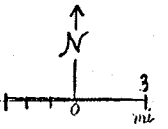
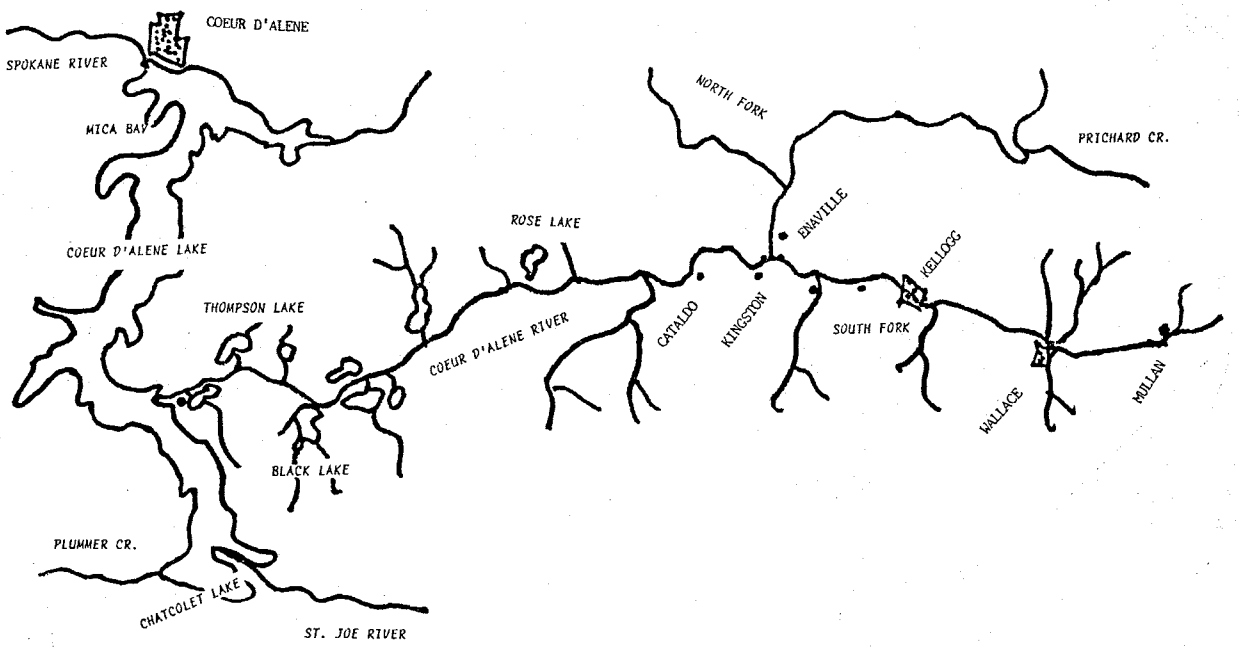
A TOPICAL REVIEW OF ENVIRONMENTAL STUDIES IN THE COEUR D'ALENE RIVER-LAKE SYSTEM

By
Nancy L. Savage





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INTRODUCTION

For over 100 years, the mining industry in the South Fork Coeur d'Alene River drainage has produced millions of dollars worth of gold, silver, zinc, lead, copper and antimony. However, waste products from mining, milling and smelting operations have seriously affected the soil, air, and water quality of the South Fork valley below Mullan. The environmental impact extends to the mouth of the main stem of the Coeur d'Alene River and into Coeur d'Alene Lake and the Spokane River (Fig. 1).

Recent treatment measures such as settling ponds for mill tailings in 1968 and tall smelter stacks in 1974 lessened the immediate impact of operations on the environment. In 1981, the lead smelter, electrolytic zinc plant, phosphoric acid and fertilizer plants, cadmium plant and sulfuric acid plants at the Bunker Hill complex closed down. At the present time, only an ore crusher and concentrator, a wastewater treatment plant, and the Bunker Hill mine pumps are operating.

Because the smelter emissions were responsible for many of the environmental and health problems in the vicinity of the complex, shutdown has removed an important point source of hazardous materials. However, hazardous materials are distributed throughout the South Fork and main stem valleys though their extent and the potential for continued contamination of surface and ground water and biological systems is unknown.

During the decade 1968-1978, numerous studies were done on the effects of contaminated wastes, especially heavy metals (Pb, Zn, and Cd) on environmental quality. When the adverse effects on human health,

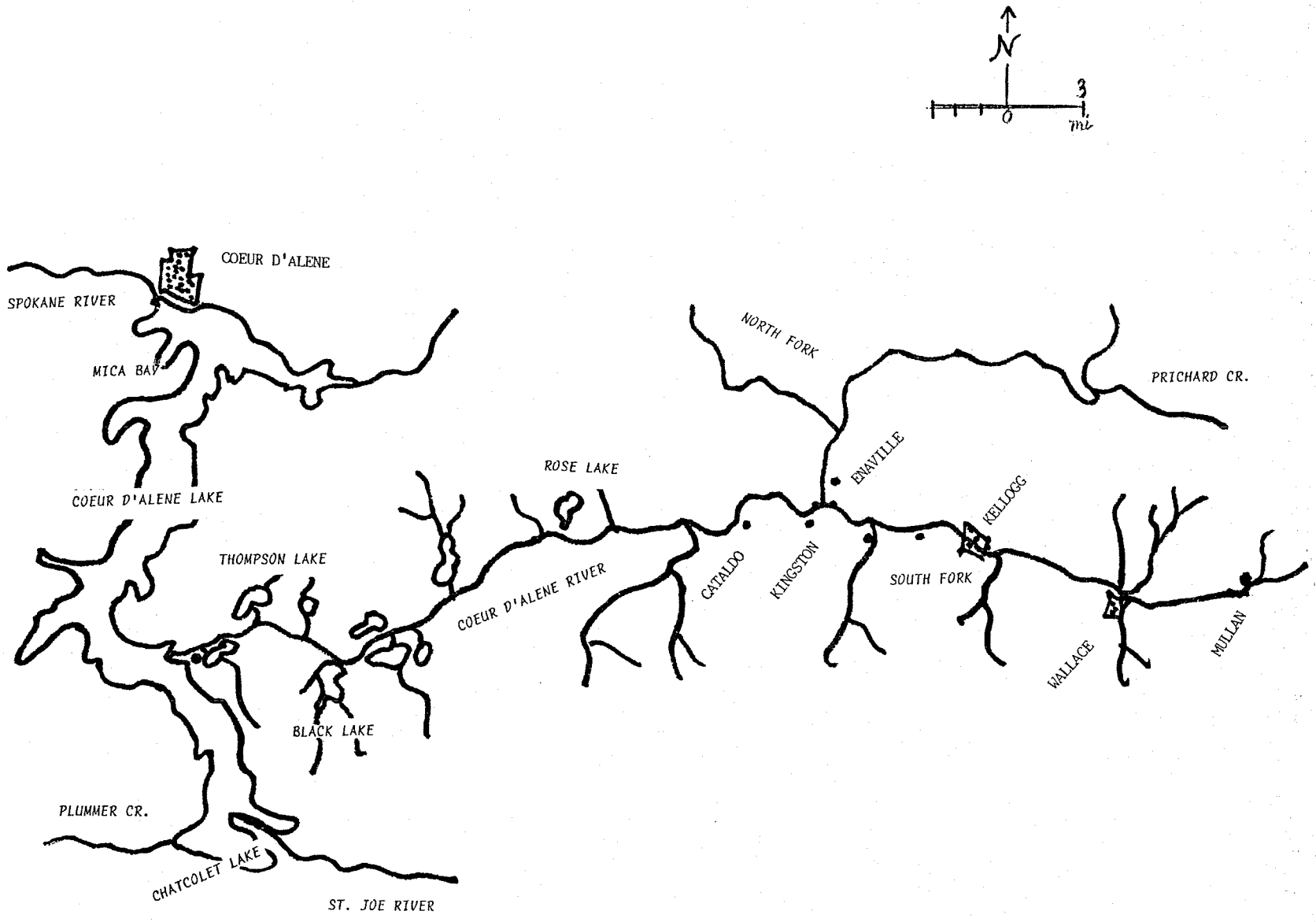

Figure 1. Location map - Coeur d'Alene River-Lake System

primarily elevated blood-lead levels in children, were documented by the Idaho Department of Health and Welfare and others, the area between Pinehurst and Kellogg was designated an EPA CERCLA (Superfund) site (Fig. 2). The object of this designation was to make past and present owners of the Bunker Hill complex legally responsible for rehabilitation of the area.

Recently there has been renewed interest in basic and applied research in the Coeur d'Alene River-Lake system in order to study and evaluate the changes that have occurred. This report was initiated in response to that interest. Preparation has been facilitated by the recent publication of two other reports, Wai et al (1985) and Woodward Clyde et al (1985). Wai presented abstracts of virtually all University of Idaho and Washington State University research performed between 1954 and 1984. Woodward Clyde presented a description of the environmental history of the Bunker Hill complex and vicinity with emphasis on contaminants, their levels in soil, air and water, and their effect on human health as a first step in the Superfund program of remedial action.

I added to the above resources by contacting state and federal agencies and University of Idaho and Washington State University personnel with a history of past work in the area for recent and ongoing studies. I also located additional past studies through bibliographic research. The bibliography of this report lists 239 environmental studies in the Coeur d'Alene River-Lake, upper Spokane River system, most, but not all, mining related.

The objectives of this report were to:

1. Bring up-to-date the literature pertaining to the environmental

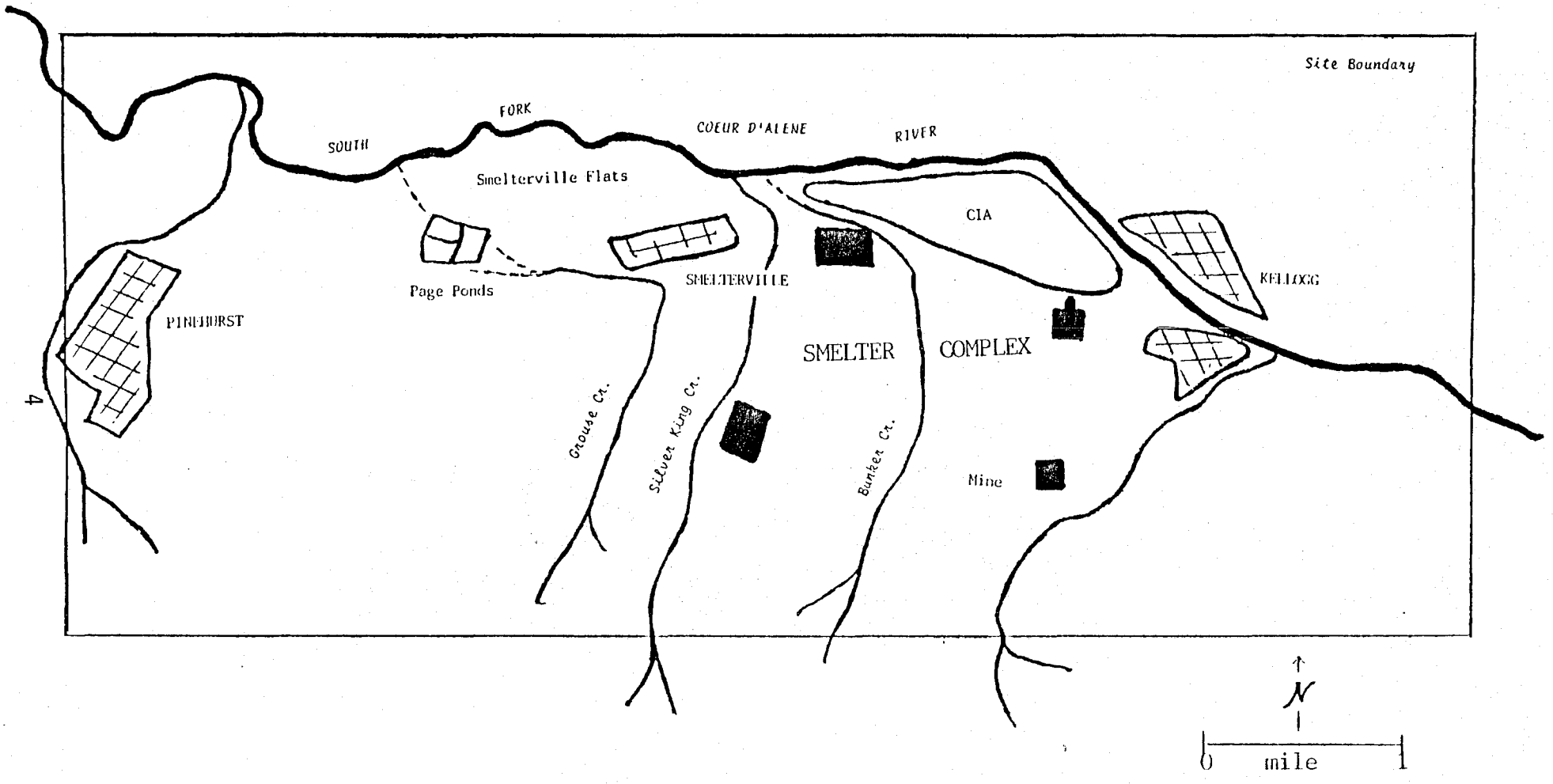

Figure 2. EPA Superfund Site and Bunker Hill Complex on South Fork Coeur d' Alene River

impact of mining and other activities in the Coeur d'Alene River-Lake system.

2. Review the literature to determine what has been done, what is being done, and what needs to be done with respect to basic and applied research in the area.

3. Describe the environmental problems that have been remedied and identify problems that still exist.

TOPICAL REVIEW

References are arranged chronologically under each topic area beginning with the most recent publications. For the most part, only recent and readily available publications have been annotated. Theses and other papers abstracted in Wai et al. (1985) are not described further here. The reader is referred to that publication for complete abstracts. The date, first author, and title only are listed in the topical bibliographies; the complete reference can be found in the alphabetical bibliography at the end of this report. Some topics are treated in more detail than others. Where environmental studies are extensive, existing problems, recent studies and research needs are detailed. In some cases recent data are presented. Other topic areas are commented on only.

A. OVERVIEW REPORTS

The following reports, articles, books, and videotapes were either prepared intentionally as general descriptions of the Coeur d'Alene mining area or were compiled from previous research studies. In addition to these overviews, many of the reports included under other topic areas contain excellent abbreviated histories of the natural and mining-related development of the area.

Overview Bibliography

1985. Woodward Clyde et al. Interim site characterization report, Bunker Hill Superfund Site.
(A compilation of past studies providing information on contaminants and their levels in soils, air, water, aquatic and terrestrial plant and animal life, and humans in a 7 mile by 3 mile area from Pinehurst to Kellogg. Environmental descriptions actually extend beyond the site to include work done throughout the Coeur d'Alene River system.)

1985. Wai, C.M. et al. A bibliography of environmental studies of the Coeur d'Alene mining area, Idaho.
(Abstracts and sample collection and analytical procedures for 80 documents representing virtually all UI and WSU faculty and graduate student research in the Coeur d'Alene River-Lake system from 1955 through 1984.)

1984. Bennett, E.H. A hundred years of mining in the Coeur d'Alene district. (1884-1984)

1979. IDHW/DOE and UI College of Mines. Abandoned mine tailings - reclamation alternatives for Idaho.
(Abstracted in Wai et al. 1985)

1978. Eisenbarth, F. et al. A plan to rehabilitate the South Fork Coeur d'Alene River.
(Physical, biological and cultural resources; identification of problems; research related to rehabilitation; sources of funding; recommendations for rehabilitation; five-year plan of action. An excellent compilation of information illustrated with photos, aerial photos, and maps.)

1976. Johnson, R.D. et al. The heavy metal problem of Silver Valley, northern Idaho.
(Abstracted in Wai et al. 1985)

1975. Funk, W.H. et al. An integrated study on the impact of metallic trace element pollution in the Coeur d'Alene-Spokane River-Lake drainage system.
(Abstracted in Wai et al. 1985)

1974. Rabe, F.W. et al. The river of green and gold.
(Abstracted in Wai et al. 1985)

1973. Flaherty, D.C. Good water? A study of the Coeur d'Alene-Spokane River region.
(Abstracted in Wai et al. 1985)

1973. Funk, W.H. et al. Biological impact of combined metallic and organic pollution in the Coeur d'Alene-Spokane River drainage system.
(Abstracted in Wai et al. 1985)

1963. Cook, E.F. (Ed.) The Coeur d'Alene mining district in 1963.

1961. IBMG. Idaho's mineral industry - the first hundred years.

B. METEOROLOGY/AIR QUALITY

Existing Problems

Although the smelter stack emissions are no longer a factor in air quality, redistribution of contaminated soils, tailings and other deposits in the form of airborne dust remains a concern.

Recent Studies

Permanent weather stations are located at Coeur d'Alene, Kellogg, Wallace, and Mullan for temperature and precipitation and at Enaville and Prichard for precipitation only. Daily records are kept at all stations and are available in monthly and annual reports published by the U.S. National Oceanographic and Atmospheric Administration (U.S. NOAA 1977, 1985).

The Department of Health and Welfare, Division of Environment, maintains and monitors a station at the Kellogg Silver King School for total suspended particulates and sulfur dioxide. Stations at the Kellogg Medical Center, Pinehurst School, and Osburn Radio Station also monitor for TSP. Particulates are analyzed for lead. These data are compiled in an annual open-file report available at the Coeur d'Alene Deptartment of Health and Welfare Office (IDHW/DOE 1985). Woodward, Clyde et al (1985) present a summary of these data from the early 1970's to 1983 showing a dramatic decrease in TSP, lead, and SO_2 following the shutdown of the smelter in 1981 (Tables B-1, B-2, B-3).

Research Needs

1. Wind data in valley area where contaminated deposits are present.
2. Additional monitoring stations for air borne particulates.

Table B-1

Summary of Silver Valley Sulfur Dioxide Measurements (ppm), 1975-1983

Year	3-hr max.	No. of 3-hr max. exceeding 0.5 ppm	24-hr max.	No. of 24-hr max. exceeding 0.14 ppm	Annual arith. mean
1975	1.98	57	0.772	68	0.084
1976	1.20	80	0.581	110	0.096
1977	0.93	31	0.453	40	0.057
1978	0.68	1	0.188	3	0.029
1979	0.45	0	0.222	7	0.032
1980	0.32	0	0.147	1	0.022
1981	0.63	1	0.160	2	0.028
1982	<0.01	0	0.001	0	0.002
1983	<0.01	0	0.003	0	0.002

Table B-2

Total Suspended Particulates (TSP), ug/m^3, ann. geom. means, 1975-1983

	1975	1976	1977	1978	1979	1980	1981	1982	1983
Kellogg Medical Center	81	92	78	67	82	102	77	44	45
Kellogg Silver King School	94	108	84	74	85	107	77	33	32
Osburn Radio Station	62	66	59	55	72	97	77	56	54
Pinehurst School	80	85	82	66	80	103	86	93	66

From: Woodward Clyde et al., 1985, Tables 2-12, 2-14

Table B-3

Lead Concentrations in TSP, ug/m^3, 1975-1983.

