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In cooperation with the
U.S. Environmental Protection Agency

Concepts for Monitoring Water Quality in the Spokane River Basin, Northern Idaho and Eastern Washington

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Concepts for Monitoring Water Quality in the Spokane River Basin, Northern Idaho and Eastern Washington

By Michael A. Beckwith

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In cooperation with the
U.S. Environmental Protection Agency

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

MULTIPLY	BY	TO OBTAIN
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Abbreviated water-quality units:

µg/L	micrograms per liter
µm	micrometers

CONCEPTS FOR MONITORING WATER QUALITY IN THE SPOKANE RIVER BASIN, NORTHERN IDAHO AND EASTERN WASHINGTON

By Michael A. Beckwith

ABSTRACT

Numerous environmental studies have been conducted in the Spokane River Basin over the past several decades by government agencies, academic institutions, and environmental engineering firms. Most of these efforts have focused on the environmental effects of more than a century of silver, lead, and zinc mining and ore-processing activities in the South Fork Coeur d'Alene River valley in northern Idaho. Several studies also have assessed the water quality and potential for eutrophication of Coeur d'Alene and Long Lakes and the Coeur d'Alene, St. Joe, and Spokane Rivers. Because past investigations often were limited in scope and employed different approaches and methods, an integrated understanding of hydrologic, water-quality, and aquatic biological conditions still is lacking for the basin as a whole. Substantial resources are being spent for water-quality and natural-resource management, and for mitigating the adverse environmental effects of past mining activities in the basin. A water-quality monitoring network, integrated with the decision-making processes associated with these efforts, could be of considerable value. The purpose of such a monitoring network is to produce high-quality information on which to base sound water-quality and natural-resource management decisions and to assess the effectiveness of those decisions.

A streamflow- and water-quality monitoring infrastructure already exists in the Spokane River Basin. This infrastructure consists of 20 lake-stage and streamflow-gaging stations, representing specific drainages or subdrainages and, in many cases, specific stream reaches or subreaches. These gaging stations are operated by the U.S. Geological Survey (USGS), several of them in cooperation with State and Federal agencies and a private utility company. Extensive streamflow data are available, some dating from the late 1800's. Water-quality data are also available from recent USGS cooperative studies in the Coeur d'Alene Lake watershed. A nutrient load / lake response (eutrophication) model has been developed for Coeur d'Alene Lake. Hydraulic models for estimating streamflow through the low-gradient reaches of the Coeur d'Alene and St. Joe Rivers have been developed. Trace-element concentrations and distributions in sediments in the lower South Fork and main-stem Coeur d'Alene River flood plain and the bed of Coeur d'Alene Lake have been assessed. Trace-element transport models have been developed for the lower Coeur d'Alene River system; estimates of annual load are available from the early 1990's to the present (1998). The USGS is monitoring trace-element concentrations and transport at seven gaging stations in the lower Coeur d'Alene River system and upper Spokane River, in cooperation with the U.S. Environmental Protection Agency.

Fish and macroinvertebrate community assessment and tissue contaminant analyses at four Coeur d'Alene and St. Joe River gaging stations will begin in 1998, either as part of the Idaho Surface-Water Quality Ambient Monitoring Network operated by USGS in cooperation with the Idaho Division of Environmental Quality, or for the Northern Rockies Intermontane Basins (NROK) study of the USGS National Water-Quality Assessment (NAWQA) Program. Several gaging stations in the Spokane River Basin are being considered for routine sampling sites for the NROK NAWQA study. Several other sites also will be sampled for contaminants in bed sediment and fish tissue for the NROK study.

Combined with appropriate sampling and data interpretation strategies, the existing USGS gaging-station network and data base could provide integrated water-quality information needed for sound environmental and resource-management decisions throughout the Spokane River Basin.

INTRODUCTION

Purpose and Scope

This report is the result of a project funded in 1997 by the U.S. Environmental Protection Agency (EPA) to design a conceptual water-quality monitoring network for producing information needed for sound decisions on water-quality and natural-resource management for the Coeur d'Alene River and Lake watershed. In response to public and agency comments about the need to expand monitoring to the entire basin, primarily the trace-element-affected reaches, the scope was expanded in early 1998 to include the entire Spokane River Basin (fig. 1), because trace elements from historical mining activities in Idaho enter Washington through the Spokane River. This report

(1) defines the major water-quality issues in the Spokane River Basin;

(2) presents the need for, and objectives of, a comprehensive, basinwide monitoring network;

(3) explores opportunities for coordinating with other local, regional, and national water-quality monitoring efforts and directives;

(4) presents a brief review of existing information and of recent and ongoing monitoring efforts, as well as the means for accessing that information;

