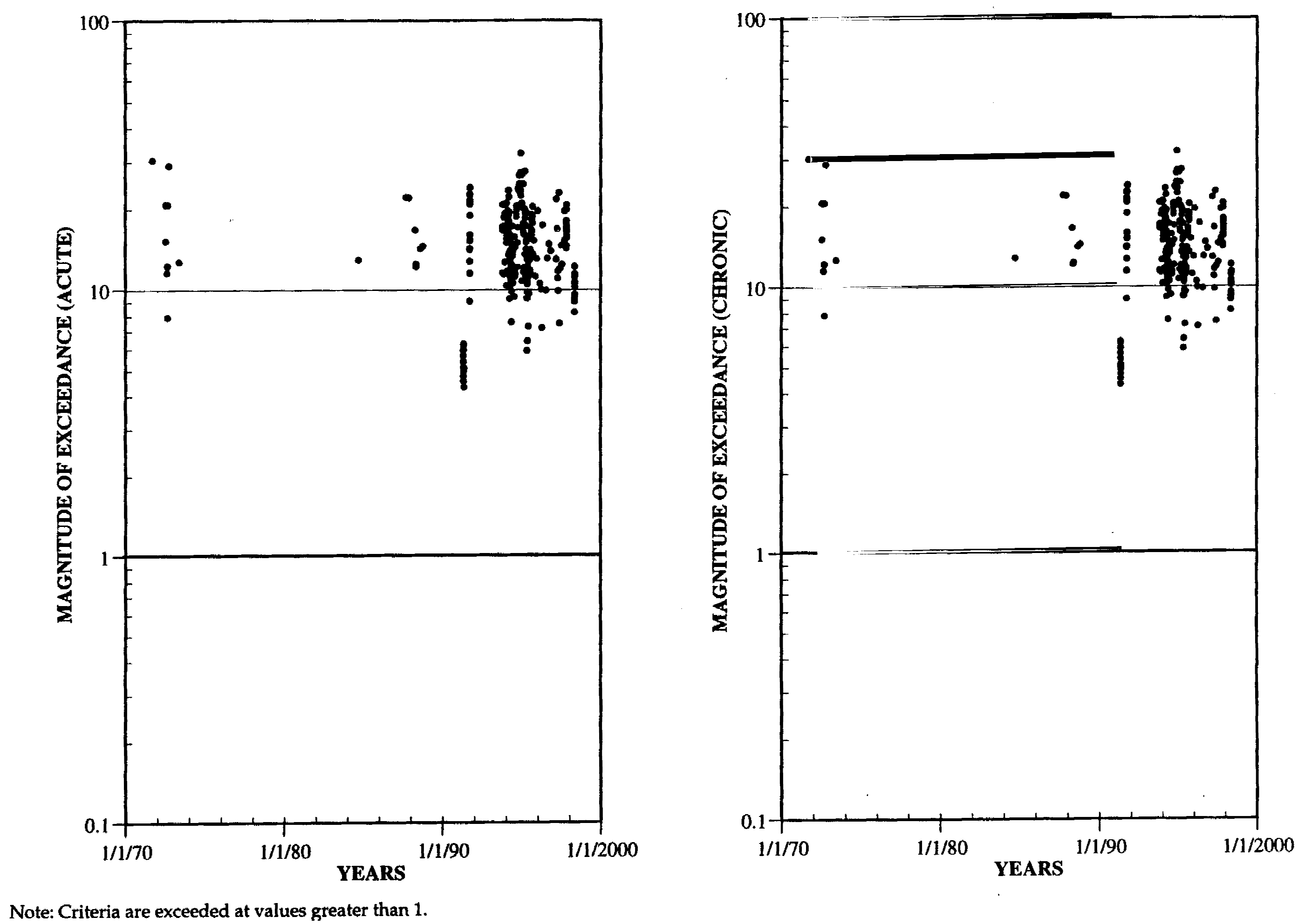

Figure 10-20. Dissolved zinc ALC exceedences, South Fork Coeur d'Alene River, Reach SFCDR-4.
Source: Ridolfi, 1999.