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983
				Kellogg Medical Center					
Annual mean	7.4	7.5	6.8	4.7	5.8	5.8	4.1	0.3	0.2
Highest 24 hr mean	53.1	25.4	22.5	36.5	29.0	27.1	16.1	2.1	0.5
				Kellogg Silver King School					
Annual mean	15.9	14.8	59.8	10.7	10.8	8.0	7.5	3.8	0.2
Highest 24 hr mean	61.2	82.1	63.0	138.4	63.9	88.6	32.8	7.7	0.3
				Osburn Radio Station					
Annual mean	1.9	1.6	2.5	1.5	1.8	1.4	0.7	0.1	0.1
Highest 24 hr mean	21.6	9.3	20.4	12.1	18.0	8.4	3.7	0.2	0.5

Modified from Woodward Clyde et al., 1985, Table 2-11

3. Location and composition of contaminated tailings and other deposits subject to wind dispersion.

Meteorology/Air Quality Bibliography

1985. U.S. NOAA. Climatological data Idaho.
(Daily temperature and precipitation data records for the year. An annual report, issued monthly, published since around 1900. Stations at Coeur d'Alene, Kellogg, Wallace, Mullan, Prichard and Enaville.)

1985. IDHW/DOE. Annual air quality report.
(Stations at Kellogg Medical Center, Kellogg Silver King School, Osburn Radio Station and Pinehurst School monitor continuously for TSP and lead concentrations; SO_2 also measured at Kellogg School. These reports are on open-file in area offices and in Boise.)

1985. PES. Draft report documenting the available means for significantly reducing emissions of lead (and their ambient impact) at the Bunker Ltd. lead and zinc smelters in Kellogg, Idaho.

1985. Woodward Clyde Consultants and Terragraphics. Draft interim site characterization report, Bunker Hill Superfund Site.
(Considerable information on air quality monitoring and analysis.)

1984. PEDCo. Emission inventory and lead air pollution control system evaluation for the development of Bunker Ltd. lead emission limits.
(Background information needed to complete the Silver Valley portion of Idaho's lead State Implementation Plan (SIP). This data includes a description of the Bunker Hill lead smelter, an inventory of lead emission sources, potential lead controls and costs for each source, and evaluations and recommendations of an ambient air model for the area. Also contains references to earlier PEDCo air analysis reports.)

1981. Alsid, Snowden and Associates. Bunker Hill Co. Source Test Observations.

1981. Cooper, J.A., et al. Determination of source contributions to air particulate lead and cadmium levels in Kellogg, Idaho using the Receptor Model.

1981. von Lindern, I. Ambient air analysis of Bunker Hill smelter emissions.

1979. Wayne, L.G. and I.J. Weisenberg. Studies of air quality in Silver Valley, Idaho - estimates of area source emissions of particulate matter and lead.

1979. IDHW/DOE. Silver Valley non-attainment area for achievement of the total suspended particulate national ambient air quality standards.

1977. Brooks, K.D. Investigative study of non-attainment of primary national TSP standards in the Silver Valley of Idaho.

1977. Ragaini, R.C. et al. Environmental trace metal contamination in Kellogg, Idaho near a lead smelting complex.
(Soil cores, grasses, and ambient air aerosols near the smelter.)

1975. North American Weather Consultants. Stack height evaluation for the Bunker Hill Company, Kellogg, Idaho.

C. GEOLOGY

Comments

The total geologic bibliography is extensive due to the economic importance of the Coeur d'Alene mining district. The following abbreviated bibliography includes books, articles, videotapes and maps dealing with geology, topography, geochemistry, mines, and mining activities. Excellent overviews of the geology of the area are presented in Eisenbarth (1978), Hobbs (1965), and Reid (1961) as well as in many of the graduate theses dealing with ground water or other aspects of the environment.

Recent work includes intensive study of the Bunker Hill Mine by University of Idaho, Department of Geology, faculty and students; theories of ore genesis by the Idaho Geological Survey; and geochemical studies by USGS personnel. The Idaho Geological Survey has a complete file of production records for Bunker Hill until closure and other records to date.

Geological Bibliography

1984. Bennett, E.H. A hundred years of mining in the Coeur d'Alene district.
(1884-1984)

1984. Bennett E.H. A hypothesis concerning the genesis of orebodies in the Coeur d'Alene mining district, Idaho.

1984. Landis, G.P. et al. Silver-base metal mineralization as a product of metamorphism - Coeur d'Alene district, Shoshone County, Idaho: Concepts of genesis.

1983. Mitchell, V.E. and E.H. Bennett. Production statistics for the Coeur d'Alene mining district, Shoshone County, Idaho -- 1884-1980.

1982. Bennett, E.H. and R. Venkatakrishnan. A palinspastic reconstruction of the Coeur d'Alene mining district based on ore deposits and structural data.

1982. Reid, R.R. and G.E. Williams (Ed.). Society of Economic Geologists' Coeur d'Alene Field Conference - 1977.

1981. Griggs, A.B. Geologic map of the Spokane quadrangle Washington, Idaho, Montana. (Scale 1:250,000).

1981. Harrison, J.E. et al. Generalized geologic map of the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho. (Scale 1:250,000).

1980. Bateman, A.F. et al. Leaseable mineral and waterpower land classification map of the Wallace quadrangle, Montana and Idaho. (Scale 1:250,000)

1980. Gott, G.B. and J.B. Cathrall. Geochemical-exploration studies in the Coeur d'Alene district, Idaho and Montana.
(Geology and geochemical distribution of selected metals in rocks and soils in the Coeur d'Alene district.)

1979 (1980). Gott, G.B. and J.B. Cathrall. Ten maps showing distribution of selected metals in rocks and soils of the Coeur d'Alene district.
(See alphabetical bibliography for specific citation on each map.)

1979 (1980). USGS. Aeromagnetic map of the Coeur d'Alene district, Idaho and Montana.

1975. Gott, G.B. and J.M. Botbol. Possible extension of mineral belts, northern part of Coeur d'Alene district, Idaho.

1973. Gott, G.B. and J.M. Botbol. Zoning of major and minor metals in the Coeur d'Alene mining district, Idaho, U.S.A.

1972. Mathewson, D.C. Structures related to the Osburn fault, Coeur d'Alene mining area, Idaho.

1969. Crosby, G.M. A preliminary examination of trace mercury in rocks, Coeur d'Alene district, Idaho.

1967. Anderson, R.A. Graben structure in the Coeur d'Alene district.

1965. Hobbs, S.W. et al. Geology of the Coeur d'Alene district Shoshone, County, Idaho.
(Most comprehensive treatment of topic)

1964. Fryklund, V.C. Ore deposits of the Coeur d'Alene district, Shoshone County, Idaho.

1961. Reid, R.R. (Ed.). Guidebook to the geology of the Coeur d'Alene mining district.

1954. Dort, W. Glaciation of the Coeur d'Alene District, Idaho.

1952. Mitcham, T.W. Indicator minerals, Coeur d'Alene silver belt (Idaho).

1940. Anderson, A.L. Geology and metalliferous deposits of Kootenai County, Idaho.

1908. Ransome, F.L. and F.C. Calkins. The geology and ore deposits of the Coeur d'Alene district Idaho.

D. SOILS

Existing Problems

1. Heavy-metal contaminated soils subject to wind and water erosion;
2. Denuded and eroded slopes from past fires and smelter effluents;
3. Above normal blood-lead levels in children attributed to contaminated soils;
4. Phytotoxicity of soils.

Recent Studies

A USDA Soil Conservation Service soil survey of Shoshone County, now underway, should be extremely valuable in characterizing soils throughout the area. Comparisons of present soil contamination levels and vegetation with earlier conditions will provide data important to research and rehabilitation. However, the results of this study may not be available for several years.

The Kootenai County area soil survey completed in 1981 includes the valley of the main stem below Cataldo and much of the lands draining into Coeur d'Alene Lake.

Woodward Clyde et al. (1985) contains an extensive analysis and discussion of soils research with emphasis on the work of Gott and Cathrall (1979) and IDHW (1974-1983). Blood-lead levels are still above normal in children born since the smelter closure in 1981. Recent studies by IDHW (1985) implicate residual soil contaminants as the primary cause. This will be a major consideration in continued EPA/IDHW involvement in the area. The soil profile or concentration gradient of contaminants will be especially significant in rehabilitation efforts such as soil removal.

Gott and Cathrall (1984) mapped distributions for selected metals in the Coeur d'Alene district and pinpointed "hot spots" of high lead and zinc contamination (Fig. D-1). Lead and zinc were high in all soil samples collected from slopes on the south side of the valley between Smelterville and Kellogg (von Lindern 1985).

Research Needs

1. Current level of soils metals (lead, cadmium and zinc) in areas sampled over ten years ago. Statistically valid resampling program using comparable methodologies.
2. Sample for additional contaminants such as copper, silver, beryllium and selenium.
3. Investigate behavior of metals in the soil profile over time, comparing past with present levels where possible.
4. Continued investigation of phytotoxicity of soils.
5. Continued investigation of human health threat of variously contaminated soils.
6. Continued investigation of methods to control soil erosion.

Soils Bibliography

1986. Terragraphics. Draft geographic information systems and soils characterization report.

1986. USDA SCS. Soil survey of Shoshone County Area, Idaho. (A general soil survey in progress; field work begun in 1985. Will include kinds of soils, their location and potential use; steepness, length and shape of slopes; size of streams and general pattern of drainage; kinds of native plants, present vegetative cover, potential for crops or other vegetation; underlying geology. Will include heavy-metal content of soils in areas impacted by mining activities.)

1985. CDC/IDHW. Kellog revisited - 1983. Childhood blood-lead and environmental status report.

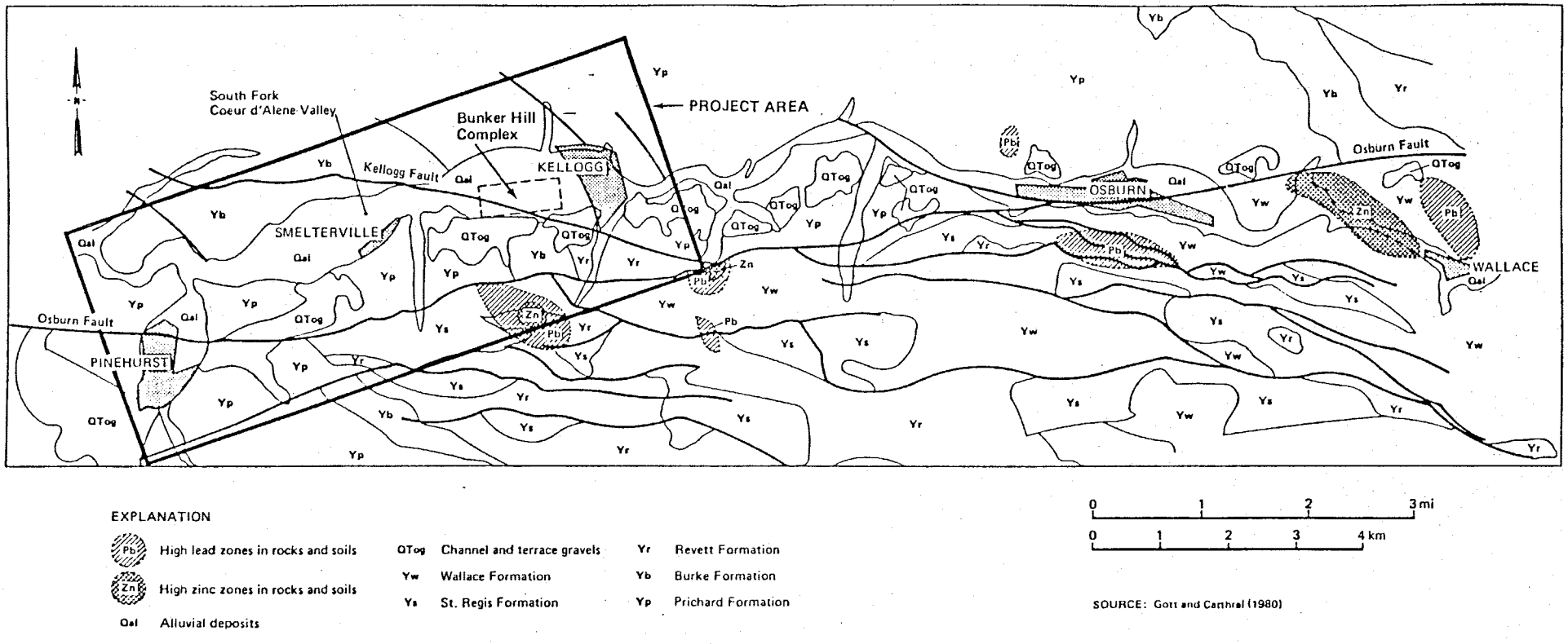

Figure D-1. Generalized map of geology and lead and zinc distributions in rocks and soils of the South Fork Coeur d'Alene River valley (Project Area denotes EPA Superfund site). (Reproduced from Woodward Clyde et al., 1985)

1985. Woodward Clyde et al. Draft interim site characterization report, Bunker Hill Superfund site.
(Results of correlation of soils data from several earlier soils studies at Bunker Hill complex site. Focus on effects of contaminated soil on human health.)

1981. USDA SCS. Soil survey of Kootenai County Area, Idaho.
(Contents as described for Shoshone County survey; field work done 1963-1975.)

1979. Gott, G.B. and J.B. Cathrall. General distribution of metals in rocks and soils in the Coeur d'Alene district, Idaho and Montana.
(Analyzed for 35 elements in 8000 soil and 4000 rock samples between confluence and Montana line.)

1979. Keely, J.F. Trace metals in soils of the Coeur d'Alene River valley and their potential effects on water quality.
(Abstract in Wai et al. 1985)

1978. Eisenbarth, F. and J. Wrigley. A plan to rehabilitate the South Fork Coeur d'Alene River.
(Includes description of topography; history of environmental impact as related to soils and vegetation; soil descriptions summarized from USDA SCS 1974)

1977. Carter, D.B. Amelioration and revegetation of smelter-contaminated soils in the Coeur d'Alene mining district of northern Idaho.
(Abstract in Wai et al. 1985)

1977. Hansen, J.E. Revegetation of toxic soils surrounding lead and zinc smelters.

1977. Ragaini, R.C. et al. Environmental trace metal contamination in Kellogg, Idaho near a lead smelting complex.
(Soil cores, grasses, and ambient air aerosols were sampled for heavy metals at 15 stations between Smelterville and Kellogg.)

1977. Yankel, A.F. et al. The Silver Valley lead study: the relationship between childhood blood-lead levels and environmental exposure.
(Variables included ambient air lead, soil lead, age of child dustiness of home, occupational status of parents; mean lead content of surface soils up to 7,500 ppm.)

1976. IDHW. Shoshone lead health project. Work summary, Jan. 1976.

1976. Keely, J.F. A study of heavy metal pollution in the Coeur d'Alene mining district.
(Abstract in Wai et al, 1985)

1974. IDHW. Phase II survey. Survey of heavy metals contamination, Shoshone County, Idaho. Status report October 2, 1974.

1974. USDA SCS. Inventory and evaluation - soil and water resources of the South Fork Coeur d'Alene River valley.

1973. Gott, G.B. and J.M. Botbol. Zoning of major and minor metals in the Coeur d'Alene mining district, Idaho.

1964. Chupp, N.R. and P.D. Dalke. Waterfowl mortality in the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1960. Kennedy, V.C. and S.W. Hobbs. Geochemical studies in the Coeur d'Alene district, Shoshone Co., Idaho, USGS Bull. 1098-A. 55 p.
(Use of soil and botanical geochemistry in prospecting for Cu, Pb, Zn and Se. Provides background concentrations in ore-rich areas.)

1959. Canney, F.C. Geochemical study of soil contamination in the Coeur d'Alene district, Shoshone County, Idaho.

1956. Chupp, N.R. An evaluation of the lower Coeur d'Alene River waterfowl habitat in Kootenai County, Idaho.
(Abstract in Wai et al. 1985)

E. GROUND WATER

Existing Problems

1. Potential ground water contamination from CIA seepage.
2. Potential ground water contamination from unconfined tailings deposits at Smelterville Flats, Cataldo Flats and other sites (charted in Ioannou, 1979; IDHW/UI, 1979; Eisenbarth, 1978).

Recent Studies

The most recent ground water work has focused on recharge and discharge studies at the Bunker Hill Mine (see Ground Water Bibliography). Earlier studies emphasized ground water contamination of the unconfined aquifer from river-worked tailings deposits such as Smelterville and Cataldo Flats and the Central Impoundment Area (CIA). Contamination from these sources is well documented and summarized in Woodward Clyde et al. (1985). However, recent data on these sources is lacking, and actual contamination of the lower confined aquifer remains unproven.

There has been only one comprehensive study of the valley aquifer (Norbeck, 1974). He sampled 49 wells and ponds for heavy metals, did seismic refraction and electrical resistivity depth soundings at 88 points from Wallace to Rose Lake to interpret thickness of valley fill, and prepared a water table map for the valley. Though considerable well log data is on file at IDWR in Coeur d'Alene, no more recent comprehensive study of the aquifer has been undertaken.

Water quality data from domestic wells is very limited and is confined almost entirely to coliform counts (Panhandle Health District). Municipal water supplies of ground water origin are analyzed regularly by IDHW/DOE for nitrates and conductivity and periodically for metals.

Recent problems include two wells at Osburn with high Cd levels and high Fe at Cataldo. Shallow wells in the Prichard area have occasional problems with high coliform.

Research Needs

1. Identify aquifer characteristics throughout the valley including aquifer type, composition and thickness; pore space, permeability and storage potential; water table position; velocity, volume and direction of ground water flow; leaching potential; and existing and potential uses.
2. Establish a monitoring program for ground water quality using existing wells.
3. Determine the extent and degree of present day ground water contamination from unconfined tailings such as Smelterville Flats.