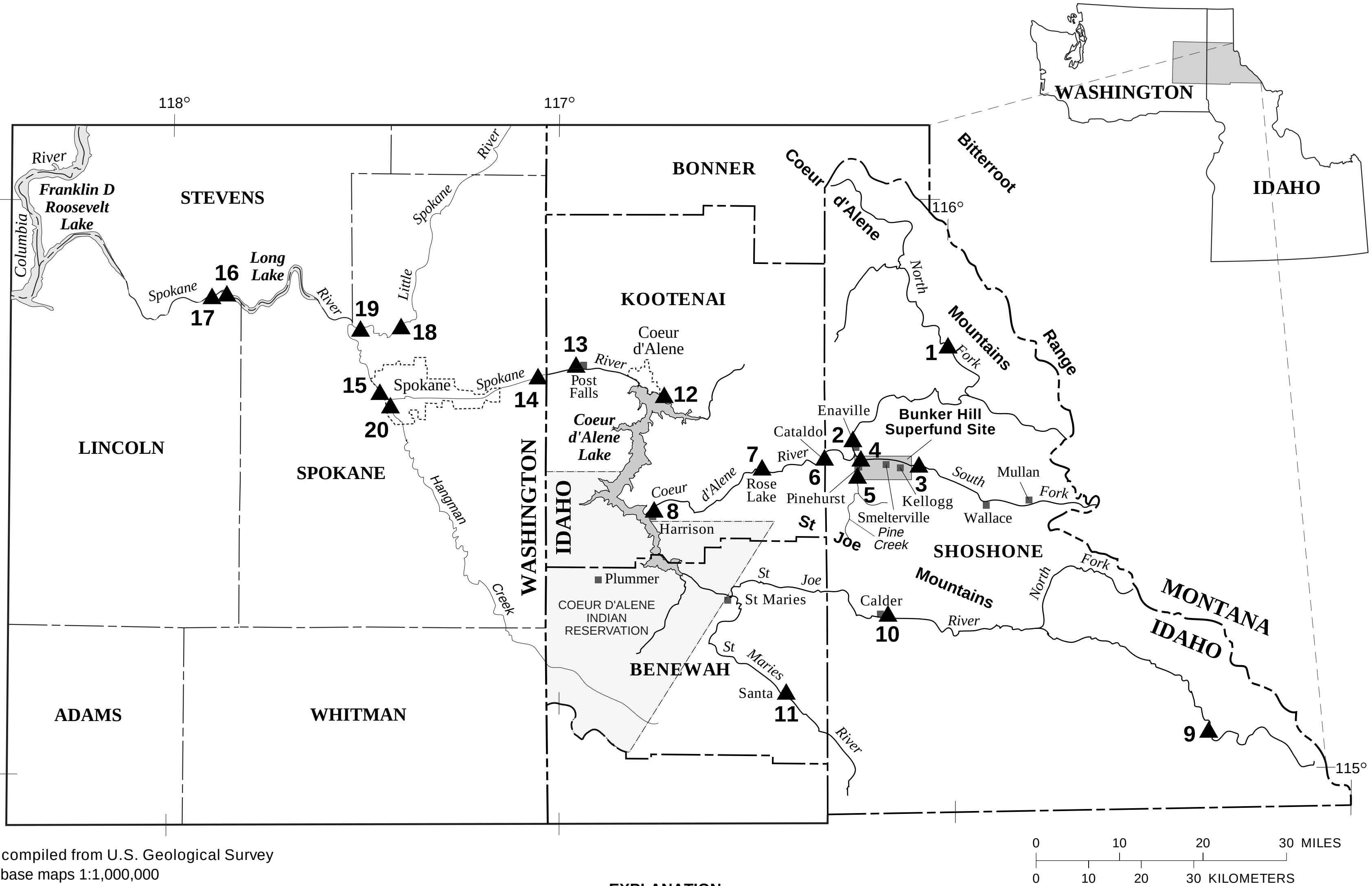
(5) provides an overview of water-quality monitoring concepts and methods; and

(6) proposes a conceptual design for a water-quality monitoring network for the Spokane River Basin.

Water-Quality Issues in the Spokane River Basin

Human activities over the last century have profoundly altered water-quality, aquatic biological, and hydrologic conditions in the Spokane River Basin (Rabe and Flaherty, 1974; Casner, 1989, 1991; Horowitz and others, 1993, 1995a, 1995b; Woods and Beckwith, 1997). The mining district in the South Fork Coeur d'Alene River valley was among the Nation's leading producers of silver, lead, and zinc. These activities produced extensive deposits of sediments contaminated with trace elements throughout the South Fork Coeur d'Alene River valley and its tributaries, the channel and extensive flood plain of the main-stem Coeur d'Alene River, and the lakebed of Coeur d'Alene Lake. Snowmelt runoff and occasional floods continue to redistribute and transport trace elements throughout the Spokane River Basin, perhaps reaching as far as the Columbia River in Washington (Bortleson and others, 1994).

Other water-quality issues also are of concern because of their complex, interactive, wide-ranging, and long-lasting nature. For example, changes in hydrologic conditions (streamflow, flood frequency, and magnitude) and resulting stream-channel and flood-plain destabilization potentially related to historical timber harvest and wildfire could influence transport of trace elements throughout the Spokane River Basin (U.S. Department of Agriculture, 1994). Increased nutrient and sediment transport associated with population growth and activities such as agriculture, land development, recreation, and wastewater disposal can accelerate eutrophication in Coeur d'Alene Lake and lead to remobilization of potentially toxic trace elements from lakebed sediments (Woods, 1989; Woods and Beckwith, 1997). Potential effects of ground- and surface-water interaction on water quality are of increasing concern, particularly in the mining-affected valleys of the South Fork and main-stem Coeur d'Alene River (Spruill, 1993; URS Greiner, Inc., written commun., 1997) and along the Spokane



Base compiled from U.S. Geological Survey
State base maps 1:1,000,000

EXPLANATION

▲ 5 **Gaging station and site number** (see table 3)

Figure 1. Location of study area.

River. Considerable exchange of water is thought to occur between the river and the large valley-fill Spokane Valley / Rathdrum Prairie aquifer, which serves more than 350,000 people and is designated “sole source” by EPA.

Considerable effort is underway to mitigate the adverse environmental effects of past mining in the basin, primarily in the South Fork Coeur d’Alene River valley and its tributaries. EPA is directing cleanup of a 21-mi^2 area surrounding the defunct Bunker Hill Mine and ore-processing complex in Kellogg, Idaho (fig. 1). The State of Idaho, other Federal agencies, and the mining industry also are conducting site-specific sediment-removal, reclamation, and stream-channel rehabilitation projects. EPA currently is evaluating environmental contamination and remediation options in mining-affected areas outside the already-designated Bunker Hill Superfund site. These areas are the lower Coeur d’Alene River, its flood plain and adjacent wetlands and shallow lateral lakes, the lakebed of Coeur d’Alene Lake, and could extend as far as Long Lake and into Franklin D. Roosevelt Lake on the Columbia River. The State of Washington is considering additional investigations of potential degradation of river, lake, and ground-water quality caused by trace-element transport from Idaho by way of the Spokane River.

Also underway is the Coeur d'Alene River Natural Resources Damage Assessment (NRDA). Federal agencies and the Coeur d'Alene Tribe have begun litigation to restore ecosystems adversely affected by past mining, ore-processing, and transportation activities. In addition, EPA and the State of Idaho are under court order to develop water-quality regulatory strategies, such as Total Maximum Daily Loads (TMDLs), for numerous water bodies in the Spokane River Basin that do not support designated beneficial uses or for which beneficial use support has not been adequately assessed.

Need for a Water-Quality Monitoring Network

A large amount of water-quality and related environmental data have been produced by previous study efforts in the Spokane River Basin. However, most previous efforts generally were limited in scope or conducted to address specific issues and interests. Also, different approaches and methods make data interpretation and comparison of results difficult and, in some cases, impossible.