10.7.2 Recoverability of Sediment Resources

As described in Chapter 3, hazardous substances in floodplain tailings deposits, creek and river bed and bank sediments, and lakebed sediments in the Coeur d'Alene River basin continue to be mobilized, transported downstream, and redeposited. Hazardous substances in suspended sediments and bed sediments from upstream sources continue to contaminate downstream resources. Although mobilization of sediments will facilitate mixing and dilution with clean sediment inputs from the North Fork Coeur d'Alene River and unmined tributaries of the South Fork Coeur d'Alene River, existing data indicate that natural recovery of sediments in the Coeur d'Alene basin to baseline conditions will be very slow.

Sediments in Coeur d'Alene Lake generally have an upper, banded zone with high metal concentrations and a lower, unbanded zone with substantially lower metal concentrations (Horowitz et al., 1993). The upper banded zone reflects deposition of mining-related sediment since the early 1900s. The highest measured hazardous substance concentrations in the lake sediments are generally at or near the base of the banded zone (Horowitz et al., 1993). This peak in concentration most likely reflects early mine processing procedures with poor recovery. Sediment metal concentrations in the lower Coeur d'Alene River basin (URSGWC and CH2M Hill, 1998) and in Coeur d'Alene Lake (Horowitz et al., 1995) generally show lower metal concentrations in the more recently deposited metal-enriched sediments than in the sediment deposited earlier in the twentieth century (e.g., Figure 3-4). This pattern reflects changes in ore processing techniques (especially conversion from jigging to flotation) during the twentieth century, and, possibly, the installation of the Cataldo Dredge in the 1930s, the installation of tailings impoundments after 1968, and the closure of many mining and milling operations during the twentieth century. These changes lowered the concentrations of hazardous substances in tailings discharged to basin streams and reduced the volume of tailings entering the lower basin.

There is no evidence that natural mechanisms (i.e., mechanisms other than past improvements in ore processing and waste disposal techniques) have significantly reduced concentrations in surface sediments of the lower basin. In 1993, the USGS collected sediment samples from the 0 to 2 in depth in the lower basin floodplain (Horowitz, 1995). At approximately 40 of the sites sampled, a Mt. St. Helens ash layer deposited in 1980 was visible within the top 2 inches (5 cm).[6] All samples in which the ash layer was visible and intact were analyzed as two samples: an above-ash portion and a below-ash portion. Figure 10-21 shows lead, cadmium, and zinc concentrations in above-ash and below-ash samples collected near Cataldo, Rose Lake, Lane, Mediment, and Black Lake in the lower basin. Data points above the line indicate greater concentration in the above-ash sediment, and points below the line indicate lower concentration in the above-ash sample. Paired t-tests for lead, cadmium, and zinc indicated no significant differences for any of the metals in above- and below-ash samples ($p > 0.05$). There is no evidence that concentrations in sediments deposited since 1980 are lower than sediments deposited before 1980.

6. In Coeur d'Alene Lake, Horowitz et al. (1993) observed the ash layer at 20 cm depth. The greater depth to the ash layer indicates a greater rate of sediment deposition on the lake bed than in the floodplains.