Ground Water Bibliography

1986. Hartman, M. Tritium dating of ground water in an underground lead-zinc mine, Coeur d'Alene mining district, Idaho. (In progress)

1986. Wai, C.M. and W.M. Mok. A new approach to evaluate redox status in the groundwater pollution problems associated with mine wastes in the Coeur d'Alene mining district, Idaho. (In progress)

1986. Frankel, P. Application of mathematical modeling to the analysis of ground water flow patterns near a deep underground mine.

1985. Erickson, D. Analysis of water movement in an underground lead-zinc mine, Coeur d'Alene mining district, Idaho.

1985. U.S. EPA. National pollutant discharge elimination system (NPDES) permit #000007-8.

1985. Woodward Clyde et al. Draft interim site characterization report - Bunker Hill Superfund site.

1984. Hunt, J.A. Analysis of recharge to an underground lead-zinc mine, Coeur d'Alene mining district, Idaho.
(Abstract in Wai et al. 1985)

1982. Eckwright, T.A. Groundwater flow systems analysis in an active underground mine in the Coeur d'Alene mining district, Idaho.
(Abstract in Wai et al. 1985)

1981. Underwood, J.E. Evaluation of ground water pollution potential from surface impoundments in northern Idaho and eastern Washington.
(Abstract in Wai et al. 1985)

1980. Norton, M.A. Hydrogeology and potential reclamation procedures for uncontrolled mine waste deposition site, Kellogg, Idaho.
(Smelterville Flats; abstract in Wai et al. 1985)

1980. Robinson, Dames, and Moore. Seepage control study central impoundment area, Kellogg, Idaho.

1979. Gaillot, G. and D.R. Ralston. Hydrogeologic analysis and reclamation alternatives for the Jack Waite Mine, Shoshone County, Idaho.

1979. Ioannou, C. Distribution, transport, and reclamation of abandoned mine tailings along the channel of the South Fork of the Coeur d'Alene River and tributaries, Idaho.
(Abstract in Wai et al. 1985)

1979. IDHW/UI. Abandoned mine tailings - reclamation alternatives for Idaho.
(Abstract in Wai et al. 1985)

1979. Williams, R.E. et al. Leakage and seepage control from tailings ponds: the Bunker Hill Company, Kellogg, Idaho.
(Abstract in Wai et al. 1985)

1978. Hawke Engineers. Engineering report - seepage control of central impoundment area and gypsum pond for Bunker Hill Co., Kellogg, Idaho.

1977. Rouse, J.V. Geohydrologic conditions in the vicinity of Bunker Hill Co. waste-disposal facility.

1975. Morilla, A.G. Hydrologic analysis of a tailings pile.
(Abstract in Wai et al. 1985)

1974. Norbeck, P.M. Water table configuration and aquifer and tailings distribution, Coeur d'Alene valley, Idaho.
(Abstract in Wai et al. 1985)

1974. Ralston, D.R. and A.G. Morilla. Ground-water movement through an abandoned tailings pile.
(Abstract in Wai et al. 1985)

1972. Mink, L.L. et al. Effect of early day mining operations on present day water quality.
(Abstract in Wai et al. 1985)

1971. Galbraith, J.H. A study of mine tailings and associated plants and ground water in the Coeur d'Alene district, Idaho.
(Cataldo Flats; abstract in Wai et al. 1985)

F. SURFACE WATER

(Hydrology, Water Quality, Aquatic Sediments)

Existing Problems

1. Sediment transport and deposition within the Coeur d'Alene River under high flow conditions due to reworking of contaminated tailings.
2. Sediment transport and deposition into Coeur d'Alene Lake from inlet streams and rivers.
3. High metal loadings to the South Fork from the Bunker Hill facility including Bunker Creek, Silver King Creek, and the Central Impoundment Area (CIA).
4. High metal loadings to the South Fork from Smelterville Flats and other river-tailings deposits.
5. Increasing nitrate levels in main stem lateral lakes and Coeur d'Alene Lake.

Recent Studies

Water Quality

Until 1979, the USGS routinely monitored the South Fork and main stem for water quality status. After that year, funding was no longer available and regular monitoring ceased. EPA personnel have done occasional sampling since then. In 1983, regular sampling which had been conducted in Coeur d'Alene Lake by EPA was discontinued. Data from these sampling programs are available in USGS Water Resources Data annual publications and in the STORET system.

Results of sampling conducted by EPA in September of 1984 in the South Fork are presented in Table F-1. Pine Creek near mouth and CDR

Table F-1. Water quality data on the South Fork Coeur d'Alene River and listed tributaries, 9/26/84.

Station	Flow	Conductivity	pH	Hardness	As	Cd	Cu	Pb	Zn	Fe	Fl	SO_4
	cfs	umhos/cm		mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l
SFCDR above BH tailings pond	95.2	117.5	7.5	65	8.1	20.9	1.4	18.4	2140	28	0.04	38.6
BH tail seep 1	-	-	6.1	744	39.9	2.8	0.6	-	25170	41130	12.9	775.0
BH tail seep 2	-	-	6.0	757	61.3	3.4	3.5	-	28690	47950	12.4	785.0
BH tail seep 3	-	-	5.8	630	38.0	13.6	2.8	13.8	31160	30410	14.7	660.0
SFCDR above Bunker Creek	93.8	158	-	70	8.6	20.3	1.3	17.4	3320	1216	0.6	64.6
Bunker Creek at mouth	13.4	975	-	849	2.2	32.7	5.4	20.4	1440	256	0.3	740.0
Silver King Cr. at mouth	0.3	145	6.5	80	0.6	28.1	36.3	79.0	9550	45	0.6	79.8
SFCDR below SK Cr.	105.5	292	7.3	190	8.3	28.6	4.1	18.6	3003	1146	0.6	163.0
SFCDR above Pine Creek	117.0	285	6.9	181	6.2	27.7	2.5	22.3	3270	940	0.6	160.0
Pine Creek near mouth	16.9	30	7.4	19	0.5	0.4	2.9	0.5	104	1	0.2	7.0
SFCDR at Enaville	145.5	240	7.0	148	4.1	69.8	22.6	25.4	2563	603	0.5	124.0
CDR at Enaville	311.0	45	7.6	23	3.0	0.2	2.1	0.5	0.5	2	0.02	2.4
CDR at Cataldo	456.0	102	7.4	80	1.4	0.7	9.3	2.5	1.6	826	0.15	381.0
EPA drinking water standards					50	10	1000	50	5000	300	2.5	500

Source: Woodward Clyde et al. (1985) after Peterson (1984).

at Enaville serve as controls. The BH tail seeps are from the Central impoundment Area (CIA) and contribute the highest levels of As, Zn, Fe, Fl, and SO_4. Bunker Creek is high in Cd, Pb and SO_4; Silver King Creek is high in Cd, Cu, Pb and Zn. Other EPA data indicate that levels of most elements decreased in 1982 over previous years but were somewhat higher in 1984 than in 1982. Continued monitoring is needed.

Summary results of zinc and fluoride loadings from 1974 to 1984 are shown in Table F-2. These comparisons indicate that although total basin loading and loading from the Bunker Hill complex have decreased, it is still too high. Also that loadings from sources above Bunker Hill have not changed significantly and now constitute a higher percentage of total basin loadings. The loadings from mile 5.3 to 2.3 are from Smelterville Flats.

In an EPA livebox bioassay in 1982, one year after closure of the smelters, no rainbow trout mortality occurred in the main stem at Cataldo (previous studies had resulted in 72 hour mortalities). However, the South Fork was still acutely toxic from below Wallace to the mouth (Peterson 1982). This study also measured significant concentrations of PCB 1260 in Bunker Creek (0.056 ug/l) and Silver King Creek (1.06 ug/l). Another livebox bioassay is scheduled for the summer of 1986 (Mike Beckwith, IDHW/DOE, personal communication).

In a study of Black Lake in 1984, 8 ug/l of zinc was recorded in several deep water samples (Kann and Falter 1985). Funk et al (1983) recorded five 225 ug/l Zn in the Spokane River at the state line in 1979-1980.

Table F-2. Estimated average loadings of fluoride and zinc in the South Fork Coeur d'Alene River basin, low flow conditions (lbs/day).

Survey Date	River Flow Kellogg cfs	All sources above CIA to mile 6.9		Seepage from CIA area from mile 6.9 to 5.3		Bunker Cr. & CIA discharge mile 6.3		Silver King Cr. discharge mile 5.0		All other inflows from mile 5.3 to 2.3	
		Zn	Fl	Zn	Fl	Zn	Fl	Zn	Fl	Zn	Fl
Oct. 9, 1974	79	1200	-	1450	-	160	-	1900	-	300	-
Oct. 7-9, 1975	122	1620	27	1950	975	400	160	1330	35	450	50
Oct. 5, 1976	79	-	15	-	965	-	170	-	30	-	60
Sept. 18-19, 1979	66	760	10	1000	400	40	690	10	5	700	0
Oct. 7-8, 1980	76	1070	17	1070	460	70	100	10	-	330	70
Sept. 21-22,1982	89	1000	16	650	350	40	250	40	5	350	0
Sept. 26, 1984	95	1100	19	550	280	100	21	20	1	250	40

Source: modified from Woodward Clyde et al (1985) after Peterson (1984).

Nitrate levels seem to be increasing in at least some lower main stem lateral lakes (Kann and Falter 1985; IDHW/DOE 1985) and in Coeur d'Alene Lake (Parker 1978; Molnau and Kessler 1985). This loading is causing eutrophication and toxic algae blooms.

Aquatic Sediments

Recent studies of aquatic sediments include work in Kidd Island Bay of Coeur d'Alene Lake (Molnau and Kessler 1985) and in the lateral lakes of the main stem of the Coeur d'Alene River (Krieger et al. 1986). The Molnau study looked at sources of sedimentation and analyzed bay sediments for bulk density, particle size, nitrate levels, and Mt. St. Helens ash distribution. The Krieger work is ongoing and results from investigation of the death of 200 swans in 1982. Equisetum sp. and high Pb levels were found in the crops of the dead birds. Sediments, food chain organisms and water quality are of particular interest. Rodents are also being analyzed.

Research needs

1. Determination of point sources of high metal loadings at the Bunker Hill complex.
2. Regular water quality monitoring throughout the Coeur d'Alene drainage in order to locate point and non-point sources of contaminants - their extent and degree.
3. Information on PCB's in the aquatic system.
4. Identification of point sources of nitrate loadings and recommendations for mitigation.
5. More research on movement of toxic metals through the food chain.

Surface Water Bibliography

Hydrology and Channel Characteristics

1985. USGS. Water resources data Idaho. Water year 1985.
(An annual report, issued in monthly installments, containing daily stream discharge at USGS gaging stations and some water quality data. Station locations in the Coeur d'Alene and upper Spokane Rivers are:
Coeur d'Alene River above Shoshone Cr. near Prichard,
Coeur d'Alene River at Enaville,
South Fork, Placer Cr. at Wallace,
South Fork at Silverton,
Coeur d'Alene Lake at Coeur d'Alene
Spokane River near Post Falls.

1985. Woodward Clyde et al. Draft site characterization report, Bunker Hill Superfund site.
(Contains hydrological data for the Coeur d'Alene River.)

1982. Seitz, H.R. and M.L. Jones. Flow characteristics and water quality conditions in the Spokane River, Coeur d'Alene Lake to Post Falls dam.

1978. Eisenbarth, F. and J. Wrigley. A plan to rehabilitate the South Fork Coeur d'Alene River.
(Hydrological and flood history; aerial photos of entire valley from Rose Lake to above Wallace.)

1974. Winner, J.E. An evaluation of stream channel relocation, South Fork of the Coeur d'Alene River.
(Results of relocation of 3,360 ft. of the South Fork east of Mullan to allow for construction of a settling pond.)

1969. U.S. Army Corps of Engineers. High velocity channel South Fork Coeur d'Alene River at Wallace, Idaho.
(Design for subsequently built concrete channel at Wallace, including hydrological data.)

Water Quality

1986. DeSmet, J. Northeast Worley water quality study.
(In progress. Analysis of water quality problems related to farming practices on lands drained by streams entering Coeur d'Alene Lake.)

1986. Gruenenfelder, C.R. Hydrological analysis and reclamation recommendations at Continental Mine.
(Appendix will contain data and discussion of follow-up activities on Gaillot and Ralston (1979) report on Jack Waite Mine. In 1980 the National Guard did some stream diversion, gabion installation, slope stabilization and revegetation work. Immediate success was fair to moderate but there has been no routine maintenance and situation is deteriorating.)

1985. Kann, J. and C.M. Falter. Blue-green algae toxicity in Black Lake, Kootenai County, Idaho.
(Plankton and water quality data related to toxic algae bloom.)

1985. IDHW/DOE. Water quality assessment, Black Lake (Kootenai County).
(Water quality characteristics, nutrient loads from tributaries, lake phytoplankton, bacteriological data.)

1985. Molnau, M. and C. Kessler. Analysis of sedimentation and water quality of Kidd Island Bay, Lake Coeur d'Alene, Idaho.
(Sedimentation and eutrophication problems in bay. Nitrate levels in water were .01-.09 ppm; Zn .01-.11; Pb and Hg below detection. High nitrate levels in sediments, 0.4-3.7.)

1985. Peterson, R. Study of the South Fork Coeur d'Alene River.
(Summarized in Woodward Clyde et al. 1985)

1985. U.S. EPA. Algal assay test results north Idaho lakes.
(Algal assay for nutrients, zinc at mouth of Coeur d'Alene River and in Wolf Lodge Bay.)

1985. Woodward Clyde, et al. Draft interim site characterization report, Bunker Hill Superfund site.
(Extensive compilation and discussion of water quality data from past studies.)

1983. Funk, W.H. et al. Water quality of the upper Spokane River and evaluation of methods for measurement of the effect of effluent upon primary and secondary producers.
(Levels of Zn reached 225 ug/l during high flow periods. Levels of most parameters increased at down river stations with water quality decreasing from Class AA at the state line to Class B at Hangman Cr.)

1983. Milligan, J.H. et al. Classification of Idaho's fresh water lakes.
(Classification methodology based on trophic status. Water quality and lake characteristics for 33 lakes including Round, Benewah, Chatcolet, Coeur d'Alene, Cave, and Rose Lakes in the Coeur d'Alene River-Lake system.)

1982. Seitz, H.R. and M.L. Jones. Flow characteristics and water-quality conditions in the Spokane River, Coeur d'Alene Lake to Post Falls Dam, northern Idaho.

1980. Harmon, T. and D. Johann. Water quality status report South Fork Coeur d'Alene River, heavy metal loading survey (Shoshone County), 1975-1976.

1979. Gaillot, G. and D.R. Ralston. Hydrogeologic analysis and reclamation alternatives for the Jack Waite Mine, Shoshone Co., Idaho.
(Surface and ground water in Tributary Cr. as affected by mine tailings and tunnels.)

1979. USGS. Water resources data for Idaho. Water year 1979.
(Total inorganic analysis at gaging stations in South Fork and elsewhere in river system back to around 1968.)

1978. Parker, J.I. and F.W. Rabe. Nutrient enrichment and phytoplankton distributions in Coeur d'Alene Lake, Idaho.
(Abstract in Wai et al. 1985)

1977. Rabe, F.W. and S.B. Bauer. Heavy metals in lakes of the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1977. U.S. EPA. Report on Coeur d'Alene Lake, Benewah and Kootenai Counties, Idaho.
(Macronutrient and coliform levels)

1975. U.S. EPA. River basin water quality status report - Spokane River basin.
(Total inorganic analysis in Coeur d'Alene River and Lake and Spokane River.)

1975. Williams, R.E. and L.L. Mink. Settling ponds as a mining waste-water treatment facility.
(Abstract in Wai et al. 1985)

1975. IDHW/DOE. Water quality status report.
(Aquatic monitoring SFCDAR basin industrial source and receiving water)

1974. Bartlett, L.D. The effects of copper, zinc and cadmium on Selenastrum capricornutum.
(Abstract in Wai et al. 1985)

1974. Bartlett, L.D. et al. Effects of copper, zinc, and cadmium on Selenastrum capricornutum.
(Abstract in Wai et al. 1985)

1974. Bauer, S.B. Heavy metals in lakes of the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1974. Bourg, A.C.M. Uptake of zinc by clay minerals in fresh water.
(Abstract in Wai et al. 1985)

1974. Bourg, A.C.M. and R.H. Filby. Adsorption isotherms for the uptake of Zn^{++} by clay minerals in a fresh-water medium.
(Abstract in Wai et al. 1985)

1974. IDHW/DOE. Water quality survey of Lake Coeur d'Alene.
(Macronutrients, coliform counts)

1974. Winner, J.E. An evaluation of stream channel relocation on the South Fork of the Coeur d'Alene River in northern Idaho.
(Relocation of 3,360 ft. of the South Fork east of Mullan to allow for construction of a settling pond for Lucky Friday Mine; some water quality, macroinvertebate, and fish data.)

1973. Rabe, F.W. et al. Plankton populations and some effects of mine drainage on primary productivity of the Coeur d'Alene River, delta, and Lake.
(Abstract in Wai et al. 1985)

1972. Mink, L.L. Evaluation of settling ponds as a mining wastewater treatment facility.
(Abstract in Wai et al. 1985)

1972. O'Neal, G. Report on Coeur d'Alene River survey May 12-17, 1970.
(Water quality characteristics including heavy metals in South Fork and main stem Coeur d'Alene River and at three transects across Coeur d'Alene Lake - near Harrison and near Coeur d'Alene.)

1972. Parker, J.I. Algae production and nutrient enrichment in Lake Coeur d'Alene, Idaho.
(Abstract in Wai et al. 1985.)

1972. Stokes, L.W. and G.L. Ralston. Water quality survey - Coeur d'Alene River and Lake.

1972. Wissmar, R.C. Some effects of mine drainage on primary production in Coeur d'Alene River and Lake.
(Abstract in Wai et al. 1985)

1971. Mink, L.L. Water Quality of the Coeur d'Alene River basin, 1969, 1970.
(Abstract in Wai et al. 1985)

1971. Mink, L.L. et al. Effect of industrial and domestic effluents on the water quality of the Coeur d'Alene River basin.
(Abstract in Wai et al. 1985)

1971. Sceva, J.E. and W. Schmidt. A reevaluation of the Coeur d'Alene River.
(Follow-up of the O'Neal survey of 1970 (1972). Water quality characteristics and heavy metals in South Fork and main stem Coeur d'Alene River from Mullan to Rose Lake, in South Fork tributary streams, and above and below major mine and mill discharges.)