Given the substantial resources devoted to environmental mitigation and water-quality management in the basin, an integrated network for producing relevant information on which to base sound decisions and to evaluate the environmental and cost effectiveness of those decisions would be of considerable value. A well-designed water-quality monitoring network would provide a common information base needed for various interests at multiple institutional levels and would make the most efficient use of limited resources.

REVIEW OF EXISTING WATER-QUALITY INFORMATION AND MONITORING EFFORTS

Early Investigations

A large amount of geologic, streamflow, water-quality, and aquatic biological data have been collected in the Spokane River Basin over more than a century. The U.S. Geological Survey (USGS) has been collecting streamflow data continuously on the Spokane River at Spokane, Wash., since 1891 and lake-level data on Coeur d’Alene Lake since 1903; several other gaging stations in the basin have periods of record dating from the early 1900’s. The USGS studied the extent of flooding and changes in the channels and flood plains of the lower St. Joe and Coeur d’Alene Rivers following construction of the hydroelectric dam on the lake outlet at Post Falls in 1906 (Davenport, 1921). Reduced dissolved oxygen levels in the lake’s bottom waters were detected in 1911 in an early evaluation of the Nation’s fisheries (Kemmerer and others, 1923).

One of the first and, until recently, one of the most comprehensive water-quality studies in the basin was conducted in the early 1930’s by the Federal Bureau of Fisheries at the request of the State of Idaho (Ellis, 1940). This study characterized the lower Coeur d’Alene River and southern end of the lake as almost totally devoid of aquatic life from mining-related pollution in the South Fork Coeur d’Alene River valley and made pollution-control recommendations (such as settling ponds) that were not implemented until the late 1960’s.

Agency and Academic Investigations

A series of water-quality studies throughout the basin by university researchers and governmental agencies were conducted in the 1970’s and 1980’s (Funk and others, 1973, 1975; U.S. Environmental Protection Agency, 1977; Thomas and Soltero, 1977;

Yearsley, 1980; Seitz and Jones, 1981; Falter and Mitchell, 1982; Hornig and others, 1988). Most of these studies described environmental conditions in the basin. However, some led to water-quality management actions such as upgrades to municipal and industrial wastewater treatment plants and processes, establishment of a TMDL for phosphorus for Long Lake, and interstate allocations of permitted phosphorus loads among dischargers (Soltero and Nichols, 1984; Soltero and others, 1993; Pelletier, 1994). A large amount of water-quality data related to the Bunker Hill Superfund site also was collected by EPA and other regulatory agencies and contractors in the 1980's.

Sediment and fish-tissue contamination in the Spokane River was assessed by the Washington State Department of Ecology (WDOE) in the early 1990's (Washington State Department of Ecology, 1995). Small-scope fish-tissue contaminant studies of Coeur d'Alene Lake and River were conducted by the Agency for Toxic Substances and Disease Registry (a branch of the Federal Centers for Disease Control) and by the Idaho Division of Environmental Quality (IDEQ). Information about the health risks posed to humans by consumption of fish generally is lacking, and risk probably cannot be determined from the available data (T.R. Maret, U.S. Geological Survey, written commun., 1998).

A considerable amount of water-quality information is available for the Spokane River downstream from Coeur d'Alene Lake and for Long Lake, much of it in the form of internal or contractor-prepared study-completion reports to the Spokane, Wash., office of WDOE. Additional water-quality information for the Coeur d'Alene Lake watershed and upper Spokane River is available in contractor and internal IDEQ reports (Hartz, 1993). Specific water-quality, aquatic biological, and channel morphometry information is available from agencies such as the Idaho Departments of Fish and Game and Lands and Water Resources (Coeur d'Alene, Idaho, offices); the U.S. Departments of the Interior (U.S. Fish and Wildlife Service, Spokane, Wash., or Boise, Idaho, offices) and Agriculture (U.S. Forest Service, Natural Resources Conservation Service, Coeur d'Alene, Idaho, offices); and the Washington State Department of Wildlife (Spokane, Wash., office).

U.S. Geological Survey Limnological Assessment of Coeur d'Alene Lake

In the early 1990's, the USGS completed a comprehensive assessment of Coeur d'Alene Lake and its watershed with an emphasis on limnology, the potential for lake eutrophication, and lakebed trace-element contamination (Woods and Beckwith, 1997). This assessment was conducted in cooperation with the IDEQ and the Coeur d'Alene Tribe and was used to develop a lake-management plan (Idaho Department of Environmental Quality, written commun., 1996).

Woods and Beckwith (1997) concluded that certain indicators of lake water quality had improved recently, probably in response to pollution control measures and the substantial reduction in mining activities in the South Fork Coeur d'Alene River valley. Biological primary productivity in the lake water column was suppressed by high concentrations of zinc (Kuwabara and others, 1994). The lake had some capacity to assimilate additional nutrient loading; however, signs of accelerated eutrophication, such as reduced dissolved oxygen concentrations in bottom waters, were evident in late summer.

Studies of trace-element conditions in Coeur d'Alene Lake by Horowitz and others (1993, 1995a, 1995b) indicated that most of the lake bottom was covered with sediments highly enriched in trace elements and that deposition of these sediments appeared to coincide with the onset of mining in the South Fork Coeur d'Alene River valley. Trace elements in lakebed sediments were present primarily in oxyhydroxide phases, not as sulfides as are the original ore bodies, making the trace elements potentially more mobile in the environment, especially under the reducing conditions associated with anoxia in the bottom waters of lakes undergoing eutrophication. Fewer organisms than might be expected were observed dwelling in lakebed sediments, perhaps as a consequence of elevated trace-element concentrations. These observations were corroborated by another study (Ruud, 1996).

Coeur d'Alene River Natural Resource Damage Assessment

Beginning in 1992–93, a large amount of data was collected during an NRDA by the U.S. Department of the Interior (Bureau of Land Management, U.S. Fish and Wildlife Service, and USGS); U.S. Department of Agriculture (U.S. Forest Service); U.S. Justice Department; the Coeur d'Alene Tribe; and associated contractors. NRDA actions are authorized by the same laws governing Superfund sites and allow citizens or affected parties to sue for damages to natural resources caused by the release of toxic or hazardous substances. NRDA actions could require environmental cleanup to conditions that existed prior to the release of hazardous substances. In contrast, the level of cleanup required at most Superfund sites is that necessary to protect human and environmental health. Information produced during the Coeur d'Alene River NRDA is being used in pending litigation. Much of this information has been summarized in public information releases (D. Pedersen, U.S. Fish and Wildlife Service, written commun., 1995 and 1996). Some of the information has been published in the scientific literature (Woodward and others, 1997). Much of it has not yet been made publicly available but is expected to be released as the NRDA action proceeds.