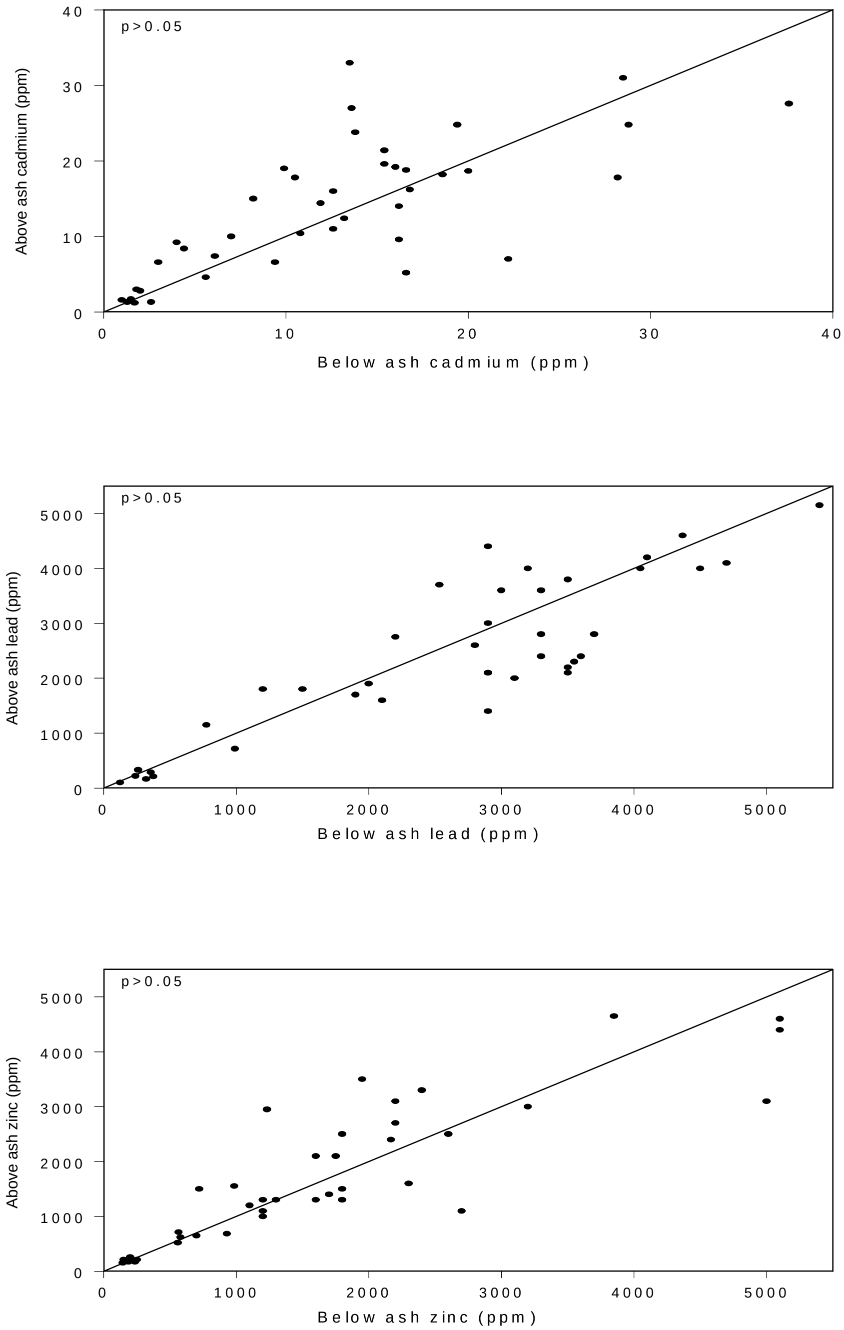

Figure 10-21. Concentrations of lead, cadmium, and zinc in above- and below-Mount Saint Helen's ash layer in 0 to 2 inch sediment samples from the lower Coeur d'Alene River basin floodplain. Line represents equal concentration in the above and below ash sample. $p > 0.05$ indicates no difference in above- and below-ash concentrations (paired t-test).
Data source: Horowitz, 1995.

For lead, cadmium, and zinc, the maximum above-ash concentration is lower than the maximum below-ash concentration for all three metals. At sites with low below-ash metal concentrations, corresponding concentrations above the ash layer are also low. At most other sites, however, there is greater variability in above- and below-ash concentrations. The variability in above- and below-ash concentrations might result from the migration of metals from reducing conditions lower in the sediment column to oxidizing conditions near the surface. Metals released from dissolving iron and manganese hydroxides in the reducing zone will migrate upward and reprecipitate on or with iron and manganese hydroxides in the oxidizing zone closer to the sediment-water interface. This process continually moves hazardous substances upward in the sediment column and obscures and inhibits any natural recovery that might have occurred in the more recently deposited sediments. Where below-ash concentrations are low, any redistribution of metals would not substantially affect concentrations above the ash layer. However, where below-ash metal concentrations are high, upward migration of metals from the reduced to the oxidized zone would again contaminate surface sediments and obscure any natural recovery.

For lead, although the difference was not significant, more of the above-ash concentrations are lower than below-ash concentrations. However, for cadmium and zinc, though also not significant, more of the above-ash concentrations are greater than below-ash concentrations. These slight differences among metals may reflect differences in the geochemical mobility of the metals in sediments and pore waters, or differences in the densities of lead sulfide, zinc sulfide, and cadmium bearing sulfides. Physical settling of lead sulfides, their immobility in oxidizing environments, and their restricted mobility in reducing environments relative to cadmium and zinc may explain the observed metal-specific concentration patterns in recently deposited lower basin sediments. The patterns of cadmium and zinc concentrations suggest evidence of a mechanism of ongoing in-situ recontamination.