1971. Williams, R.E. et al. Impact of a well managed tailings pond system on a stream.
(Abstract in Wai et al. 1985)

1970. Savage, N.L. The effect of industrial and domestic pollution on benthic macroinvertebrate communities in two northern Idaho rivers.
(Abstract in Wai et al. 1985)

1969. Sappington, C.W. The acute toxicity of zinc to cutthroat trout (Salmo clarki).
(Abstract in Wai et al. 1985)

1964. Schecter, B. and M.F. Adams. Mine, industrial and domestic waste disposal study for the South Fork Coeur d'Alene River.

Aquatic Sediments

1986. Krieger, R. et al. Lead poisoning in swans in the lower Coeur d'Alene River valley.
(Reports lead concentrations in sediments up to 8000 ppm.)

1985. Molnau, M. and C. Kessler. Analysis of sedimentation and water quality of Kidd Island Bay, Lake Coeur d'Alene, Idaho.
(Sedimentation and eutrophication problems in bay. Study addressed sources of sedimentation, analysis of bay sediments and water quality. Nitrates in sediments were high at 0.4-3.7 ppm.)

1983. Leach, D.L. et al. Distribution of cadmium, antimony, copper, zinc, and silver in samples of nonmagnetic heavy-mineral concentrate and in samples of stream sediment from the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho.

1982. Leach, D.L. et al. Data report and statistical summary for samples of stream sediment and nonmagnetic heavy-mineral concentrates from the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho.

1979. Ioannou, C. Distribution, transport and reclamation of abandoned mine tailings along the channel of the South Fork of the Coeur d'Alene River and tributaries.
(Abstract in Wai et al. 1985)

1978. Reece, D.E. et al. Heavy metal pollution in the sediments of the Coeur d'Alene River, Idaho.
(Abstract in Wai et al. 1985)

1978. Winner, J.E. Sediment discharge of the South Fork of the Coeur d'Alene River.

1977. Rabe, F.W. and S.B. Bauer. Heavy metals in lakes of the Coeur d'Alene valley, Idaho.
(Abstract in Wai et al. 1985)

1974. Bauer, S.B. Heavy metals in lakes of the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1974. Maxfield, D. et al. Heavy metal content in the sediments of the southern part of the Coeur d'Alene Lake.
(Abstract in Wai et al. 1985)

1974. Maxfield, D. et al. Heavy metal pollution in the sediments of the Coeur d'Alene River delta.
(Abstract in Wai et al. 1985)

1974. Reece, D.E. A study of leaching of metals from sediments and ores and the information of acid mine water in the Bunker Hill Mine.
(Abstract in Wai et al. 1985)

1972. Winner, J.E. Macrobenthic communities in the Coeur d'Alene Lake system.
(Abstract in Wai et al. 1985)

1972. Galbraith, J.H. A study of mine tailings and associated plants and ground water in the Coeur d'Alene district, Idaho.
(Abstract in Wai et al. 1985)

1971. Maxfield, D. et al. Heavy metal pollution in the sediments of the Coeur d'Alene River delta.
(Abstract in Wai et al. 1985)

G. AQUATIC ECOLOGY

Existing Problems

1. Toxic blue-green algae (Nostoc commune) in Black Lake.
2. Increasing algae growth throughout river-lake system.
3. Potentially toxic levels of Zn, Pb and Cd in physical and biological systems.

Recent Studies

Several recent studies have described the aquatic ecology of the upper Spokane River in considerable detail (Falter and Mitchell 1982; Funk et al. 1983; Nielsen 1984; T. Underwood, in progress). Although there are some problems with elevated Zn, nutrient, and coliform levels, the overall condition of the various biotic communities is excellent.

Fisheries, especially the Kokanee population, have been studied intensively in Coeur d'Alene Lake (Bennett 1984; IDFG 1975-present). An example of the information acquired during a typical IDFG kokanee survey is shown on the following page (Fig. G-1). Bennett (1983) has also studied bass populations in main stem lateral lakes. Lowry (1986) reports the establishment of a northern pike fishery in the lateral lakes. He has also recorded cutthroat and kokanee spawners in South Fork tributary streams indicating a decreased toxicity of South Fork waters to these species.

Research Needs

1. Study and treatment of algae problems.
2. The aquatic ecology of the Coeur d'Alene River.
3. Pathways of toxic contaminants in the aquatic food chain.

JOB PERFORMANCE REPORT

State of Idaho Name: LAKE AND RESERVOIR INVESTIGATIONS

Project No. F-73-R-3 Title: Kokanee Stock Status in Pend Oreille, Priest and Coeur d'Alene Lakes

Subproject III

Study No. VI

Job No. I

Period Covered: 1 March 1980 to 28 February 1981

ABSTRACT

We made kokanee population estimates in Pend Oreille, Priest and Coeur d'Alene Lakes during 1980 using hydroacoustic and mid-water trawl techniques. We also measured potential egg deposition, monitored survival of both hatchery and wild kokanee stocks and estimated year-class strength for predicting future angler success. A permanent weir station was utilized on Pend Oreille Lake to help assess the status of a kokanee enhancement program on the lake.

Pend Oreille Lake supported 4.7 million kokanee (207/ha, 84/acre) during the fall of 1980 compared to an estimated 12.1 million (534/ha, 275/acre) measured in 1974. Fall estimates in Coeur d'Alene Lake yielded 6.6 million kokanee (679/ha, 275/acre) which was 0.5 million more than estimated in 1979. Kokanee were practically nonexistent in Priest Lake with the population dropping from 279,000 (49/ha, 20/acre) measured in 1978 to less than 43,000 (7.5/ha, 3/acre) in 1979.

We measured survival of wild kokanee fry in Pend Oreille and Coeur d'Alene Lakes by comparing potential egg deposition in the fall of 1979 to abundance of fall fry in 1980. Pend Oreille Lake supported a wild survival rate of 1.3% compared to 2.2% in Coeur d'Alene Lake. Hatchery survival was estimated between 20 and 30% from mid-summer released fry to age 1+ and age 2+ fish and 10% from summer release to age 3+ spawning adult in Pend Oreille Lake.

Estimates of year-class strength made during 1980 for the 1977, 1978 and 1979 year-classes indicate that kokanee catch and catch rates will not improve through the 1983 fishing year in Pend Oreille Lake but they will likely remain the same or increase in Coeur d'Alene Lake. Kokanee fishing in Priest Lake will be practically nonexistent through 1983.

Substantial increases (3 fold) in returns of spawning kokanee to Granite Creek on Pend Oreille Lake suggest that mid-summer releasing fry to better coincide lake residency with available food is a viable management alternative for enhancing kokanee populations.

Author:

Bert Bowler
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Figure G-1. IDFG Job Performance Report

4. Levels of contaminants in biotic components.

5. The effects of contaminants on metabolism of biotic components.

Aquatic Ecology Bibliography

General

1985. Woodward, Clyde et al. Draft interim site characterization report Bunker Hill Superfund site.

1982. Falter, C.M. and B.D. Mitchell. Aquatic ecology of the Spokane River between Coeur d'Alene and Post Falls, Idaho.

1982. Rieman, B.E. Coeur d'Alene Lake Limnology.

1975. Funk, W.H. et al. An integrated study on the impact of metallic trace element pollution in the Coeur d'Alene-Spokane Rivers-Lake drainage system.
(Abstract in Wai et al. 1985)

1973. Funk, W.H. et al. The biological impact of combined metallic and organic pollution in the Coeur d'Alene-Spokane River drainage system.
(Abstract in Wai et al. 1985)

1966. Marcuson, P.E. Limnology and fish food abundance in Round Lake, Idaho.
(Water quality, macronutrients, aquatic vegetation, invertebrates, plankton, and fish.)

1923. Kemmerer, G. et al. Northwest lakes of the United States: Biological and chemical studies with reference to possibilities in production of fish.
(Southern end of Coeur d'Alene Lake)

Algae, Periphyton, Plankton

1985. Kann, J. and C.M. Falter. Blue-green algae toxicity in Black Lake, Kootenai County, Idaho.
(Seasonal composition of zooplankton and phytoplankton communities, seasonal trends in chlorophyll "a", some water quality and macrophyte data.)

1985. IDHW/DOE. Water quality assessment, Black Lake (Kootenai County).
(Water quality characteristics, nutrient concentrations, nutrient loads from tributaries, lake phytoplankton, algal bio-assay results, bacteriological data. Field work done in 1983, 1984.)

1985. U.S. EPA. Algal assay test results north Idaho lakes.
(Algal assay for nutrients and zinc at mouth of Coeur d'Alene River and in Wolf Lodge Bay.)

1984. Nielsen, T.S. et al. A comparison of periphyton growth on artificial and natural substrates in the Upper Spokane River.

1983. Funk, W.H. et al. Water quality of the upper Spokane River and evaluation of methods for measurement of the effect of effluent upon primary and secondary producers.
(Artificial and natural substrates compared and methodologies described for periphyton sampling)

1983. Milligan, J.H. et al. Classification of Idaho's fresh water lakes.
(Phytoplankton and chlorophyll 'a' data)

1978. Parker, J.I. and F.W. Rabe. Nutrient enrichment and phytoplankton distributions in Coeur d'Alene Lake, Idaho.
(Abstract in Wai et al. 1985)

1974. Bartlett, L.D. The effects of copper, zinc and cadmium on Selenastrum capricornutum.
(Abstract in Wai et al. 1985)

1974. Bartlett, L.D. et al. Effects of copper, zinc and cadmium on Selenastrum capricornutum.
(Abstract in Wai et al. 1985)

1973. Rabe, F.W. et al. Plankton populations and some effects of mine drainage on primary productivity of the Coeur d'Alene River, delta, and Lake.
(Abstract in Wai et al. 1985)

1972. Parker, J.I. Algae production and nutrient enrichment in Lake Coeur d'Alene, Idaho.
(Abstract in Wai et al. 1985)

1972. Wissmar, R.C. Some effects of mine drainage on primary production in Coeur d'Alene River and Lake, Idaho.
(Abstract in Wai et al. 19850

1971. Minter, R.F. Plankton population structure in the lower Coeur d'Alene River, delta, and Lake.
(Abstract in Wai et al. 1985)

Macrophytes

1985. Kann, J. and C.M. Falter. Blue-green algae toxicity in Black Lake, Kootenai County, Idaho.
(Includes some observations on macrophytes)

1966. Marcuson, P.E. Limnology and fish food abundance in Round Lake, Idaho.
(Includes macrophytes and associated macroinvertebrates)

1964. Chupp, N.R. and P.D. Dalke. Waterfowl mortality in the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1956. Chupp, N.R. An evaluation of the lower Coeur d'Alene River water-fowl habitat in Kootenai County, Idaho.
(Abstract in Wai et al. 1985)

Macroinvertebrates

1985. Holland, W.K. and M. Chaney. A comparison of the diversity of macroinvertebrates in the South Fork, North Fork, and Main Fork of the Coeur d'Alene River.
(Collection in early spring; Trichoptera, Ephemeroptera, and Plecoptera present in lower South Fork.)

1983. Funk, W.H. et al. Water quality of the upper Spokane River and evaluation of methods for measurement of the effect of effluent upon primary and secondary producers.
(Macroinvertebrates collected by basket, multiple-plate sampler and suction; methodologies described and results compared.)

1977. Rabe, F.W. and S.B. Bauer. Heavy metals in lakes of the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1974. Bauer, S.B. Heavy metals in lakes of the Coeur d'Alene River valley.
(Abstract in Wai et al. 1985)

1974. Winner, J.E. An evaluation of stream channel relocation, South Fork of the Coeur d'Alene River.
(Relocation of a portion of the South Fork channel east of Mullan to allow for construction of a settling pond. Some water quality, macroinvertebrate and fish data.)

1973. Savage, N.L. and F.W. Rabe. The effects of mine and domestic wastes on macroinvertebrate community structure in the Coeur d'Alene River.
(Abstract in Wai et al. 1985)

1972. Winner, J.E. Macrobenthic communities in the Coeur d'Alene Lakes system.
(Abstract in Wai et al. 1985)

1971. Maxfield, D. et al. Heavy metal pollution in the sediments of the Coeur d'Alene River delta.
(Abstract in Wai et al. 1985)

1970. Savage, N.L. The effect of industrial and domestic pollution on benthic macroinvertebrate communities in two northern Idaho rivers.
(Abstract in Wai et al. 1985)

1966. Marcuson, P.E. Limnology and fish food abundance in Round Lake, Kootenai County, Idaho.
(Macroinvertebrates associated with macrophytes)

1963. Olson, R.P. Biological survey of the Coeur d'Alene River.
(Emphasis on macroinvertebrate community)

Fish, Fish Habitat

1986. Lowry, D. Personal communication.
(Cutthroat and Kokanee spawners regularly run the South Fork and are caught in side tributaries and upstream reaches. A large northern pike fishery has been established in the lateral lakes since 1978 - fish grow to 44 inches and 28 lbs.)

1985. Bennett, D.H. and E. Bull. Recruitment and survival of young-of-the year largemouth bass (Micropterus salmoides) in the Coeur d'Alene Lake system, Idaho.
(Bass fishery in lateral lakes)

1984. Bennett, D.H. and P.F. Hassemer. Examination of the spawning ecology and early life history of Kokanee (Oncorhynchus nerka) in Coeur d'Alene Lake.

1984. Tiedemann, R.B. An evaluation of cutthroat trout habitat within the Cedar and Fourth of July Creek drainages Kootenai Co., Idaho.
(Evaluation of physical habitat for spawning and rearing; identification of barriers to adfluvial runs; complete raw data.)

1983. Bennett, D.H. and E.C. Bowles. Recruitment of largemouth bass (Micropterus salmoides) in the Coeur d'Alene Lake system.

1983. Cochnauer, T. Kokanee stock status in Pend Oreille, Priest, and Coeur d'Alene Lakes.

1983. Lewynsky, V.A. and T.C. Bjornn. Coeur d'Alene River fisheries investigations.
(Coeur d'Alene River above Enaville and North Fork fish species, abundance, and distribution, April, 1981 - Feb., 1982. Followup of Bowler 1974 study.)

1982. Bennett, D.H. and P.F. Hassemer. Effects of I-90 construction activities on the spawning success of Kokanee.

1982. Cochnauer, T. Kokanee investigations.

1981. Bowler, B. Kokanee stock status in Pend Oreille, Priest, and Coeur d'Alene Lakes.

1981. Rieman, B.E. and L. LaBolle. Coeur d'Alene Lake creel census.

1978. Ringe, R.R. et al. Survey of streams in the Emerald Empire and Cottonwood resource Areas of Idaho.
(Fishery habitat survey for streams in the South Fork drainage. Includes number and species of fish obtained by electrofishing.)

1977. Rabe, F.W. and S.B. Bauer. Heavy metals in lakes of the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1976. Goodknight, W.H. and T.L. Watkins. Coeur d'Alene Lake fisheries investigations.

1975. Bauer, S.B. Coeur d'Alene River fishery studies.
(Main stem, tributaries, lateral lakes and South Fork fish species and counts; results of live box bioassays.)

1975. Bowler, B. Coeur d'Alene Lake fisheries investigations.

1974. Bowler, B. Coeur d'Alene River study.
(Fishery data from creel census; management plan for Coeur d'Alene River above Enaville.)

1974. Winner, J.E. An evaluation of stream channel relocation, South Fork of the Coeur d'Alene River.
(Relocation of a portion of the South Fork east of Mullan to allow for construction of a settling pond. Some water quality, macroinvertebrate, and fish data.)

1973. Kreizenbeck, R. Coeur d'Alene livebox bioassay.
(All rainbow trout placed in live boxes at 11 points along the South fork were dead within 72 hours; trout in boxes at Smelterville died within 5 hours.)

1972. Bjornn, T.C. and C.M. Falter. Current status of fish and wildlife, Cedar Canyon - Rose Lake Junction section of I-90 (Idaho).

1970. Rabe, F.W. and C.W. Sappington. Biological productivity of the Coeur d'Alene River as related to water quality.
(Abstract in Wai et al. 1985)

1969. Sappington, C.W. The acute toxicity of zinc to cutthroat trout (Salmo clarki).

1966. Marcuson, P.E. Limnology and fish food abundance in Round Lake, Kootenai County, Idaho.
(Includes fish species and abundance)

H. TERRESTRIAL BIOTA

Existing Problems

1. Toxic substances such as Zn, Pb, DDT, and PCB in the food chain.
2. Mortality of birds and mammals due to lead poisoning.
3. Intolerance of many plant species to contaminated soils.
4. High Zn concentrations in garden vegetables.

Recent Studies

Little recent work has been done on levels of contaminants in the food chain. Those that have indicate a serious problem exists. At present, Krieger et al. (1986) are investigating causes of mortality in swans and other water-fowl in main stem lateral lakes. They have found high lead levels in dead swans. Sediments and horsetail (Equisetum arvensa) are suspect as sources of lead. Other food items will also be analyzed. Future studies will include rodents, fish and livestock.

In 1982, Wolflin reported high levels of several metals in fish from Chatcolet Lake and lead in mice and mink from the Coeur d'Alene River valley (Woodward Clyde et al. 1985). Johnson (UI, Biol. Sci.) continues to monitor migration and nesting success of osprey in the Coeur d'Alene River area.

High levels of metals have been reported in vegetation throughout the past decade. The only recent study was done in 1983 by IDHW comparing Pb and Cd levels in garden vegetables with 1975 levels (Table H-1). Zn levels appear to be high but there are no comparative values from earlier years (Woodward Clyde et al. 1985).

Research Needs

1. A comprehensive survey of levels of contaminants, particularly lead

Table H-1. Lead, Cadmium and Zinc Concentrations in Garden Vegetables in the Lower South Fork Valley.

Area	Vegetable	Range and mean (ppm) Lead 1975	Lead 1983	Cadmium 1975	Cadmium 1983	Zinc 1975	Zinc 1983
Smelterville	Carrots	-	11-33	-	-	-	41-348 (246)
	Lettuce	174-287 (231)	- (48)	- (28)	21-34 -	- -	- (78)
Kellogg, Warner, Page	Carrots	6-36 (20)	12-146 (61)	2-9 (5)	2-26 (8)	- -	39-539 (141)
	Beets	27-130 (108)	14-121 (47)	18-34 (23)	2-42 (15)	- -	39-1332 (618)
	Lettuce	19-303 (161)	12-155 (65)	2-61 (24)	2-66 (18)	- -	139-751 (279)
Pinehurst	Carrots	6-111 (37)	6-92 (25)	2-6 (4)	1-11 (4)	- -	30-235 (94)
	Beets	9-15 (12)	11-30 (16)	11-15 (13)	2-13 (6)	- -	109-619 (301)
	Lettuce	6-29 (10)	11-83 (32)	2-25 (12)	4-28 (10)	- -	49-558 (246_)

Source: Woodward Clyde et al (1985) from IDHW 1984 data.

and zinc, in all biotic components.