As part of the NRDA effort, the USGS characterized trace-element concentrations and loads (amount of a substance transported by a river or stream over a given time period) in the lower North Fork, South Fork, and main-stem Coeur d'Alene Rivers during water years 1993 and 1994 and during periods of high streamflow and floods in 1995 and 1996. USGS results have been published in reports by Harenberg and others (1994); Brennan and others (1995, 1996, 1997); Beckwith (1996); and Beckwith and others (1997). Water-quality and associated streamflow data for these rivers were collected by the USGS during the second-largest floods on record in February 1996 (Beckwith, 1996).

Trace-element concentrations in riverbank, channel, and flood-plain sediments also were assessed. In 1992, continuous vertical riverbank samples were collected from the lower North Fork, South Fork, and main-stem Coeur d'Alene Rivers and from the lower St. Joe River. In 1993, the flood plain of the lower South Fork and main-stem Coeur d'Alene Rivers, from the western part of the Bunker Hill Superfund site to Coeur d'Alene Lake, was sampled using a 1-kilometer (0.62-mi) grid sampling scheme. Surface samples to a depth of about 6 in. were collected at 176 sites. In 1994, cores to a depth of 10 to 16 ft were obtained at 22 sites, primarily from the banks of the Coeur d'Alene River, where the surface samples were the most highly enriched in trace elements. Riverbank and flood-plain sediments of the lower South Fork and main-stem Coeur d'Alene Rivers were highly enriched in arsenic, lead, mercury, silver, tin, and zinc; less enriched in cadmium, copper, iron, and manganese; and depleted in aluminum and titanium relative to unenriched median values (Fousek, 1996). Maximum thickness of the trace-element enriched zone in these cores was about 8 ft (Fousek, 1996). Trace-element concentrations across the flood plain generally decreased laterally away from the riverbanks, lateral lakes, wetlands, and depositional flats (Fousek, 1996).

The USGS NRDA studies indicate that

(1) zinc is transported primarily in dissolved or colloidal phase; the primary source of zinc is the lower South Fork Coeur d'Alene River valley;

(2) lead transport is associated primarily with sediment eroded from the bed, banks, and flood plain of the lower Coeur d'Alene River, especially during high flow conditions;

(3) trace-element concentrations increase substantially, and annual loads approximately double through the Bunker Hill Superfund site;

(4) mining-contaminated sediments in the lower Coeur d'Alene River valley continue to be eroded and redistributed; and

(5) floods transport large quantities of sediment and trace elements in short time periods (A.J. Horowitz, U.S. Geological Survey, written commun., 1995; Fousek, 1996; Beckwith and others, 1997; L.H. Tornes, U.S. Geological Survey, written commun., 1997).

U.S. Geological Survey Hydraulic Models

Backwater conditions created by fluctuations in the level of Coeur d'Alene Lake prevent correlation of streamflow with river stage for much of the year in the lower St. Joe and Coeur d'Alene Rivers. The USGS limnological study of Coeur d'Alene Lake and the NRDA characterization of trace-element transport in the lower Coeur d'Alene River system required accurate estimates of streamflow through these reaches. Therefore, hydraulic computer models were developed to estimate streamflow in the St. Joe River from St. Maries, Idaho, to the mouth, and in the Coeur d'Alene River from Cataldo, Idaho, to the mouth. These USGS models (BRANCH and FourPt) are based on river stage and elevation differences between multiple, accurately surveyed channel cross sections; channel morphology and capacity; and one-dimensional, partial-differential equations of continuity and momentum that govern unsteady, open-channel streamflow (Schaffranek and others, 1981; DeLong and others, 1997).

Trace-Element Transport Models for the Lower Coeur d'Alene River System

Beginning in water years 1996 and 1997, the EPA cooperated with the USGS in collecting streamflow and trace-element data at seven gaging stations in the lower North Fork, South Fork, and main-stem Coeur d'Alene Rivers and Spokane River. These efforts are essentially a continuation of the monitoring efforts conducted for the NRDA during 1993 and 1994 and are continuing in 1998. Trace-element transport was estimated using regression-based loading models capable of estimating constituent transport over a wide range of user-defined time periods (Walker, 1996). A wide range of streamflow conditions have been sampled at the seven stations. With data collected at some sites since 1990, robust estimates of transport for various time periods (including daily) are now possible.

Environmental Remediation Project Effectiveness and Total Maximum Daily Loads Monitoring

Extensive water-quality data have been collected by State and Federal regulatory agencies and their contractors since the early 1990's, often in the form of synoptic assessments of water chemistry and streamflow conditions (McCulley, Frick, and Gillman, Inc., written commun., 1991, 1992; Ecology and Environment, Inc., written commun., 1993). The primary objective of these assessments was to identify sources of trace elements and to characterize relative loading contributions at the tributary and stream-reach level.

The IDEQ has monitored water quality to assess the effectiveness of recent remediation projects in the South Fork Coeur d'Alene River and tributaries conducted by the mining industry and State and Federal agencies (Idaho Department of Environmental Quality, written commun., 1997). The IDEQ also has conducted monitoring throughout the Coeur d'Alene River and Lake watershed and the Spokane River to characterize water-quality conditions and to estimate trace-element loads for purposes of determining support (or nonsupport) of beneficial uses in specific water bodies and for developing TMDLs and site-specific water-quality criteria (Idaho Department of Environmental Quality, written commun., 1997). Review of selected IDEQ data indicates that the results of these monitoring efforts might be of limited utility because they do not represent an adequate range of streamflow conditions.

Idaho Surface-Water Quality Ambient Monitoring Network

In cooperation with the IDEQ, the USGS currently is operating a statewide water-quality and aquatic biological monitoring network. The Idaho Surface-Water Quality Ambient Monitoring Network (ISWN) includes four sites in the Coeur d'Alene River Basin. Physical and chemical constituents (table 1) throughout the water column are collected monthly from April through September, every year at the South Fork Coeur d'Alene River near Pinehurst and the Coeur d'Alene River at Cataldo (sites 4 and 6, fig. 1), and every 3 years at the North Fork Coeur d'Alene River at Enaville and the St. Joe River at Calder (sites 2 and 10, fig. 1). Fish and macroinvertebrate communities will be assessed and tissue contaminant data (table 2) will be collected every 3 years at three of these sites (Pinehurst, Enaville, and Calder) beginning in 1998.