There has been no consistent sampling of sediments over time at designated locations as there has been for surface water. Although numerous sediment samples have been collected (Tables 2-9 through 2-11 and 2-14 through 2-17 and additional data collected recently for the RI/FS), sampling locations, depths, and methods have varied. In general, however, recent sediment data collected from the lower basin for the NRDA (Hagler Bailly, 1995; Campbell et al., 1999) and the RI/FS (URSG and CH2M Hill, 1998) are consistent with data collected previously. There are no indications that sediment concentrations of cadmium, lead, and zinc are consistently decreasing over the past 20 years, for example, based on qualitative comparison to results of some of the earliest studies in the basin (e.g., Bauer 1974; Maxfield et al., 1974; Reece et al., 1978). The data ranges presented in Tables 2-9 through 2-11 and 2-14 through 2-17 are overlapping across years. Neither maximum nor mean values have consistently decreased.

In conclusion, metals concentrations in sediments above the ash layer deposited in 1980 do not differ significantly from metals concentrations immediately below the ash. This analysis compares an approximately 15-year period since the ash was deposited (samples were collected in 1993) to an unknown but approximately similar period before 1980. The results indicate no recovery of surface sediments in the lower basin. Comparison of sediment data collected in the late 1990s to data collected in the 1970s also shows no sign of recovery.

10.7.3 Recovery of the Coeur d'Alene River Basin Ecosystem

Recovery of fish, benthic invertebrate, wildlife, and riparian resources is dependent on recovery of surface water, sediment, and floodplain soil resources. Once surface water, sediment, and floodplain soil resources have recovered to a condition that will support biological resources, recovery of the Coeur d'Alene River basin ecosystem will be constrained by the rate of natural physical and biological recovery (vegetation reestablishment and physical habitat rebuilding by natural hydrologic, geologic, and biological processes).

For wildlife resources of the lower basin, recovery will occur rapidly once sediments are nontoxic, since physical modifications resulting from sediment injuries are not negatively affecting habitat use. Since there is a source of clean sediments from the North Fork Coeur d'Alene River basin and from clean South Fork Coeur d'Alene River tributaries to the lower basin, it is possible that eventually the contaminated sediments will be buried. Although natural recovery of sediments will probably take hundreds to thousands of years and major floods may continue to re-expose buried contaminated sediments, wildlife populations will benefit incrementally during the time when sediment metal concentrations in feeding areas diminish.

As surface water and sediment conditions improve, benthic macroinvertebrates from upstream clean reaches and clean tributaries will colonize recovered areas naturally and rapidly. Partial recovery of benthic macroinvertebrate communities was observed after tailings discharges to the basin ceased in 1968 and the physical stress of the large volume of unstable bed sediments in the upper basin diminished. Recovery will not be complete until water quality improves and physical habitat recovers.

Fish populations and communities can also begin to recover as water quality improves. Fish already present in the headwaters and clean tributaries of the upper basin can move into recovered reaches as the habitat allows. Recovery time for fish will include time required for natural reestablishment of physical features of habitats that were degraded as a result of the injuries, such as overhanging banks, vegetative overhang, and pools created by woody debris and roots. Natural recovery of the aquatic physical habitat of the upper basin will depend strongly on recovery of riparian resources.

Natural recovery time for riparian resources will depend on time required for floodplain soils to become diluted to nonphytotoxic levels, followed by primary vegetation succession, organic soil development, and development of vertically and horizontally diverse vegetation communities. Natural recovery of riparian resources includes development of vegetation that will overhang the stream, modulate stream temperatures, and provide security cover for fish. It includes recovery of riparian vegetation to the point where the vegetation provides habitat structure (e.g., large woody debris; bank stabilization) and a source of energy (i.e., detritus) to the aquatic ecosystem. It also includes reestablishment of diverse early and late successional vegetation and the expected range of terrestrial habitat features (e.g., mature tree boles for tree-cavity nesting birds).

Throughout the Coeur d'Alene River basin, the hazardous substances cadmium, lead, and zinc are the cause of the injuries described in this report. Existing concentrations of cadmium, lead, and zinc in the basin, ongoing releases of these hazardous substances from sources, and ongoing transport and exposure pathways limit natural recovery of the injured resources. There will be little recovery unless releases from sources are eliminated and transport and exposure pathways are eliminated. Existing surface water and sediment data show no evidence of either elimination of sources or pathways over the last 20 to 30 years. Therefore, it is reasonable to expect that natural recovery of the Coeur d'Alene River basin ecosystem will take hundreds of years.

10.8 REFERENCES

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