Terrestrial Biota Bibliography

Birds/Waterfowl

1986. Blus, L.J., et al. Heavy metals and organochlorines in mink and other mammals from Washington and Idaho.

1986. Henny, C.J. and L.J. Blus. Heavy metals study of Kestrels.

1986. Krieger, R.I. et al. Lead poisoning in swans in the lower Coeur d'Alene River valley.
(Since 1982, 200 out of 1200 tundra swans have died from lead poisoning. High amounts of lead have been found in liver, kidneys and proventriculus. Lead shot and disease have been ruled out. Sediments and Equisetum sp. may be sources of lead.

1978. Melquist, W.E. et al. Migration patterns of northern Idaho and northeastern Washington ospreys.

1977. U.S. Bureau of Land Management. The Bald Eagle of Wolf Lodge Bay.

1975. Johnson, D.R. et al. DDT and PCB levels in Lake Coeur d'Alene, Idaho, osprey eggs.
(Total DDT levels ranged from 2.0 to 19.1 ppm with an average of 10.3 $\pm$ 1.71; PCB levels ranged from 1.2 to 4.0 ppm with an average of 1.18; shell thickness had declined 17% since 1932.)

1964. Chupp, N.R. and P.D. Dalke. Waterfowl mortality in the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1956. Chupp, N.R. An evaluation of the lower Coeur d'Alene River waterfowl habitat in Kootenai County, Idaho.
(Abstract in Wai et al. 1985)

Mammals

1985. Woodward Clyde et al. Draft interim site characterization report, Bunker Hill Superfund site.
(Reports Wolflin data on metal levels in mice and mink.)

1982. Burrows, G.E. and R.E. Borchard. Experimental lead toxicosis in ponies: comparison of the effects of smelter effluent-contaminated hay and lead acetate.
(Abstract in Wai et al. 1985)

1981. Burrows, G.E. Lead toxicosis in domestic animals: a review of the role of lead mining and primary lead smelters in the United States.
(Abstract in Wai et al. 1985)

1981. Burrows, G.E. et al. A survey of blood lead concentrations in horses in the north Idaho lead/silver belt area.
(Abstract in Wai et al. 1985)

1978. Lowry, D.A. and K.L. McArthur. Domestic dogs as predators on deer.
(Documentation of an increase in this problem as residential development increases in the Coeur d'Alene River valley).

1972. Bjornn, T.C. and C.M. Falter. Current status of fish and wildlife Cedar Canyon - Rose Lake Junction Section of I-90 (Idaho).

1972. Sharp, J.W. and R.G. Root. Report on environmental lead contamination survey in north Idaho.
(Abstract in Wai et al. 1985)

1976. Keely, J.F. A study of heavy metal pollution in the Coeur d'Alene mining district.
(Abstract in Wai et al. 1985)

Vegetation*

1985. Woodward Clyde et al. Draft interim site characterization report-Bunker Hill Superfund Site.
(Reports on IDHW 1983 study of metal levels in garden vegetables.)

1985. CDC/IDHW. Kellogg revisited - 1983. Childhood Blood-lead and environmental status report.

1982. Burrows, C.E. and R.E. Borchard. Experimental lead toxicosis in ponies: comparison of the effects of smelter effluent-contaminated hay and lead acetate.
(Abstract in Wai et al. 1985)

1981. U.S. SCS. A soil survey of Kootenai County Area, Idaho.
(Includes kinds of native plants, present vegetative cover and potential for crops or vegetation.

1977. Ragaini, R.C. et al. Environmental trace metal contamination in Kellogg, Idaho near a lead smelting complex.
(Levels of heavy metals and other trace elements in grasses in the Smelterville-Kellogg vicinity in 1973-1974)

1976. Keely, J.F. A study of heavy metal pollution in the Coeur d'Alene mining district.
(Abstract in Wai et al. 1985)

*Revegetation studies are listed elsewhere.

1975. Sheppard, J.C. and W.H. Funk. Trees as environmental sensors monitoring long-term heavy metal contamination of Spokane River, Idaho.
(Abstract in Wai et al. 1985)

1971. Galbraith, J.H. A study of mine tailings and associated plants and ground water in the Coeur d'Alene district, Idaho.
(Abstract in Wai et al. 1985)

1971. Maxfield, D. et al. Heavy metal pollution in the sediments of the Coeur d'Alene River delta.
(Abstract in Wai et al. 1985)

1964. Chupp, N.R. and P.D. Dalke. Waterfowl mortality in the Coeur d'Alene River valley, Idaho.
(Abstract in Wai et al. 1985)

1961. Kennedy, V.C. and S.W. Hobbs. Geochemical studies in the Coeur d'Alene district, Shoshone Co., Idaho.
(Use of soil and botanical geochemistry in prospecting for Cu, Pb, Zn, and Sb.)

1956. Chupp, N.R. An evaluation of the lower Coeur d'Alene River waterfowl habitat in Kootenai County, Idaho.
(Abstract in Wai et al. 1985)

I. RECREATION

Comments

I have found few studies in this topic area, but recreation is part of the human impact on the environment and can be an important factor. For example, wave action caused by boats can wash and erode banks and stir up bottom sediments. Boater and fisherman use of bank areas can cause disturbance. On the other hand, demand for a good quality environment for recreational activities can put pressure on land owners to redress degradational activities. As the population of the area continues to increase and water quality improves, recreation will become more important in the Coeur d'Alene River. The Department of Wildland Recreation management at the University of Idaho is studying some of these problems.

Recreation Bibliography

1983. McLaughlin, W.J. and M.D. Feldman. Idaho river study: a look at boater use on ten non-designated river segments in Idaho. Vol. 2: Coeur d'Alene River results.
(River segment Senator Cr. campground to Prichard. Variables were boater characteristics, type and pattern of use, choosing river segments, boater opinions, and user comments.)

1977. Murphy, P.J. Monitoring recreational activities on six Idaho lakes using remote sensing techniques.
(Study deals primarily with Coeur d'Alene Lake. Divides the lake into seven sections, finds that boat usage is well below carrying capacity as outlined in State Comprehensive Outdoor Recreation Plan of 1973. Uses a formula, deviation index of shoreline, for categorizing lakes based on shoreline configuration.)

J. HUMAN HEALTH

Comments

I include human health studies here although this topic is a little out of the realm of usual environmental studies. However, the impact of environmental lead on human health was responsible for the area being designated a Superfund site, and much future IDHW and EPA research will be directed toward a solution to this problem.

In 1974, blood-lead toxicity in local children was found to correlate most strongly with airborne lead exposure. Soil was a secondary source. Lead and Cd in garden vegetables was also at unacceptable levels. In 1983, following closure of the smelter in 1981, soil was found to be the most significant source and vegetables were still contaminated (see Table H-1). Mean blood-lead levels in children from Smelterville have dropped from 68 ug/dl in 1974 to 31 in 1980 and 21 in 1983. Levels in the Kellogg area have dropped from 49 in 1974 to 26 in 1980 and 17 in 1983. Strongest correlations now are with residential soil lead and household dust lead concentrations (Woodward Clyde et al. 1985).

Human Health Bibliography

1985. CDC/IDHW. Kellogg revisited - 1983. Childhood blood-lead and environmental status report.

1985. Woodward Clyde et al. Draft interim site characterization report, Bunker Hill Superfund Site.

1980. Walter, S.D. et al. Age-specific risk factors for lead absorption in children.

1977. Yankel, A.J. et al. The silver valley lead study: the relationship between childhood blood lead levels and environmental exposure.

1975. Ashby, J.F. A study of trace metals in human hair in relation to achievement scores of school children in some selected northern Idaho communities.
(Abstract in Wai et al. 1985)

1975. Landrigan, P.T. et al. Increased lead absorption with anemia and subclinical neuropathy in children near a lead smelter.

1974. Park, C.A. A study of trace heavy metals in the hair of individuals in selected northern Idaho communities.
(Abstract in Wai et al. 1985)

1972. Ellsworth, L.E. Community perception in the Coeur d'Alene mining district.

K. MINE WASTES

Existing Problems

1. Seepage and leakage of contaminated water from tailings ponds to the surface and ground water systems.
2. Leaching of contaminants from river/tailings deposits in the flood plain of the South Fork and main stem into the surface and ground water.
3. Disposition of acid mine water from abandoned mine tunnels.
4. Existence of "hot spots" of hazardous wastes on and off the Bunker Hill complex.
5. Some of the problems associated with tailings deposits are listed below (reproduced from IDHW/UI 1979):

-- Most of the abandoned tailings sites inventoried in this study have a low potential for massive failure; however, a number of the sites are susceptible to erosion by surface streams and, to a lesser degree, sheet wash and wind erosion.

-- Although insufficient data exists to accurately assess the potential for chemical hazards from the inventoried sites, one of the three controlled sites with available data has a high potential for water quality problems. A least two of the uncontrolled sites present a major water quality problem from chemical activities.

-- Any attempts to link a particular abandoned uncontrolled tailings site with a particular mill is rendered impossible because of the large number of mills in the project area; the transport of ore from a mine to a mill at another location; and the later reworking of old tailings deposits for metal extraction.

-- Many of the inventoried uncontrolled tailings sites are aesthetically displeasing because of public visibility and visual quality.

-- Physical removal of tailings is a viable reclamation alternative only where recoverable metal values in the wastes are high or where the site includes only a small volume of waste.

-- Chemical stabilization through removal of acid producing wastes to a more controlled environment is viable only for small piles.

-- Flooding of sites as a chemical stabilization procedure is difficult at most sites and increases the potential for slope failure at controlled sites.

-- Estimating costs of tailings reclamation is difficult to do, since costs are very site specific.

-- The procedure for determination of legal ownership of abandoned mine tailings can be delineated clearly. The actual determination is expensive and time-consuming.

-- Existing authorities in Idaho provide a basis, though somewhat tenuous, for requiring an owner of abandoned mine tailings to abate water pollution from them.

-- Reversion to public ownership may be the only feasible way to reclaim some abandoned tailings, even though the process is cumbersome.

-- Mine tailings in the project area have been widely dispersed throughout the floodplain, thus precluding an easy solution to the reclamation problem.

-- Ownership of tailings in the project area is complex and varied.

-- Where tailings have been widely dispersed; where reclamation would primarily benefit the general public; and where reclamation would not increase land value markedly, public funding of reclamation is not unreasonable.

-- Funding for reclamation exists, but it is limited and widely sought. Lead time is extensive.

-- There are few incentives to spur landowners or mining companies on to reclaim or rework abandoned sites.

-- No regulations have been promulgated to date under the Idaho Surface and Dredge Mining Acts.

-- The extension of the Federal Surface Mining Act to non-coal minerals, though it would not be a panacea, would provide Idaho with an abandoned mine reclamation program and a program to ensure adequate reclamation prior to abandonment.

-- Idaho's mine reclamation laws do not address surface effects of underground mining.

Recent Studies

During the 1970's, there were numerous investigations of the effectiveness of settling ponds, especially the Central Impoundment

Area (CIA), in containing mining wastewater. Recent data on seepage and leakage is not available. Other studies addressed the role of confined tailings piles and river/tailings deposits in surface and ground water contamination. Recent studies of mine wastes have centered on acid mine water formation and discharge in the Bunker Hill mine. This waste water is pumped to the CIA and is partially responsible for the low pH of water leaking from that facility. Most of these studies were done by graduate students in the Department of Geology at the University of Idaho under the direction of Drs. Dale Ralston and Roy Williams. Comprehensive abstracts and sampling and analytical methodologies are presented in Wai et al. (1985).

Research Needs

1. Detailed survey of extent and degree of hazardous waste deposits within Bunker Hill complex which are exposed to wind or water transport.
2. Identification of "hot spots" of hazardous waste deposits throughout the South Fork valley including ponds, piles, and river/tailings deposits.

Mine Wastes Bibliography

Tailings Ponds

1981. IDWR. Spokane River basin, Bunker Hill Mine tailings impoundment structure No. 3, Shoshone County, Idaho. Phase 1 inspection report.

1981. Underwood, J.E. Evaluation of ground water pollution potential from surface impoundments in northern Idaho and eastern Washington. (Abstract in Wai et al. 1985)

1980. IWRB. Safety of mine tailings impoundment structures: rules and regulations.
(Applies to structures being constructed or modified after July 1, 1978.)

1980. Robinson et al. Seepage control study central impoundment area, Kellogg, Idaho for Bunker Hill Co.

1979. Williams, R.E. et al. Leakage and seepage from tailings ponds; the Bunker Hill central impoundment area, Kellogg, Idaho.
(Abstract in Wai et al. 1985)

1978. Hawke Engineers. Engineering report seepage control of central impoundment area and gypsum pond for Bunker Hill Co. Kellogg, Idaho.

1977. Mabes, D.L. The engineering properties of mill tailings.
(Abstract in Wai et al. 1985)

1977. Norman, L.D. The grain size distribution of tailings and other solids in the Bunker Hill central impoundment area and its relationship to the occurrence and control of leakage and seepage.
(Abstract in Wai et al. 1985)

1977. Reece, D. Hydrochemical tracers as a mechanism for identifying points of leakage in mineral resource waste disposal facilities.
(Abstract in Wai et al. 1985)

1975. Williams, R.E. and L.L. Mink. Settling ponds as a mining waste-water treatment facility.
(Abstract in Wai et al. 1985)

1973. Mink, L.L. et al. Renovation of wastes by mine tailings ponds.
(Abstract in Wai et al. 1985)

1973. Williams, R.E. Modernization of Coeur d'Alene tailings disposal practices.
(Abstract in Wai et al. 1985)

1973. Williams, R.E. and A.T. Wallace. The role of mine tailings ponds in reducing the discharge of heavy metal ions to the environment.
(Abstract in Wai et al. 1985)

1973. Williams, R.E. et al. Effects and prevention of leakage from mine tailings ponds.
(Abstract in Wai et al. 1985)

1972. Ellsworth, C.B. Investigations of physical-chemical properties of mine tailings.
(Abstract in Wai et al. 1985)

1972. Mink, L.L. Evaluation of settling ponds as a mining wastewater treatment facility.
(Abstract in Wai et al. 1985)

1972. Mink, L.L. et al. Effect of early day mining operations on present day water quality.
(Abstract in Wai et al. 1985)

1971. Toukan, Z.R. Cation exchange properties of mine tailings.
(Abstract in Wai et al. 1985)

1971. Williams, R.E. et al. Impact of a well managed tailings pond system on a stream.
(Abstract in Wai et al. 1985)

Tailings Piles (Confined)

1982. Bodien, G. et al. Bunker Hill field inspection, Oct. 22, 1982.
(Status of waste sites within Bunker Hill complex; intended disposal of wastes on and off site.)

1982. Gross, M.R. Reclamation plans for abandoned mill tailing impoundments in the South Fork Coeur d'Alene River basin.
(Abstract in Wai et al. 1985)

1979. IDHW/UI. Abandoned mine tailings - reclamation alternatives for Idaho.
(Abstract in Wai et al. 1985)

1976. Williams, R.E. and D.R. Ralston. An investigation of selected wastes produced by mining in northern Idaho.
(Abstract in Wai et al. 1985)

1975. Morilla, A.G. Hydrogeologic analysis of an abandoned tailings pile.
(Abstract in Wai et al. 1985)

1974. Hitt, R.J. A short term study of the suitability of locating a sewage lagoon system on an abandoned tailings pile.
(Abstract in Wai et al. 1985)

1974. Ralston, D.R. and A.G. Morilla. Ground-water movement through an abandoned tailings pile.
(Abstract in Wai et al. 1985)

1973. Ralston, D.R. et al. Solutions to problems of pollution associated with mining in northern Idaho.
(Abstract in Wai et al. 1985)

1971. Galbraith, J.H. A study of mine tailings and associated plants and ground water in the Coeur d'Alene district, Idaho.
(Abstract in Wai et al. 1985)

Unconfined Tailings/River Flats

1980. Norton, M.A. Hydrogeology and potential reclamation procedures for an uncontrolled mine waste deposition site, Kellogg, Idaho.
(Abstract in Wai et al. 1985)

1979. IDHW/UI. Abandoned mine tailings - reclamation alternatives for Idaho.
(Abstract in Wai et al. 1985)

1979. Ioannou, C. Distribution, transport and reclamation of abandoned mine tailings along the channel of the South Fork of the Coeur d'Alene River and tributaries, Idaho.
(Abstract in Wai et al. 1985)

1979. Keely, J.F. Trace metals in soils of the Coeur d'Alene River valley and their potential effects on water quality.
(Abstract in Wai et al. 1985)

1979. Marcy, D. The chemistry of unconfined mine wastes.
(Abstract in Wai et al. 1985)

1976. Johnson, R.D. et al. The heavy metal problem of Silver Valley, northern Idaho.
(Abstract in Wai et al. 1985)

1976. Keely, J.F. A study of heavy metal pollution in the Coeur d'Alene mining district.
(Abstract in Wai et al. 1985)

1974. Norbeck, P.M. Water table configuration and aquifer and tailings distribution, Coeur d'Alene valley, Idaho
(Abstract in Wai et al. 1985)

1974. Reece, D.E. A study of leaching of metals from sediments and ores and the formation of acid mine water in the Bunker Hill mine.
(Abstract in Wai et al. 1985)

1972. Galbraith, J.H. et al. Migration and leaching of metals from old mine tailings deposits.
(Abstract in Wai et al. 1985)

1972. Mink, L.L. et al. Effect of early day mining operations on present day water quality.
(Abstract in Wai et al. 1985)

1971. Galbraith, J.H. A study of mine tailings and associated plants and ground water in the Coeur d'Alene district, Idaho.
(Abstract in Wai et al. 1985)

Acid Mine Water

1986. Riley, J.A. Ph.D. in progress; continuation of M.S. research.

1985. Riley, J.A. Acid water implications for mine abandonment, Coeur d'Alene mining district, Idaho.
(Abstract in Wai et al. 1985)

1985. Wai, C.M. and W.M. Mok. Arsenic speciation and acid water production associated with mining in the Coeur d'Alene mining district.