Washington Ambient Water-Quality Monitoring

The State of Washington has collected water-quality data throughout the State since 1959. For this monitoring program, samples generally were collected monthly and consist of centroid-of-flow grab samples from bridges. The resulting data include physical characteristics such as temperature, and chemical constituents such as common ions, nutrients, and selected trace elements. Data have been collected downstream from the City of Spokane wastewater treatment plant since 1972. Data have been collected from near the mouth of Hangman Creek from the late 1970's to the present, except for 1992 and 1994. Water-quality data also have been collected from near the mouth of the Little Spokane River during 1971, 1973, 1977 through 1991, and 1994 to present.

Data have been collected from the Spokane River near the Idaho-Washington border during 1959 to the present, except for 1966–68. Currently, samples from this site are collected monthly from February through June and every other month from August through December. The samples are analyzed for common ions, nutrients (nitrogen and phosphorus), and total recoverable and dissolved cadmium, copper, lead, mercury, and zinc.

U.S. Geological Survey Gaging-Station Data

USGS activities in the Coeur d'Alene River Basin (especially those from 1990 to present) have produced an extensive set of streamflow and water-quality data. Water-chemistry data can be linked to streamflow data (monitored continuously in most cases at 15-minute intervals) representing a wide range of conditions in major stream and river reaches, drainages, and subdrainages, and over long time periods. This data base and gaging-station network are well suited to assessing water-quality and streamflow conditions, trends, and constituent transport, and, compared with other discontinuous data sets, can serve as the basis for a long-term monitoring network throughout the Spokane River Basin.

Repository for Existing Information

Savage (1986) compiled a topical review of environmental studies on the Coeur d'Alene River and Lake system. WDOE water-quality monitoring information and reports now can be accessed or requested through the World Wide Web. Information on IDEQ data and reports can be obtained by contacting the local IDEQ office in Coeur d'Alene. In addition, the Coeur d'Alene Tribe has assembled perhaps the most extensive library of information, reports, and geographic information system (GIS) data for the Coeur d'Alene Lake and River watershed. A searchable data base has been constructed to assist potential users and can be accessed by contacting the Tribe's Natural Resource Damage Assessment Project Office in Coeur d'Alene or Tribal Headquarters in Plummer, Idaho. In addition, national data bases such as the EPA Storage and Retrieval (STORET) system and the USGS National Water Information System (NWIS) contain water-quality data for the Spokane River Basin.

Table 1. Constituents in water-column samples collected at selected sites in the Coeur d'Alene River Basin and analyzed for the Idaho Surface-Water Quality Ambient Monitoring Network

[EPA, U.S. Environmental Protection Agency; STORET, Storage and Retrieval system]

Constituents	EPA STORET code
Physical characteristics	
Alkalinity	00410
Barometric pressure	00025
Discharge	00060
Oxygen, dissolved	00300
pH	00400
Specific conductance	00095
Suspended sediment	80154
Temperature, continuous, June–September	00010
Turbidity	00076
Common ions, dissolved (milligrams per liter)	
Calcium	00915
Chloride	00940
Fluoride	00950
Magnesium	00925
Potassium	00935
Silica	00955
Sodium	00930
Sulfate	00945
Nutrients (milligrams per liter)	
Ammonia-nitrogen, total	00610
Ammonia+organic–nitrogen, total	00625
Nitrite+nitrate–nitrogen, dissolved	00631
Phosphorus, total	00665
Orthophosphate-phosphorus, dissolved	00671
Bacteria (colonies per 100 milliliters)	
Fecal coliform	31625
Fecal streptococci	31673

Table 2. Constituents in tissue of fish collected at selected sites in the Coeur d'Alene River Basin and analyzed for the Idaho Surface-Water Quality Ambient Monitoring Network and U.S. Geological Survey National Water-Quality Assessment Program

Trace elements in fish livers (parts per million, dry weight)	
Aluminum	Manganese
Antimony	Mercury
Arsenic	Molybdenum
Barium	Nickel
Beryllium	Selenium
Cadmium	Silver
Chromium	Strontium
Cobalt	Thorium
Copper	Uranium
Iron	Vanadium
Lead	Zinc

Organochlorine insecticides and polychlorinated biphenyls in whole-body fish (parts per million, dry weight)	
Aldrin	beta-HCH
cis-Chlordane	gamma-HCH (Lindane)
trans-Chlordane	Methoxychlor, *o,p'*
Dacthal	Methoxychlor, *p,p'*
o,p' -DDD	Mirex
p,p' -DDD	*cis*-Nonachlor
o,p' -DDE	*trans*-Nonachlor
o,p' -DDT	Oxychlordane
p,p' -DDT	Pentachloroanisole
Dieldrin	Polychlorinated biphenyls (PCBs-total)
Endrin	Toxaphene
Heptachlor	
Heptachlor epoxide	
alpha-HCH	

OPPORTUNITIES FOR COORDINATING WITH OTHER MONITORING EFFORTS

U.S. Geological Survey National Water-Quality Assessment Program

A timely opportunity exists to develop and implement a water-quality monitoring network in the Spokane River Basin that is complementary to (but independent of) the USGS Northern Rockies Intermontane Basins study of the National Water-Quality Assessment Program (NROK NAWQA). The NROK NAWQA began in 1997 and encompasses the Pend Oreille and Spokane River Basins in northwestern Montana, northern Idaho, and northeastern Washington.

The goals of the USGS NAWQA Program are to

(1) assess current water-quality conditions for a large part of the Nation’s surface and ground water by using consistent and standardized methods. The standardized methods and protocols of the NAWQA Program are described in reports by Cuffney and others (1993a, 1993b); Meador and others (1993a, 1993b); Porter and others (1993); Shelton (1994); Shelton and Capel (1994); Gilliom and others (1995); Koterba and others (1995); and Lapham and others (1995, 1997);

(2) describe how water quality is changing over time; and

(3) characterize the natural and human factors affecting water quality at the local, regional, and national levels.

Because of the national scope of the NAWQA Program and large size of the study area, the NROK NAWQA cannot be expected to provide information at the level of detail needed for water-quality and resource-management decisions at the specific environmental remediation project, tributary, or stream-reach level in the Spokane River Basin. However, because of the emphasis placed on consistency of study methods, the NROK NAWQA could provide a useful framework for comparing water-quality and aquatic biological conditions in the Spokane River Basin with those throughout the Northern Rocky Mountains physiographic province. The NROK NAWQA also could assist in evaluating the effectiveness of water-quality and resource-management actions in the Spokane River Basin compared with those in other large, mining-affected basins, such as the upper Clark Fork in Montana, that share similar water-quality and institutional issues.

Upper Clark Fork Monitoring, Montana

Since the mid-1980’s, USGS, EPA, the State of Montana, and the mining industry have cooperated in a water-quality monitoring effort in the upper Clark Fork drainage, where the Nation’s largest Superfund and NRDA sites are located. An integrated streamflow, water-quality, and aquatic biological monitoring network operated by USGS has been in place since water year 1993 (Lambing and others, 1994, 1995; Dodge and others, 1997; Hornberger and others, 1997). Accurate assessment of water-quality effects and trends resulting from extensive cleanup activities is only now becoming possible. These efforts could serve as a model for establishing and operating a similar network in the Spokane River Basin.

Intergovernmental Task Force on Monitoring Water Quality

A comprehensive water-quality monitoring network and information system for the Spokane River Basin could serve as a model for implementing recent recommendations of the Intergovernmental Task Force on Monitoring Water Quality (ITFM). The ITFM was established in 1992 in response to a memorandum from the U.S. Office of Management and Budget calling for a nationwide technical and fiscal evaluation of water-quality monitoring. The ITFM is a partnership of Federal, State, Tribal, public, and private interests charged with evaluating water-quality monitoring activities for the Nation as a whole and recommending improvements.

In its final report, the ITFM (1995) proposed a strategy for nationwide changes in water-quality monitoring needed to produce relevant, high-quality information to support sound decision making at all levels of government and in the private sector in the most cost-effective manner possible. Major goals of the ITFM strategy are to (1) improve the overall technical quality and consistency of the Nation’s water-quality information base; (2) make it more useful to a wider variety of interests at multiple geographic and time scales; and (3) achieve a better return on public and private investments in monitoring, water-quality protection, and natural-resource management. In some cases, the ITFM strategy endorses current and ongoing efforts; in others, it calls for fundamental changes in ways that water-quality monitoring efforts are defined, designed, prioritized, conducted, and funded.

OVERVIEW OF WATER-QUALITY MONITORING CONCEPTS

Defining Water Quality

The phrase "water quality" is both subjective and perspective-dependent. Water quality traditionally has been defined in terms of physical characteristics (temperature, for example) and concentrations of chemical constituents (the amount of a substance present in a given amount of water) in the water column. However, aquatic biological conditions (at a given point or throughout an entire river basin) can be the ultimate temporal and spatial expression of water quality (Cuffney and others, 1993b; Gurtz, 1994). Effective water-quality monitoring includes streamflow, channel morphometry and stability, and aquatic biological conditions and habitat.

A Systems Approach to Water-Quality Monitoring

Over the past three decades, water-quality monitoring programs have produced large amounts of data; however, information needed for actual decisions at local, regional, and national levels often remains lacking (International Task Force on Monitoring Water Quality, 1995). In the end, many monitoring efforts become less-than-successful attempts to make sense out of large amounts of the wrong kinds of data or data that are not directly related to the issues at hand. A systems approach (Sanders and others, 1990; Ward and others, 1990) to developing a water-quality monitoring program would ensure that (1) specific objectives or water-quality information needs determine the type of data collected and the actual data-collection (monitoring) activities, (2) the collected data are processed into usable and needed information, and (3) that information ultimately is incorporated into actual decisions.

Types of Water-Quality Monitoring

Water-quality monitoring objectives generally can be characterized as regulatory, resource assessment, resource management, or, most likely, as some combination thereof. Monitoring that produces information about current conditions can be described as "ambient" monitoring. In contrast, monitoring conducted to detect changes in water-quality conditions resulting from a specific environmental remediation project or regulatory action can be described as "effectiveness" monitoring.

Changes in water-quality conditions can be detected if ambient monitoring is performed using sound, consistent methods and appropriate sampling frequencies over appropriate time periods and at appropriate sites, and using appropriate quality control, statistical, and other data-interpretation techniques. Likewise, changes in water-quality conditions resulting from specific projects or actions can be detected if conditions existing before and after the project are adequately characterized and if appropriate statistical tests are used to make comparisons. In general, effectiveness monitoring can be more difficult and resource intensive than ambient monitoring. The timeframes and resources allotted to characterize before-and-after conditions and to identify cause and effect usually are constrained, and water-quality conditions often must be characterized at multiple locations, which requires additional resources or further disperses available resources.

In both ambient and effectiveness monitoring, the challenge is to determine whether observed differences or changes are the result of an identifiable cause or event, or merely due to the variations inherent in natural systems and environmental data. Statistical procedures are available to assist in making this distinction (Helsel and Hirsch, 1992). However, their data requirements are strongly linked to the degree of confidence (level of uncertainty) associated with the answers they provide. In general, greater statistical confidence (lower levels of uncertainty) requires more extensive data-collection efforts, often over longer time periods, and therefore requires more resources.

Hydrology-Based Water-Quality Monitoring

River and stream systems are extremely variable in both time and space. Distinguishing real changes from this inherent variability is the primary challenge in all environmental monitoring. Unfortunately, most currently accepted and commonly employed monitoring strategies fail to meet this challenge. Obtaining a series of samples that truly reflect conditions in a river or stream throughout the channel cross section, over a full range of flow conditions, and over a given time period is at best difficult and, at worst, nearly impossible.

In river and stream water-quality monitoring, both streamflow and concentration data should be collected. This approach often is referred to as hydrology-based monitoring. When accurate streamflow and concentration data, collected over an adequate time period and representing a wide range of conditions, are combined with appropriate data-interpretation techniques, most or all monitoring objectives can be met. For example, the flux or load is the product of concentration, streamflow, and time. Although concentration data can be used to determine whether regulatory concentration standards or criteria are being met, concentration data alone generally cannot be used to infer trends or identify cause-and-effect relations. In contrast, flux or load data, because they are an expression of concentration and streamflow over time, can be used to identify trends at specific locations or to make comparisons between different locations or over different timeframes. Aquatic biological communities also are often affected by streamflow conditions and constituent concentrations.