1984. Hunt, J.A. Analysis of recharge to an underground lead-zinc mine, Coeur d'Alene mining district, Idaho.
(Abstract in Wai et al. 1985)

1982. Trexler, B.D. et al. Hard rock mine hydrogeology and acid water drainage.
(Abstract in Wai et al. 1985)

1980. Wai, C.M. et al. Production of acid water in a lead-zinc mine, Coeur d'Alene, Idaho.
(Abstract in Wai et al. 1985)

1976. Williams, R.E. and D.R. Ralston. An investigation of selected wastes produced by mining in northern Idaho.
(Abstract in Wai et al. 1985)

1975. Trexler, B.D. The hydrogeology of acid production in a lead-zinc mine.
(Abstract in Wai et al. 1985)

1975. Trexler, B.D. et al. Sources and causes of acid mine drainage.
(Abstract in Wai et al. 1985)

1974. Reece, D.E. A study of leaching of metals from sediments and ores and the formation of acid mine water in the Bunker Hill mine.
(Abstract in Wai et al. 1985)

1973. Ralston, D.R. et al. Solutions to problems of pollution associated with mining in northern Idaho.
(Abstract in Wai et al. 1985)

L. RECLAMATION/REHABILITATION/REVEGETATION

Comments

The subject of reclamation of the South Fork valley has been given thorough treatment in a number of studies since 1978 (Eisenbarth and Wrigley 1978; Ralston et al, 1979; IDHW/UI 1979; Ioannou 1979; Gross 1982). The comprehensive Eisenbarth report contains a detailed plan of action for reclamation which is reproduced on the following pages (Fig. L-1). Personal communication with Fred Eisenbarth (Jan. 21, 1986) revealed that this plan had not been implemented due to lack of support and funding from the legislature. Most of the same problems that his plan addressed exist now with little change. Idaho Department of Water Resources personnel in Coeur d'Alene, who have immediate responsibility for stream channel alterations, knew of no recent work other than some rip rapping near Kingston in the late 1970's and more recently near Wallace along the highway right-of-way.

On the positive side, there are three proposed or ongoing projects of limited scope but addressing some problems of immediate importance. Under the auspices of the Superfund program, city parks, playgrounds, school yards and public roads within the Superfund site (a seven mile by three mile rectangle between Pinehurst and Wallace) are slated for cleanup in 1986. Six inches of surface soil will be removed and replaced (von Lindern, personal communication; Woodward Clyde 1986). From 1977-1982, Bunker Hill personnel seeded and planted both north and south facing slopes in the area of the Bunker Hill complex with reasonably good success. They are now gearing up to resume this effort (Winner, personal communication). Another ongoing project is

FIVE YEAR PLAN OF ACTION SCHEDULE

FEATURE	DESCRIPTION	IMPLEMENTATION TIME PHASING 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
I Erosion and Sediment Control:		
A) Major outslopes	Major grading, drainage and revegetation of 18,100 acres.	
B) Minor outslopes	Drainage and revegetation of 3,000 acres.	
C) River channel	Revegetation of 2,000 acres along 29.65 miles of South Fork Channel; 600 acres along 6.0 miles of Pine Creek Channel; 1,000 acres along 10.0 miles of tributary streams.	
D) Bedload	Construct bedload traps as the following locations: a) South Fork near Osburn b) Pine Creek above Pinehurst c) Canyon Creek above Wallace	
E) Waste rock dump sites	Remove material or remove cribbing and grade to stable slope of waste rock dump sites in Canyon's tributary to South Fork. Riprap stream channels near dumps and back fill with waste rock.	
F) Tailings deposits	Remove tailings where economically feasible. Where not feasible, drainage systems around the deposits will be installed. Topsoil added and revegetated. Where necessary, water will be drained into an acid neutralizer.	
G) Cataldo Flats	The ongoing revegetation of this area will continue at an increased rate.	
H) Organic matter	Use sludge from South Fork Sewer District on a regional basis for fertilizer and organic matter for acid neutralization and revegetation.	
II Flood Control:		
A) Flood channel	Major redesign and channelization of 6.7 miles Class 1; 17.4 miles of Class 2; 5.4 miles of Class 3 to 100-year capacity on South Fork Canyon Creek Nine-Mile Creek Pine Creek South Fork - Mile 29.5 to Mile 8 South Fork - Mile 8 to confluence with main Coeur d'Alene	
B) Dikes		
1) Kellogg	Construct 2,455 feet of levee and 800 feet of concrete flood wall between Hill and Division Streets to 100-year elevation.	
2) Pinehurst	Raise dike on Pine Creek to 100-year elevation.	
C) Bridges	Raise Hill and Division Street bridges to pass 100-year flow. Conduct flood routing and back water studies on all other bridges.	
D) Flood plain studies	Conduct studies to determine flood hazard on: 1) Milo Creek - CH2M 2) Pine Creek - HUD 3) Lake Creek 4) Canyon Creek 5) Nine-Mile Creek	
E) Flood control information	Provide data as available to local officials to be used for planning and non-structural measures and development of flood plain management.	
III Water Quality:		
A) Acid drainage	Construct limestone acid neutralizers in areas as needed. Develop a demonstration site near Bunker Creek or the Star Mine.	
IV Mine Waste:		
A) Tailing ponds	Construct tailing ponds at Wallace Gun Club, Shoshone County Golf Course, and above Mullan with capacity to last until the year 2000.	
V Recreation:		
A) Park	Construct Miners Memorial Park near Big Creek on 56 acres of reclaimed channel. Develop day-use recreation facilities.	
VI Fish & Wildlife		
A) Fishery	Construct velocity dissipater, fish rocks, pools, eddies, overhanging banks, etc. in all suitable areas on the South Fork and tributaries.	
B) Wildlife	Develop winter range on 1,500 acres near Smelterville. Construct water fowl habitat on Cataldo Flats.	
VII Program Management and Analysis	Monitor the effects of the reclamation program and where necessary enhancing stabilization efforts.	

Figure L-1. Five year plan of action for valley rehabilitation (from Eisenbarth and Wrigley 1978)

rehabilitation in Grouse Creek, a small drainage basin above Smelterville which drains into the marshy area on the east end of the Page pond complex. The Kootenai-Shoshone Soil Conservation District (1982) in conjunction with the USDA Soil Conservation Service has done extensive revegetation and other erosion and flood control work in that drainage (Kim Golden, SCS, personal communication).

Elsewhere in the Coeur d'Alene drainage, a follow-up study of the work done by Gaillot and Ralston (1979) at the Jack Waite Mine revealed that some reclamation measures had been undertaken with poor to fair results due to lack of continued maintenance (Gruenenfelder, personal communication). Also, studies are underway in the Kidd Island Bay area of northern Coeur d'Alene Lake to control deteriorating conditions in the bay (Kootenai-Shoshone 1984).

Reclamation/Rehabilitation/Revegetation Bibliography

1986. Gruenenfelder, C.R. Hyrological analysis and reclamation recommendations at the Continental Mine.
(Appendix includes information on reclamation at the Jack Waite Mine.)

1986. Winner, J.E. Personal communication (Morrison-Knudsen Co., Boise)
(M-K has a contract with Bunker Hill to provide them with information on site rehabilitation. Bunker Hill did extensive hillside revegetation in the Smelterville area from 1977-1982 which was reasonably successful. Natural vegetation is now becoming established; a small fern is one of the first species to occupy a site. Bunker Hill has a nursery in a deep mine tunnel where temperature and humidity along with artificial light and absence of pests provide optimum growing conditions; gearing up to start another round of revegetation. Ed Pommerening is in charge.)

1986. Woodward Clyde Consultants. Bunker Hill Superfund Site preliminary engineering alternatives and cost for publicly owned IRM (interim remedial measures) sites. Jan. 30, 1986.
(Describes sites, alternatives for clean up and cost estimates. Four more reports coming out in April, 1986: 1) legal, 2) recontamination, 3) health, 4) soil).

1985. Woodward Clyde et al. Draft interim site characterization report, Bunker Hill Superfund site.

1984. Kootenai-Shoshone Soil Conservation District. Kidd Island Bay reclamation measure.
(Findings and recommendations of interagency effort to address problems of deterioration of water quality in Kidd Island Bay.)

1982. Bodien, G. et al. Bunker Hill Field Inspection, Oct. 22, 1982.
(Contains plans for disposition of hazardous wastes)

1982. Kootenai-Shoshone Soil Conservation District. Smelterville critical area treatment measure.
(Rehabilitation of Grouse Cr. Basin near Smelterville. Upper portion of basin denuded of vegetation from smelter fumes causing erosion problems; lower end of basin altered in past causing erosion and flood problems. Ongoing project started with seeding of grass-legume mixture and planting of tree seedlings in 1983; installation of debris basins, rip rapping, and reconstruction of access road in 1985; construction of deflection structure at mouth 1986.)

1982. Gross, M.R. Reclamation plans for abandoned mill tailings impoundments in the South Fork Coeur d'Alene River basin.
(Abstract in Wai et al. 1985)

1980. Norton, M.A. Hydrogeology and potential reclamation procedures for an uncontrolled mine waste deposition site, Kellogg, Idaho.
(Abstract in Wai et al. 1985)

1979. Gaillot, G. and D.R. Ralston. Hydrogeologic analysis and reclamation alternatives for the Jack Waite Mine, Shoshone County, Idaho.
(Recommendations for reclamation procedures to minimize water quality and visual impacts from the mine area.)

1979. IDHW/UI. Abandoned mine tailings - reclamation alternatives for Idaho.
(Abstract in Wai et al. 1985)

1979. Ioannou, C. Distribution, transport and reclamation of abandoned mine tailings along the channel of the South Fork of the Coeur d'Alene River and tributaries.
(Abstract in Wai et al. 1985)

1979. Ralston, D.R. et al. Demonstration control program for reclamation of abandoned mine tailings dumps.
(Abstract in Wai et al. 1985)

1978. Cobb, J. and L. Comer. Plan of study for wastewater facilities planning for South Fork Coeur d'Alene River gulches.

1978. Eisenbarth, F. and J. Wrigley. A plan to rehabilitate the South Fork Coeur d'Alene River.
(Physical, biological and cultural resources; identification of problems; research related to rehabilitation; sources of funding; recommendations for rehabilitaltion; five-year plan of action. An excellent compilation of information illustrated with ground and aerial photos, and maps.)

1977. Hansen, J.E. Revegetation of toxic soils surrounding lead and zinc smelters.
(Field and laboratory experiments in revegetation of slopes above Bunker Hill complex. Liming and addition of phosphorus increased emergence and yield of grasses; high Zn and SO_2 killed tree seedlings.)

1974. Winner, J.E. An evaluation of stream channel relocation, South Fork of the Coeur d'Alene River.
(Description of relocation of a portion of the South Fork east of Mullan; effects on water quality and biota.)

1973. Ralston, D.R. et al. Solutions to problems of pollution associated with mining in northern Idaho.
(Abstract in Wai et al. 1985)

ALPHABETICAL BIBLIOGRAPHY

Alsid, Snowden and Associates. Bunker Hill Co. source test observations. Prepared for State of Idaho Department of Health and Welfare. February 1981. 23 p.

Anderson, A.L. 1940. Geology and metalliferous deposits of Kootenai County, Idaho. Idaho Bur. Mines & Geol. Pamphlet 53. 67 p.

Anderson, R.A. 1967. Graben structure in the Coeur d'Alene district. Econ. Geol. 62: 1092-1094.

Ashby, J.F. 1975. A study of trace metals in human hair in relation to achievement scores of school children in some selected northern Idaho communities. M.S. Thesis, Dept. of Chemistry, Univ. of Idaho, Moscow. 166 p.

Bartlett, L.D. 1974. The effects of copper, zinc and cadmium on Selenastrum capricornutum. M.S. Thesis, Dept. of Biol. Sci., Univ. of Idaho, Moscow. 34 p.

Bartlett, L.D., F.W. Rabe and W.H. Funk. 1974. Effects of copper, zinc and cadmium on Selenastrum capricornutum. Water Research 8: 179-185.

Bateman, A.F. Jr., M.A. Baca, and J.L. Colbert. 1980. Leasable mineral and waterpower land classification map of the Wallace quadrangle, Idaho, Montana. USGS Open-file report, 1 over-size sheet, scale 1:250,000.

Bauer, S.B. 1974. Heavy metals in lakes of the Coeur d'Alene River valley. M.S. Thesis, Dept. of Biol. Sci., Univ. of Idaho, Moscow. 55 p.

Bauer, S.B. 1975. Coeur d'Alene River fishery studies. Idaho Dept. Fish & Game. 26 p.

Bennett, D.H. and E.C. Bowles. 1983. Recruitment of largemouth bass (Micropterus salmoides) in the Coeur d'Alene Lake systems. Progress report to Washington Water Power Co.

Bennett, D.H. and E. Bull. 1985. Recruitment and survival of young-of-the-year largemouth bass (Micropterus salmoides) in the Coeur d'Alene lake system, Idaho. Completion report to Washington Water Power Co.

Bennett, D.H. and P.F. Hassemer. 1982. Effects of I-90 construction activities on the spawning success of Kokanee. Completion report to Idaho Dept. of Transportation. 104 p.

Bennett, D.H. and P.F. Hassemer. 1984. Examination of the spawning ecology and early life history of Kokanee (Oncorhynchus nerka) in Coeur d'Alene Lake. Completion report to Washington Water Power Co.

Bennett, E.H. 1984a. A hundred years of mining in the Coeur d'Alene district. IBMG. Part 1 - 45 min. Part 2 - 50 min. (Videotapes).

Bennett, E.H. 1984b. A hypothesis concerning the genesis of orebodies in the Coeur d'Alene mining district, Idaho. Idaho Geological Survey, Tech. Report 84-7. 39 p.

Bennett, E.H. and R. Venkatakrishnan. 1982. A palinspastic reconstruction of the Coeur d'Alene mining district based on ore deposits and structural data. Econ. Geology 77: 1851-1866.

Bjornn, T.C. and C.M. Falter, 1972. Current status of fish and wildlife Cedar Canyon - Rose Lake Junction Section of I-90 (Idaho). Col. of Forestry, Wildlife & Range Sci., Univ. of Idaho, Moscow.

Blus, L.J., C.J. Henny, and E. Cromantre, 1986. Heavy metals and organochlorines in mink and other mammals from Washington and Idaho. Unpublished report. U.S. Fish and Wildlife Service. Corvallis, OR.

Bodien, G. et al. 1982. Bunker Hill Field Inspection, Oct. 22, 1982. U.S. EPA Seattle, Region X.

Bourg, A.C.M. 1974. Uptake of zinc by clay minerals in fresh water. Ph.D. Dissertation, Dept. of Chemistry, Wash. State Univ. 90 p.

Bourg, A.C.M. and R.H. Filby. 1974. Adsorption isotherms for the uptake of Zn^{++} by clay minerals in a fresh-water medium. Proceedings of the International Conf. on Transport of Persistent Chemicals in Aquatic Ecosystems. 6 p.

Bowler, B. 1975. Coeur d'Alene Lake fisheries investigations. Idaho Dept. Fish and Game, Lake and Reservoir Investigations, JPR F-53-R-10. 16 p.

Bowler, B. 1974. Coeur d'Alene River study. IDFG Lake and Reservoir Investigations Job Performance Report F-53-R-9. 28 p.

Bowler, B. 1981. Kokanee stock status in Pend Oreille, Priest, and Coeur d'Alene Lakes. IDFG Lake and Reservoir Investigations Job Performance Report F-73-R-3, Study VI, Job I.

Brooks, K.D. 1977. Investigative study of non-attainment of primary national TSP standards in the Silver Valley of Idaho. U.S. EPA Seattle, Region X.

Burrows, G.E. 1981. Lead toxicosis in domestic animals: A review of the role of lead mining and primary lead smelters in the United States. Vet. and Human Toxicology 23:337-343.

Burrows, G.E. and R.E. Borchard. 1982. Experimental lead toxicosis in ponies: Comparison of the effects of smelter effluent-contaminated hay and lead acetate. Amer. Jour. Vet. Res. 43: 2129-2133.

Burrows, G.E., J.W. Sharp and R.G. Root. 1981. A survey of blood lead concentrations in horses in the north Idaho lead/silver belt area. Vet. and Human Toxicology 23: 328-330.

Canney, F.C. 1959. Geochemical study of soil contamination in the Coeur d'Alene district, Shoshone County, Idaho. Mining Eng. 11(2): 205-210.

Carter, D.B. 1977. Amelioration and revegetation of smelter- contaminated soils in the Coeur d'Alene mining district of northern Idaho. M.S. Thesis, Dept. of Forest Resources, Univ. of Idaho, Moscow. 66 p.

Centers for Disease Control/Idaho Dept. of Health and Welfare (CDC/IDHW). 1985. Kellogg revisited - 1983. Childhood blood-lead and environmental status report.

Chupp, N.R. 1956. An evaluation of the lower Coeur d'Alene River waterfowl habitat in Kootenai County, Idaho. M.S. Thesis, Col. of Forestry, Wildlife & Range Sci., Univ. of Idaho, Moscow. 130 p.

Chupp, N.R. and P.D. Dalke. 1964. Waterfowl mortality in the Coeur d'Alene River valley, Idaho. Jour. of Wildlife Management 28: 692-702.

Cobb, J. and L. Comer. 1978. Plan of study for wastewater facilities planning for South Fork Coeur d'Alene River gulches. Panhandle Health District and IDHW/Doe presentation to shoshone County Commissioners, July 1978.

Cochnauer, T. 1982. Kokanee investigations. IDFG Lake and Reservoir Investigations Job Performance Report F-73-R-4, Study VI, Job I.

Cochnauer, T. 1983. Kokanee stock status in Pend Oreille, Priest, and Coeur d'Alene Lakes. IDFG Lake and Reservoir Investigations Job Performance Report F-73-R-5, Study VI, Jobs I and II. 26 p.

Cook, E.F. (Ed.) 1963. The Coeur d'Alene mining district in 1963. IBMG Pamphlet 133. 104 p.

Cooper, J.A., R.T. Decesar, C.A. Frazier, J.E. Houck, and J.F. Mohan. 1981. Determination of source contributions to air particulate lead and cadmium levels in Kellogg, Idaho using the Receptor Model. Volumes I and II. Contract No. 40523. NEA, Inc. Beaverton, Oregon, 97005. December 10, 1981.

Crosby, G.M. 1969. A preliminary examination of trace mercury in rocks, Coeur d'Alene district, Idaho. International Geochemical Exploration Symposium, 2nd Golden, CO., 1968. Proceedings: Quarterly of the Colorado School of Mines 64(1): 169-194.

De Smet, J. 1985. Northeast Worley water quality study. IDHW/DOE, Coeur d'Alene.

Dort, W., Jr. 1954. Glaciation of the Coeur d'Alene district, Idaho. Ph.D. Thesis, Stanford Univ. 106 p.