In addition, data collection over the full range of streamflow conditions, particularly during hydrologic extremes such as spring runoff, heavy storms, and (or) floods, would best represent overall water-quality conditions. Rivers and streams generally transport large amounts of constituents (such as sediment and sediment-associated and dissolved substances) over a relatively short time, generally during periods of high streamflow. Also, concentration often is strongly influenced by streamflow; soluble substances can be diluted, whereas sediment-associated substances can be entrained by high streamflow.

For example, in early February 1996, during the second-largest floods on record, the Coeur d'Alene River transported, in a few days, amounts of sediment, nutrients, and trace elements equivalent to amounts transported in each of several previous water years (Beckwith, 1996; Beckwith and others, 1997; Woods and Beckwith, 1997). Concentrations of some constituents observed during the floods were orders of magnitude larger than mean concentrations observed during previous water years (Beckwith and others, 1997). For example, shortly after the peak of the floods, concentrations of whole-water recoverable (WWR) and dissolved lead at the mouth of the Coeur d'Alene River were 6,500 and 100 µg/L, respectively. These concentrations greatly exceeded toxicity criteria recommended by EPA for the protection of aquatic biota, as well as criteria recommended for drinking water. In contrast, mean WWR lead concentrations during water years 1993 and 1994 were 116 and 51.6 µg/L, respectively (Beckwith and others, 1997).

Linking data-collection efforts to streamflow conditions provides a better representation of water-quality conditions. For example, a common practice in water-quality monitoring is calendar-based sampling at regularly scheduled intervals. However, if extreme streamflow conditions occur between intervals and data are not collected, water-quality conditions over a given time period will not be adequately represented. This generally has been the case in the Coeur d'Alene River Basin in recent water-quality monitoring efforts conducted by regulatory agencies. If data collection is not linked to streamflow conditions, the resulting estimates of loads and mean (or even median) constituent concentrations can misrepresent actual water-quality conditions.

An advantage of hydrology-based monitoring, especially when used as the basis for regression-based loading models, is that as the data base accumulates for a given site, additional data can be collected more efficiently. Because streamflow and water-quality data often are not normally distributed (statistically), the data tend to be clustered in a narrow range, with outliers representing extreme conditions or rare events such as large floods or droughts. Once this normal or generally expected range of streamflow and concentration conditions is adequately characterized, data collection can be targeted on extreme conditions when most transport occurs or can fill in gaps in the continuum of observed or expected conditions.

Methods for Sampling and Analysis that Represent Actual Environmental Conditions

Suspended-sediment and associated trace-element concentrations are highly variable in rivers and streams. Samples collected from discrete points such as near the bank, from a bridge, or even from the centroid of flow, often do not represent conditions throughout the entire stream cross section. Spatially representative samples can be obtained only by collecting a series of subsamples using depth-, flow-, and width-integrating sampling techniques (Horowitz, 1997). Temporally representative samples require nearly continuous or very high frequency collection and analysis, which is generally impractical. Therefore, samples would be most representative of actual conditions if sample-collection frequency were distributed as evenly as possible throughout the full range of observed streamflow conditions and an approximately equal number of samples allocated to each decile or quartile (increments of 10 and 25 percent, respectively) of the streamflow range.

Results from laboratory analyses might not always reflect actual environmental conditions, but instead might be simply a function of traditional sampling, sample processing, and analysis procedures. Recent evidence (Horowitz, 1995, 1997) indicates that most trace-element transport is associated with solid materials, present in the water either as discrete particles (suspended sediment) or as colloids (semisolid materials). Reported dissolved trace-element concentrations might be primarily colloidal material that has passed through the filter, rather than constituents that are actually dissolved in the water (Horowitz and others, 1996a, 1996b). Furthermore, the amount of colloidal material passing through a filter has been shown to vary greatly with (1) filter type, diameter, and manufacturer; (2) filtration method (vacuum or pressure); (3) suspended-sediment concentration and grain-size distribution; (4) presence and concentrations of colloids and organic material; and (5) the amount and type of material collected on the filter prior to collecting the subsample for chemical analysis (Horowitz and others, 1996a, 1996b; Horowitz, 1997).

In addition, "total" constituent concentrations (determined from unfiltered samples that still contain solid materials) often are reported to be smaller than corresponding dissolved concentrations (determined from samples from which solid materials supposedly have been removed by filtration). This seemingly impossible situation is probably the result of contamination associated with sampling and sample handling, artifacts introduced by filtration processes, and the inherent errors associated with any measurement or analytical technique. The situation is so common for recent and historical water-quality data (including USGS data) that the USGS recently developed and adopted sampling and filtration protocols that essentially standardize an operational definition of dissolved constituents. These protocols involve the use of "clean" sampling and processing techniques, the use of capsule filters of 0.45-µm pore size that have a large filtration surface area compared with traditional flat plate filters, and enhanced quality assurance / quality control procedures. Similar protocols also are now recommended by EPA.

The fact that analytical results might not reflect actual environmental conditions also presents a serious regulatory dilemma. Agencies often are required by law to use dissolved concentration data for regulatory purposes. However, the reported dissolved concentration values produced by commonly used or traditional protocols might be of questionable validity.

Suspended Sediment as a Surrogate for Monitoring Other Constituents

The hydrology-based monitoring concept can be expanded, for example, to use suspended sediment as a surrogate for estimating trace-element transport. Horowitz (1995) described this approach in detail. This approach also could employ advanced instrumentation (such as nephelometers and particle counters) installed at gaging stations to optically or acoustically measure instream suspended-sediment concentrations.

Because this approach infers actual constituent concentrations (of trace elements, for example) on the basis of a surrogate constituent (suspended sediment), it may not be readily adaptable to monitoring for compliance with numerical concentration standards or criteria established by regulatory agencies. However, instream turbidity monitoring stations were installed recently in the lower South Fork Coeur d'Alene River by the USGS for the U.S. Army Corps of Engineers to monitor compliance with State turbidity standards applicable to near-stream construction activities associated with Bunker Hill Superfund site remediation. The surrogate approach also could not be expected to address directly the effects of sediment-associated trace-element concentrations or transport on aquatic biota, but the resulting information could be linked to appropriate biological assessments and bioassays.