Eckwright, T.A. 1982. Groundwater flow systems analysis in an active underground mine in the Coeur d'Alene mining district, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 58 p.

Eisenbarth, F. and J. Wrigley. 1978. A plan to rehabilitate the South Fork Coeur d'Alene River. Idaho Water Resource Board. 146 p.

Ellsworth, C.B. 1972. Investigations of physical-chemical properties of mine tailings. M.S. Thesis, Dept. of Civil Eng., Univ. of Idaho. 73 p.

Ellsworth, L.E. 1972. Community perception in the Coeur d'Alene mining district. Idaho Geol. Survey Pamphlet 152. 43 p.

Ellis, M.M. 1932. Pollution of the Coeur d'Alene River and adjacent waters by mine wastes. Report to U.S. Bur. of Fisheries. 55 p.

Erikson, D. 1985. Analysis of water movement in an underground lead-zinc mine, Coeur d'Alene mining district, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow.

Falter, C.M. and B.D. Mitchell. 1982. Aquatic ecology of the Spokane River between Coeur d'Alene and Post Falls, Idaho, 1980. Completion report to IDHW, Contract No. 1032. 94 p. plus 4 maps.

Flaherty, D.C. 1973. Good Water? A study of the Coeur d'Alene-Spokane River region. Wash. State Univ. Special Publ. 27 p.

Frankel, P. 1986. Application of mathematical modeling to the analysis of ground water flow patterns near a deep underground mine. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow.

Fryklund, V.C. 1964. Ore deposits of the Coeur d'Alene district, Shoshone Co., Idaho USGS Prof. Paper 445. 99 p.

Funk, W.H., F.W. Rabe, and R. Filby. 1973. The biological impact of combined metallic and organic pollution in the Coeur d'Alene-Spokane River drainage system. Joint project completion report to OWRR (B-044 Wash. & B-015 Ida.) 202 p.

Funk, W.H., F.W. Rabe, et al. 1975. An integrated study on the impact of metallic trace element pollution in the Coeur d'Alene-Spokane Rivers-Lakes drainage system. Wash. State Univ./Univ. of Idaho joint project completion report to OWRT. 350 p.

Funk, W.H., H.L. Gibbons, R.M. Duffner, T. Notestine and T. Nielsen. 1983. Water quality of the upper Spokane River and evaluation of methods for measurement of the effect of effluent upon primary and secondary producers. Technical completion report No. 48, Washington Water Research Institute. 130 p.

Gaillot, G. and D.R. Ralston. 1979. Hydrogeologic analysis and reclamation alternatives for the Jack Waite Mine, Shoshone County, Idaho. Univ. of Idaho, College of Mines completion report to USDA Forest Service. 126 p.

Galbraith, J.H. 1971. A study of mine tailings and associated plants and ground water in the Coeur d'Alene district, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. p.149.

Galbraith, J.H., R.E. Williams and P.L. Siems. 1972. Migration and leaching of metals from old mine tailings deposits. Ground Water 10(3): 33-44.

Goodnight, W.H. and T.L. Watkins. 1976. Coeur d'Alene Lake fisheries investigations. Idaho Dept. Fish and Game, lake and reservoir investigations, JPR F-53-R-11.

Gott, G.B. and J.M. Botbol. 1973. Zoning of major and minor metals in the Coeur d'Alene mining district, Idaho, U.S.A. in M.J. Jones (ed.), Geochemical exploration 1972: International geochemical Exploration Symposium, 4th, London, 1972, Proceedings No. 4, p. 1-12.

Gott, G.B. and J.M. Botbol. 1975. Possible extension of mineral belts, northern part of Coeur d'Alene district, Idaho. USGS Jour. of Research 3(1): 1-7.

Gott, G.B. and J.B. Cathrall. 1979 (1980)a. General distribution of antimony and silver in rocks and soils of the Coeur d'Alene district, Idaho and Montana. Scale 1:62,500, sheet 36 x 41 inches. USGS Map I-1093-B.

_____. 1979 (1980)b. General distribution of arsenic in rocks and sulfur in rocks in the Coeur d'Alene district, Idaho and Montana. Scale 1:62,500, sheet 37 x 41 inches. USGS Map I-1093-C.

_____. 1979 (1980)c. General distribution of barium and mercury in the Coeur d'Alene district, Idaho and Montana. Scale 1:62,500,

_____. 1979 (1980)d. General distribution of copper and lead in rocks and soils in the Coeur d'Alene district, Idaho and Montana. Scale 1:62,500, sheet 37 x 41 inches. USGS Map I-1093-E.

_____. 1979 (1980)e. General distribution of manganese in rocks and soils in Coeur d'Alene district, Idaho and Montana. Scale 1:62,500, sheet 21 x 41 inches. USGS Map I-1093-F.

_____. 1979 (1980)f. General distribution of nickel and boron in the Coeur d'Alene district, Idaho and Montana. scale 1:62,500, sheet 37 x 41 inches. USGS Map I-1093-G.

_____. 1979 g. General distribution of zinc and cadmium in rocks and soils in the Coeur d'Alene district, Idaho and Montana. Scale 1:62,500, sheet 37 x 41 inches. USGS Map I-1093-H.

_____. 1979 (1980)h. Dispersion patterns in rocks formed by the ration of Cd/Zn, Pb/Zn, and Cu/Pb in the Coeur d'Alene district, Idaho and Montana. Two sheets, scale 1:62,500; sheet 1, 37 x 41 inches, sheet 2, 21 x 41 inches. USGS Map I-1093-I.

_____. 1979 (1980)i. The sum of enrichments in rocks above the district median values for Cu, Sb, Ag, and S; Sb, Ag, and Mn; and Sb and Ag in the Coeur d'Alene district, Idaho and Montana. Two sheets, scale 1:62,500; sheet 1, 37 x 41 inches, sheet 2, 21 x 41 inches. USGS Map I-1093-J.

_____. 1980 j. Geochemical-exploration studies in the Coeur d'Alene district, Idaho and Montana. USGS Prof. Paper P-1116. 63 p., 7 color plates.

Griggs, A.B. 1981. Geologic map of the Spokane quadrangle, Washington, Idaho, and Montana. USGS Map I-768, scale 1:62,500 (Reprinted from 1973 map).

Gross, M.R. 1982. Reclamation plans for abandoned mill tailing impoundments in the South Fork Coeur d'Alene basin. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 150 p.

Gruenenfelder, C.R. 1986. Hydrological analysis and reclamation recommendations at the Continental Mine. In progress. M.S. Thesis and completion report to U.S. Forest Service.

Hampton, K. 1985. Delineation of abandonment procedures for the Bunker Hill and Crescent Mines, Shoshone County, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow.

Hansen, J.E. 1977. Revegetation of toxic soils surrounding lead and zinc smelters. M.S. Thesis, Dept. of Range Resources, Univ. of Idaho, Moscow. 51 p.

Harmon, T. and D. Johann. 1980. Water quality status report South Fork Coeur d'Alene River, Heavy Metal Loading Survey (Shoshone County) 1975-1976. IDHW, Boise. 37 p.

Harrison, J.E., A.B. Griggs, and J.D. Wells. 1981. Generalized geologic map of the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho. Scale 1:250,000. USGS Map MF-1354-A.

Hartman, M. 1985. Tritium dating of ground water in an underground lead-zinc mine, Coeur d'Alene mining district, Idaho. M.S. Thesis in progress, Dept. of Geology, Univ. of Idaho, Moscow.

Hawke Engineers. 1978. Engineering report seepage control of Central Impoundment Area and Gypsum pond for Bunker Hill Co. Kellogg, Idaho.

Henny, C.J. In progress. Heavy-metal study of Kestrels. U.S. Fish and Wildlife Service, Corvallis, OR.

Herman, S.G. 1975. lead and cadmium in soils, vegetation, and small animals near Kellogg, Idaho. Evergreen State College, Olympia, WN.

Hitt, R.J. 1974. A short term study of the suitability of locating a sewage lagoon system on abandoned tailings pile. M.S. Thesis, Dept. of Civil Eng. Univ. of Idaho, Moscow. 86 p.

Hobbs, S.W., A.B. Griggs, R.E. Wallace, and A.B. Campbell. 1965. Geology of the Coeur d'Alene district, Shoshone County, Idaho. USGS Prof. Paper 478. 139 p.

Hoiland, W.K. and M. Chaney. 1985. A comparison of the diversity of macroinvertebrates in the South Fork, North Fork, and Main Fork of the Coeur d'Alene River. Undergrad. report to F.W. Rabe, Dept. of Biol. Sci., Univ. of Idaho, Moscow. 5 p.

Hunt, J.A. 1984. Analysis of recharge to an underground lead-zinc mine, Coeur d'Alene mining district, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 101 p.

Idaho Bureau of Mines & Geology (IBMG), 1961. Idaho's mineral industry-the first hundred years. Bulletin No. 18. 71 p.

Idaho Dept. of Health and Welfare/Division of Environment (IDHW/DOE). 1974. Water quality survey of Lake Coeur d'Alene. Open-file report, Coeur d'Alene.

IDHW/DOE. 1975. Water quality status report - aquatic monitoring South Fork Coeur d'Alene River basins, industrial source evaluation and receiving water survey. 29 p.

IDHW/DOE. 1979. Silver Valley non-attainment area for achievement of the total suspended particulate national ambient air quality standards. Region 1, Coeur d'Alene.

IDHW/DOE. 1983. Idaho air quality annual report, part 1: Air monitoring summary. Boise.

IDHW/DOE. 1985 a. Annual Air quality Report. Open-file report, Coeur d'Alene or Boise.

IDHW/DOE. 1985. b. Water quality assessment, Black Lake (Kootenai County). Report No. WQ-54. Compiled by M. Beckwith from data collected by D. Hagihara, Coeur d'Alene. 67 p.

IDHW/DOE and Univ. of Idaho, College of Mines. 1979. Abandoned mine tailings - reclamation alternatives for Idaho. 275 p.

IDHW, Div. of Health. 1974. Phase II Survey. Survey of heavy metals contamination, Shoshone County, Idaho. Status report October 2, 1974.

IDHW. Division of Health. 1976. Shoshone lead health project. Work Summary. Jan. 1976. Boise, ID.

Idaho Department of Water Resources. 1981. Spokane River basin, Bunker Hill Mine tailings impoundment structure No. 3, Shoshone County, Idaho. Phase I inspection report, National Dam Safety Program. Walla Walla District: U.S. Army Corps of Engineers.

Idaho Geological Survey. 1985. Bunker Hill file. IGS library materials.

Idaho Water Resources Board. 1980. Safety of mine tailings impoundment structures: rules and regulations. Statehouse, Boise.

Ioannou, C. 1979. Distribution, transport and reclamation of abandoned mine tailings along the channel of the South Fork of the Coeur d'Alene River and tributaries, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 156 p.

Johnson, D.R., W.E. Melquist, and G. J. Schroeder. 1975. DDT and PCB levels in Lake Coeur d'Alene, Idaho, osprey eggs. Bul. of Env. Contam. & Toxicol. 13(4): 401-405.

Johnson, R.D., R.J. Miller, R.E. Williams, C.M. Wai, A.C. Wiese, and J.E. Mitchell. 1976. The heavy metal problem of Silver Valley, northern Idaho. Proc. International Conf. on Heavy Metals in the Environment, National Research Council of Canada, Ottawa: 465-485.

Juras, D.S. 1982. Structure of the Bunker Hill mine, Kellogg, Idaho. Idaho Geol. Survey Bul. 24, p. 31-34.

Jutze, G.A. 1975. Interim report: Silver Valley/Bunker Hill smelter environmental investigation. PEDCo.

Kann, J. and C.M. Falter. 1985. Blue-green algae toxicity in Black Lake, Kootenai County, Idaho. Research technical completion report to IWRRI, Univ. of Idaho, Moscow. 55 p.

Keely, J.F. 1976. A study of heavy metal pollution in the Coeur d'Alene mining district. Student Originated Studies project report to the NSF, Dept. of Chemistry, Univ. of Idaho, Moscow. 358 p.

Keely, J.F. Jr. 1979. Trace metals in soils of the Coeur d'Alene River valley and their potential effects on water quality. M.S. Thesis, Dept. of Chemistry, Univ. of Idaho, Moscow. 121 p.

Kemmerer, G., J.F. Bovard, and W.R. Boorman. 1923. Northwest lakes of the United States: Biological and chemical studies with reference to possibilities in production of fish. Bulletin, U.S. Bureau of Fisheries 39: 51-140.

Kennedy, V.C. 1960. Geochemical studies in the Coeur d'Alene district, Shoshone County, Idaho. USGS Bul. 1098-A. 54 p.

Kootenai-Shoshone Soil Conservation District. 1982. Smelterville critical area treatment measure. #16-6001-079-008. Sponsored by City of Smelterville and Shoshone County with assistance from USDA SCS, Coeur d'Alene.

Kootenai-Shoshone Soil Conservation District. 1984. Kidd Island Bay reclamation measure. #16-6001-155-140.13 p.

Krieger, R., D. Krieger, K. Tomson, W. Warner, J. Homan, and D. Stone. 1986. Lead poisoning in swans in the lower Coeur d'Alene River valley. Paper at 1986 annual meeting Society of Toxicology. UI and WSU Dept. of Vet. Med.

Kreizenbeck, R.A. 1979. South Fork Coeur d'Alene River live box bioassay data. U.S. EPA Seattle, Region X.

Landis, G.P., D.L. Leach, and A.H. Hofstra. 1984. Silver-base metal mineralization as a product of metamorphism - Coeur d'Alene district, Shoshone County, Idaho: Concepts of genesis. in Hobbs, S.W. (Ed.). The Belt: Abstracts with Summaries, Belt Symposium II, 1983. Mont. Bur. of Mines, Butte.

Landrigan, P.T., E.L. Banker, Jr., et al. 1975. Increased lead absorption with anemia and subclinical neuropathy in children near a lead smelter. U.S. Public Health Service, Center for Disease Control, Boston Univ. School of Medicine and IDHW. 32 p.

Leach, D.L., J.A. Domenico, D.M. Hopkins, H.E. Dawson, and R.J. Goldfarb. 1982. Data report and statistical summary for samples of stream-sediment and nonmagnetic heavy-mineral concentrates from the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho. USGS Open-file report OF 82-0494. 247 p., 1 oversize sheet.

_____, 1983a. Distribution of cadmium in samples of nonmagnetic heavy-mineral concentrate and in samples of stream sediment from the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho. 6 p., 1 oversize sheet, scale 1:250,000. USGS OF 83-0305.

_____, 1983b. Distributions of total antimony in samples of nonmagnetic heavy-mineral concentrate and of total and partially extractable antimony in samples of stream sediment from the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho. 7 p., 2 oversize sheets, scale 1:250,000. USGS OF 83-0306.

_____, 1983c. Distributions of total copper in samples of nonmagnetic heavy-mineral concentrate and of total and partially extractable copper in samples of stream sediment from the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho. 7 p., 3 oversize sheets, scale 1:250,000. USGS OF 83-0307.

_____, 1983d. Distributions of total zinc in samples of nonmagnetic heavy-mineral concentrate and of total and partially extractable zinc in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho. 7 p., 3 oversize sheets, scale 1:250,000. USGS OF 83-0308.

_____, 1983e. Distribution of total silver in samples of nonmagnetic heavy-mineral concentrate and of total and partially extractable silver in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho. 7 p., 3 oversize sheets, scale 1:250,000. USGS OF 83-0309.

Lewensky, V.A. and T.C. Bjornn. 1983. Coeur d'Alene River fisheries investigations. IDFG Job completion report F-73-R-4. 33 p.

Lowry, D. 1986. Personal communication (IDFG Conservation Officer at Osburn.)

Lowry, D.A. and K.L. McArthur. 1978. Domestic dogs as predators on deer. Wildlife Soc. Bul. 6(1): 38-39.

Mabes, D.L. 1977. The engineering properties of mill tailings. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 113 p.

Mallet, J.L. 1968. Coeur d'Alene Lake fisheries investigations. Idaho Dept. Fish and Game. 18 p.

Marcuson, P.E. 1966. Limnology and fish food abundance in Round Lake, Idaho. M.S. Thesis, Col. of Forestry, Wildlife & Range Sci., Univ. of Idaho, Moscow. 22 p.

Marcy, D. 1979. The chemistry of unconfined mine wastes. M.S. Thesis, Dept. of Chemistry, Univ. of Idaho, Moscow, 208 p.

Martin, L.J. 1981. Potential for acid formation from tailings from the Coeur d'Alene mining area, Idaho. M.S. thesis, Dept. of Geology, Univ. of Idaho, Moscow. 64 p.

Mathewson, D.C. 1972. Structures related to the Osburn fault, Coeur d'Alene mining district, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 57 p.

Maxfield, D., J.M. Rodriguez, M. Buettner, J. Davis, L. Forbes, R. Kovacs, W. Russel, L. Schultz, R. Smith, J. Stanton, and C.M. Wai. 1974. Heavy metal content in the sediments of the southern part of the Coeur d'Alene Lake. Env. Pollution 6: 2 63-266.

Maxfield, D. et al. 1974. Heavy metal pollution in the sediments of the Coeur d'Alene River delta. Env. Pollution 7: 1-6.

Maxfield, D., C.M. Wai, et al. 1971. Heavy metal pollution in the sediments of the Coeur d'Alene River delta. Student Originated Studies project report to NSF, Univ. of Idaho. 51 p.

McLaughlin, W.J. and M.D. Feldman. 1983. Idaho river study: a look at boater use on ten non-designated river segments in Idaho. Vol. 2: Coeur d'Alene River results. Dept. of Wildland Recreation, UI, report to Idaho Dept. Parks and Recreation. 44 p.

McMasters, J.J. and E. Tulloch. 19__. Sanitary water quality status, South Fork Coeur d'Alene River, Elizabeth Park to Rose. IDHW.

Melquist, W.E., D.K. Johnson, and W.D. Carrier. 1978. Migration patterns of northern Idaho and northeastern Washington ospreys. Bird-Banding 49: 234-236.

Milligan, J.H., R.A. Lyman, C.M. Falter, E.E. Krumpe and J.E. Carlson. 1983. Classification of Idaho's fresh water lakes. IWRRI completion report to IDHW/DOE. 140 p.

Mink, L.L. 1971. Water quality of the Coeur d'Alene River basin, 1969, 1970. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 104 p.

Mink, L.L. 1972. Evaluation of settling ponds as a mining waste-water treatment facility. Ph.D. Dissertation, Dept. of Geology, Univ. of Idaho, Moscow. 255 p.

Mink, L., R.E. Williams, and A. Wallace. 1971. Effect of industrial and domestic effluents on the water quality of the Coeur d'Alene River basin. IBMG, Pamphlet 149. 103 p.

Mink, L.L. R.E. Williams and A.T. Wallace. 1972. Effects of early day mining operations on present day water quality. Ground Water 10(1): 17-26.

Mink, L.L., R.E. Williams, A.T. Wallace and L.M. McNay. 1973. Renovation of wastes by mine tailings ponds. Mining Eng. 25(7): 81-88.

Minter, R.F., Jr. 1971. Plankton population structure in the lower Coeur d'Alene River, delta, and Lake. M.S. Thesis, dept. of Biol. Sci., Univ. of Idaho, Moscow. 81 p.

Mitcham, T.W. 1952. Indicator minerals, Coeur d'Alene silver belt (Idaho). Econ. Geol. 47(4): 414-450.

Mitchell, V.E. and E.H. Bennett. 1983. Production statistics for the Coeur d'Alene mining district, Shoshone County, Idaho--1884-1980. Tech. report (Open-file) 83-3. IGS. 33 p.

Molnau, M. and C. Kessler. 1985. Analysis of sedimentation and water quality of Kidd Island Bay, Lake Coeur d'Alene, Idaho. IWRRI for Kidd Island Bay Reclamation Project, Inc. 26 p.

Morilla, A.G. 1975. Hydrologic analysis of a tailings pile. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 97 p.

Murphy, P.J. 1977. Monitoring recreational activities on six Idaho lakes using remote sensing techniques. M.S. Thesis, Dept. of Univ. of Idaho, Moscow.

Nielsen, T.S., W.H. Funk, H.L. Gibbons and R.M. Duffner. 1984. A comparison of periphyton growth on artificial and natural substrates in the Upper Spokane River. Northwest Science 58: 243-248.

Norbeck, P.M. 1974. Water table configuration and aquifer and tailings distribution, Coeur d'Alene valley, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 106 p.

Norman, L.D. 1977. The grain size distribution of tailings and other solids in the Bunker Hill central impoundment area and its relationship to the occurrence and control of leakage and seepage. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 76 p.

North American Weather Consultants. 1975. Stack height evaluation for the Bunker Hill Company, Kellogg, Idaho. Salt Lake City.

Norton, M.A. 1980. Hydrogeology and potential reclamation procedures for an uncontrolled mine waste deposition site, Kellogg, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 282 p.

Olson, R.P. 1963. Biological survey of the Coeur d'Alene River. Open-file report, IDHW/DOE, Coeur d'Alene.

O'Neal, G. 1972. Report on Coeur d'Alene River survey May 12-17, 1970. U.S. EPA, Region X, Seattle. 33 p.

Pacific Environmental Services (PES). 1985. Draft report documenting the available means for significantly reducing emissions of lead (and their ambient impact) at the Bunker Ltd. lead and zinc smelters in Kellogg, ID. Santa monica, CA.

Park, C.A. 1974. A study of trace heavy metals in the hair of individuals in selected northern Idaho communities. M.S. Thesis, Dept. of Chemistry, Univ. of Idaho, Moscow. 89 p.

Parker, J.I. 1972. Algae production and nutrient enrichment in Lake Coeur d'Alene, Idaho M.S. Thesis, Dept. of Biol. Sci., Univ. of Idaho, Moscow. 46 p.

Parker, J.I. and F.W. Rabe. 1978. Nutrient enrichment and phytoplankton distributions in Coeur d'Alene Lake, Idaho. Jour. of the Idaho Acad. of Sci. 14: 1-10.

PEDCo. 1984. Emission inventory and lead air pollution control system evaluation for the development of Bunker Ltd. Lead emission limits. Cincinnati, OH.

Peterson, R. Study of the South Fork Coeur d'Alene River. U.S. EPA, Region X, Seattle. Open-file data.

Rabe, F.W. and S.B. Bauer. 1977. Heavy metals in lakes of the Coeur d'Alene River Valley, Idaho. Northwest Science 51(3): 183-197.

Rabe, F.W. and D. Flaherty. 1974. The river of green and gold. Idaho Research Foundation, Inc. Moscow. Natural Resource Series No. 4. 98 p.

Rabe, F.W., R.C. Wissmar, and R.F. Minter. 1973. Plankton populations and some effects of mine drainage on primary productivity of the Coeur d'Alene River, delta, and lake. Completion report to IWRRI, Univ. of Idaho, Moscow. 27 p.

Ragaini, R.C., H.R. Ralston, and N. Roberts. 1977. Environmental trace metal contamination in Kellogg, Idaho near a lead smelting complex. Env. Sci. and Tech. 11: 773-781.

Ralston, D.R., M.R. Gross, C. Ioannou, D.A. Marcy, and M.A. Norton. 1979. Demonstration control program for reclamation of abandoned mine tailings dumps. Completion report for IDHW, Contract No. 20728, Univ. of Idaho.

Ralston, D.R. and A.G. Morilla. 1974. Ground-water movement through an abandoned tailings pile. Amer. Water Resources Symposium on Water Resources Problems Related to mining, Proc. No. 18: 174-183.

Ralston, D.R. B.D. Trexler, C.M. Wai, W.T. Renison and F.E. Rickman, Jr. 1973. Solutions to problems of pollution associated with mining in northern Idaho. Dept. of Geology, Univ. of Idaho IBMG, U.S. Bureau of Mines Contract report H0122070. 99 p.

Ransome, F.L. and F.C. Calkins. 1908. The geology and ore deposits of the Coeur d'Alene district Idaho. USGS Prof. Paper 42. 203 p.

Reece, D.E. 1974. A study of leaching of metals from sediments and ores and the formation of acid mine water in the Bunker Hill mine. M.S. Thesis Dept. of Chemistry, Univ. of Idaho, Moscow. 117 p.

Reece, D. 1977. Hydrochemical tracers as a mechanism for identifying points of leakage in mineral resource waste disposal facilities. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 146 p.

Reece, D.E., J.R. Felkey, and C.M. Wai. 1978. Heavy metal pollution in the sediments of the Coeur d'Alene River, Idaho. Env. Geol. 2(5): 289-293.

Reid, R.R. (Ed.) 1961. Guidebook to the geology of the Coeur d'Alene mining district. IBMG Bul. 16. 37 p.

Reid, R.R. and G.E. Williams (Eds.) 1982. Society of Economic Geologists' Coeur d'Alene Field Conference - 1977. 139 p.

Rieman, B.E. 198 . Coeur d'Alene Lake Limnology. IDFG Lake and Reservoir Investigations Job Completion Report F-73-R-2, Study V, Job III.

Rieman, B.E. and L. LaBolle. 1980. Coeur d'Alene Lake Creel Census IDFG Lake and Reservoir Investigations Job Performance Report F-73-R-2, Study VI, Job I.

Rieman, B.E. and B. Ward. 1981. Coeur d'Alene Creel Census. IDFG Lake and Reservoir Investigations, Study VI, Job III.

Riley, J.A. 1986. Ph.D. in progress; continuation of M.S. research (see below).

Riley, J.A. 1985. Acid water implications for mine abandonment, Coeur d'Alene mining district, Idaho. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 158 p.

Ringe, R.R., J.R. Lukens, P.D. Hiebert and W.D. Norton. 1978. Survey of streams in the Emerald Empire and Cottonwood Resource Areas of Idaho. Idaho Cooperative Fishery Unit for Bureau of Land Management. Final report No. YA-515-IA7-15. 69 p.

Robinson, Dames and Moore. 1980. Seepage control study central impoundment area, Kellogg, Idaho for Bunker Hill Co. June 25, 1980. Job No. B-01.

Rouse, J.V. 1977. Geohydrologic conditions in the vicinity of Bunker Hill Co. waste-disposal facility. U.S. EPA 3030/2-77-006, Denver, CO: National Enforcement Investigations Center. 46 p.

Sappington, C.W. 1969. The acute toxicity of zinc to cutthroat trout (Salmo clarki). M.S. Thesis, Dept. of Biol. Sci., Univ. of Idaho, Moscow. 32 p.

Savage, N.L. 1970. The effect of industrial and domestic pollution on benthic macroinvertebrate communities in two northern Idaho rivers. M.S. Thesis, Dept. of Biol. Sci., Univ. of Idaho, Moscow. 59 p.

Savage, N.L. and F.W. Rabe. 1973. The effects of mine and domestic wastes on macroinvertebrate community structure in the Coeur d'Alene River. Northwest Science 47(3): 159-168.

Sceva, J.E. and W. Schmidt. 1971. A reexamination of the Coeur d'Alene River. U.S. EPA Seattle, Region X. 43 p.

Schecter, B. and M.F. Adams. 1964. Mine, industrial and domestic waste disposal study for the South Fork Coeur d'Alene River. CH2M Hill Engineers and Planners, Corvallis, OR. 102 p.

Seitz, H.R. and M.L. Jones. 1982. Flow characteristics and water-quality conditions in the Spokane River, Coeur d'Alene Lake to Post Falls Dam, northern Idaho. USGS Open-file report OF 82-0102. 60 p.

Sharp, J.W. and R.G. Root. 1972. Report on environmental lead contamination survey in north Idaho. NIH Undergrad. research project report, Col. of Vet. Med., Washington State Univ., Pullman. 12 p.

Sheppard, J.C. and W.H. Funk. 1975. Trees as environmental sensors monitoring long-term heavy metal contamination of Spokane River, Idaho. Env. Sci. & Tech. 9: 638-642.

Stokes, L.W. and G.L. Ralston. 1972. Water quality survey - Coeur d'Alene River and Lake. IDHW, Env. Improvement Division.

Terragraphics. 1986. Draft geographic information systems and soils characterization report - Bunker Hill site remedial investigation and feasability study. Prepared for IDHW. Boise, Idaho, Jan. 15, 1986. 275 p.

Tiedemann, R.B. 1984. An evaluation of cutthroat trout habitat within the Cedar and Fourth of July creek drainages Kootenai, Co., Idaho. Idaho Dept. of transportation. 85 p. plus app.

Toukan, Z.R. 1971. Cation exchange properties of mine tailings. M.S. Thesis, Dept. of Geology, Univ. of Idaho, Moscow. 55 p.

Trexler, B.D., Jr. 1975. The hydrogeology of acid production in a lead-zinc mine. Ph.D. Dissertation, Dept. of Geology, Univ. of Idaho, Moscow. 164 p.

Trexler, B.D., D.R. Ralston, D.E. Reece, and R.E. Williams. 1975. Sources and causes of acid mine drainage. IBMG Pamphlet 165. 142 p.

Trexler, B.D., D.R. Ralston, and R.E. Williams. 1982. Hard rock mine hydrogeology and acid water drainage. Univ. of Idaho presentation at the SME-AIME annual meeting. 11 p.

Underwood, J.E. 1981. Evaluation of ground water pollution potential from surface impoundments in northern Idaho and eastern Washington. M.S. Thesis, dept. of Geology, Univ. of Idaho, Moscow. 191 p.

Underwood, T. In progress. Dynamics and ecology of salmonid fishes in the upper Spokane River. M.S. Thesis, Dept. of Fish and Wildlife Resources, Univ. of Idaho, Moscow.

U.S. Army Corps of Engineers, Division Hydraulic Lab. 1969. High velocity channel South Fork Coeur d'Alene River at Wallace, Idaho. Report to Idaho Dept. of Highways.

_____. 1970. Placer Creek at Wallace, Idaho. reports. U.S. Govt. Printing Office, Washington, D.C. 45 p. ill., maps.

U.S. Bureau of Land Management. 1977. The Bald Eagle of Wolf Lodge Bay. Coeur d'Alene District, BLM. 20 p.

U.S. Environmental Protection Agency (EPA). 1975. River basin water quality status report - Spokane River basin. EPA, Survey and Analysis Division, Region X, Seattle.

_____. 1977. Report on Coeur d'Alene Lake, Benewah and Kootenai Counties, Idaho. National Eutrophication Survey. Working paper 778, Region X, Seattle.

_____. 1980. STORET data for Coeur d'Alene Lake (1976-1980).

_____. 1985. Draft interim site characterization report, Bunker Hill superfund site. EPA/IDHW. 333 p.

_____. 1985. Algal assay test results north Idaho lakes. Unpublished data, Corvallis Environmental Research Lab.

_____. 1985. National pollutant discharge elimination (NPDES) permit #000007-8. Draft technical information applicant: Bunker Hill Limited Partnership. 11 p.

U.S. Geological Survey (USGS). 1979 (1980). Aeromagnetic map of the Coeur d'Alene district, Idaho and Montana. Scale 1:62,500, sheet 21 x 41 inches.

_____. 1985. Water resources data Idaho. Water year 1985. USGS water-data report ID-85-1.

U.S. NOAA. 1985. Climatological data Idaho. Environmental Data Service. National Climatology Center, Ashville, NC.

_____. 1977. Climatography of the United States No. 60. Climate of Idaho. Environmental Data Service, National Climatology Center, Asheville, NC.

USDA Soil Conservation Service (SCS). 1974. Inventory and evaluation - soil and water resources of the South Fork Coeur d'Alene River Valley. SCS, Coeur d'Alene.

_____. 1981. Soil survey of Kootenai County Area, Idaho., C.J. Weisel, party leader. USDA SCS, Coeur d'Alene.

_____. In progress. Soil survey of Shoshone County Area, Idaho. C.J. Weisel, party leader. USDA SCS, Coeur d'Alene.

Venkatakrishnan, R. 1982. A remote sensing study of the fracture control of mineralization in the Coeur d'Alene mining district, Shoshone County, Idaho. Ph.D. Dissertation, Dept. of Geology, Univ. of Idaho, Moscow. 275 p.

von Lindern, I.H. 1981. Ambient air analysis of Bunker Hill lead emissions. Prepared for EPA, Region X, Seattle. Order No. IY0117NASX.

Wai, C.M., S.G. Hutchison, J.D. Kauffman, and F.I. Hutchison. 1985. A bibliography of environmental studies of the Coeur d'Alene mining area, Idaho. Project completion report to IDHW-EPA. 80 p. (Available from Wai, Dept. of Chemistry, UI or Water Resources Research Institute, UI).

Wai, C.M. and W.M. Mok. 1985. Arsenic speciation and acid water production associated with mining in the Coeur d'Alene mining district. Completion report to IWRRI, Univ. of Idaho, Moscow.

Wai, C.M., D.E. Reece, B.D. Trexler, D.R. Ralston, and R.E. Williams. 1980. Production of acid water in a lead-zinc mine, Coeur d'Alene, Idaho. Env. Geology 3: 159-162.

Wai, C.M. and W.M. Mok. (1986) A new approach to evaluate redox status in the ground water pollution problems associated with mine wastes in the Coeur d'Alene mining district, Idaho. (In progress).

Walter, S.D., A.J. Yankel, and I.H. von Lindern. 1980. Age-specific risk factors for lead absorption in children. Arch. of Env. Health 35(1): 53-58.

Washington Water Research Center et al. 1985. protection and management of aquifers with emphasis on the Spokane-Rathdrum aquifer. Conference proceedings. WWRI report no. 62. 118 p.

Wayne, L.G. and I.J. Weisenberg. 1979. Studies of air quality in Silver Valley, Idaho - Estimates of area source emissions of particulate matter and lead. Air quality modeling using VALLEY model. Pacific Environmental Sevices (PES), Santa Monica, CA.

Williams, R.E. 1973. Modernization of Coeur d'Alene tailings disposal practices in Tailings Disposal Today, Alpin and Argall, (Eds.), Miller Freeman Publ., Inc., San Francisco, CA p. 634-673.

Williams, R.E., C.D. Kealy, and L.L. Mink. 1973. Effects and prevention of leakage from mine tailings ponds. Soc. of Mining Engineers, AIME, Transactions 254: 212-216.

Williams, R.E. and L.L. Mink. 1975. Settling ponds as a mining wastewater treatment facility. IGS Pamphlet 164. 41 p.

Williams, R.E., D. Ortman, D.L. Mabes, D. Reece, and L.D. Norman. 1979. Leakage and seepage control from tailings ponds: The Bunker Hill Company, Kellogg, Idaho. Annual report to U.S. Bureau of Mines, Contract G0155210, College of mines, Univ. of Idaho, Moscow. 104 p.

Williams, R.E. and D.R. Ralston. 1976. An investigation of selected wastes produced by mining in north Idaho. Completion report, U.S. Bureau of Mines, Contract H0232065.

Williams, R.E. and A.T. Wallace. 1973. The role of mine tailings ponds in reducing the discharge of heavy metal ions to the environment. Completion report, U.S. Bureau of Mines, Contract H0110088. 110 p.

Williams, R.E., A.T. Wallace, and L.L. Mink. 1971. Impact of a well managed tailings pond system on a stream. Mining Congress Jour. 57: 48-56.

Winner, J.E. 1972. Macrobenthic communities in the Coeur d'Alene Lake system. M.S. Thesis, dept. of Biol. Sci. Univ. of Idaho, Moscow. 47 p.

Winner, J.E. 1974. An evaluation of stream channel relocation, South Fork of the Coeur d'Alene River. Idaho Dept. of Water Resources, Boise. 29 p.

Winner, J.E. 1975, 1978. Sediment discharge of the South Fork of the Coeur d'Alene River. Idaho Dept. of Water Resources, Unpublished report.

Winner, J.E. 1986. Personal communication. Morrison-Knudson Co., Environmental Engineering Division, Hazardous Waste Cleanup Section.

Wise, S.M. 1981. The current status of heavy metal pollution in the Coeur d'Alene River system and its impact on the salmonid fishery. Univ. of Idaho, Moscow. 24 p.

Wissmar, R.C. 1972. Some effects of mine drainage on primary production in Coeur d'Alene River and Lake, Idaho. Ph.D. Dissertation, Dept. of Biol. Sci., Univ. of Idaho, Moscow. 68 p.

Woodward Clyde Consultants. 1986. Bunker Hill Superfund site preliminary engineering alternatives and cost for publicly owned IRM site. Jan. 30, 1986.

Woodward Clyde Consultants and Terragraphics. 1985. Draft interim site characterization report - Bunker Hill Superfund Site. EPA contract No. 68-01-6939, work assignment No. 590L26. 333 p.

Yankel, A.F., I.H. von Lindern, and S.D. Walter. 1977. The silver Valley lead study: The relationship between childhood blood-levels and environmental exposure. Jour. Air Pollution control Assoc. 27(8): 763-767.