The surrogate approach probably offers the greatest potential for identifying and accurately assessing changes in constituent transport resulting from environmental remediation or resource-management actions. It probably is best suited to monitoring constituent transport at the river basin or subbasin level over relatively long time periods (greater than 5 to 10 years). Although resource intensive initially, over the long term, this approach could be the most cost effective and ultimately could produce the best information about the cumulative response of river basins or subbasins to environmental remediation and management actions in terms of changes in constituent transport. For these reasons, the USGS now is using the surrogate approach to assess off-continent constituent transport at the mouths of very large rivers such as the Columbia and Mississippi. This approach has been used for monitoring trace-element transport from mining-affected areas of the upper Clark Fork in Montana for nearly a decade. It also could be used, for example, to monitor sediment transport or yield at the drainage or subdrainage level, such as in the North Fork Coeur d'Alene and upper St. Joe River Basins, where sediment from timber harvest and other land-management activities are water-quality issues of concern.

The surrogate approach is presented here primarily for future consideration of its use as a means of meeting specific monitoring objectives where traditional methods might not be effective or appropriate. The surrogate approach is not incorporated in the conceptual monitoring network for the Spokane River Basin described in the next section of this report.

CONCEPTUAL WATER-QUALITY MONITORING NETWORK FOR THE SPOKANE RIVER BASIN

Defining information needs is an important step in designing a water-quality monitoring network for the Spokane River Basin. Toward that end, the USGS solicited comments from 65 governmental agencies, industry and environmental interest groups, and involved citizens. Six written and three verbal responses were received. A common theme in the responses was that a water-quality monitoring network for the basin should not be "just another study" of the already well-documented trace-element contamination issues, but must define temporal changes in water-quality and aquatic biological conditions resulting from the extensive environmental remediation, regulatory, and resource-management activities ongoing and planned in the basin. Furthermore, the resulting information actually must be used to make sound decisions regarding these activities. Issues other than mining-related trace-element contamination also were identified and included (1) nutrient loading and the potential for accelerated eutrophication, (2) potential changes in basin hydrologic conditions and stream-channel conditions related to past and present land-management activities and natural environmental causes, and (3) the need to monitor downstream from Coeur d'Alene Lake to assess the interstate aspects of water-quality issues and actions in Idaho that affect receiving water in Washington.

Objectives

The overall objective of a water-quality monitoring network for the Spokane River Basin would be to provide relevant, technically valid, cost-effective information needed for sound water-quality and natural-resource management decisions at multiple institutional levels. Such a network would be capable of (1) characterizing hydrologic, water-quality, and aquatic biological conditions throughout the basin; and (2) detecting changes in those conditions at multiple spatial and temporal scales.

Existing Monitoring Network

The basis for a water-quality monitoring network in the Spokane River Basin is essentially in place and operational. Twenty USGS gaging stations (2 lake-stage and 18 streamflow stations) are located throughout the basin (fig. 1; table 3). Continuous streamflow or lake-stage data are collected at all stations and are published in annual USGS Water Resources Data reports. Half of these stations transmit near-real time streamflow and other data, which are made available on the World Wide Web by the USGS. Water-quality sampling by the USGS in cooperation with IDEQ or EPA is ongoing at eight of the stations. National Weather Service precipitation-monitoring stations are co-located at four of the USGS stations. In addition, instruments were installed recently at three stations in the lower South Fork Coeur d'Alene River—at Kellogg, at Smelterville, and near Pinehurst (site 4, fig. 1)—to monitor turbidity in near-real time in support of Bunker Hill Superfund site remediation activities.

These gaging stations are strategically located at major "nodes" in the basin, so that each represents a specific drainage, subdrainage, or stream reach. Combined with appropriate monitoring strategies designed and conducted to produce relevant information needed for specific environmental and natural-resource management decisions, this network could serve as the basis for monitoring ambient water-quality conditions throughout the basin. It also could be used to characterize constituent transport at various spatial and temporal scales.

Additional stations could be established to provide better information or to address specific geographic areas or water-quality issues if necessary. For example, USGS monitoring indicates that trace-element concentrations and annual loads in the South Fork Coeur d'Alene River increase substantially through the Bunker Hill Superfund site between the Elizabeth Park and Pinehurst gaging stations (sites 3 and 4, fig. 1) (Beckwith and others, 1997). However, this increase cannot be attributed entirely to the Superfund site because the contribution from Pine Creek, which joins the South Fork upstream from the Pinehurst gaging station, was not monitored. Water-quality monitoring could be instituted at the recently installed gaging station (site 5, fig. 1) in the lower Pine Creek drainage to quantify its contribution and, thus, better define trace-element loading through the Superfund site as remediation activities progress. Water-quality monitoring at the Pine Creek station also could be used to assess the cumulative effects of environmental remediation and stream-channel rehabilitation projects planned and underway in this drainage.

In another example, USGS monitoring shows that zinc load is transported primarily in a dissolved and (or) colloidal form, and most of it comes from the lower South Fork Coeur d'Alene River valley. In con-

Table 3. U.S. Geological Survey gaging stations operating in the Spokane River Basin in water year 1998

[Sites are in Idaho unless otherwise noted; WA, Washington; EPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; NR, not a real-time gaging station; —, no monitoring currently]

Site No. (fig. 1)	Gaging station No.	Gaging station name	Period of record	Data available in real time	Current monitoring sponsor, type of data, and sampling frequency[1]
1	12411000	North Fork Coeur d'Alene River above Shoshone Creek near Prichard	Dec. 1950–present	Stage / discharge, precipitation	—
2	12413000	North Fork Coeur d'Alene River at Enaville	Mar. 1911–Apr. 1913, Oct. 1939–present	Stage / discharge, precipitation	ISWNc + Biology
3	12413210	South Fork Coeur d'Alene River at Elizabeth Park near Kellogg	Aug. 1987–Feb. 1991, May 1991–present	NR	EPA
4	12413470	South Fork Coeur d'Alene River near Pinehurst	Aug. 1987–present	Stage / discharge	ISWNa + Biology, EPA, NROK
5	12413445	Pine Creek below Amy Gulch near Pinehurst	Nov. 1997–present	Stage / discharge	—
6	12413500	Coeur d'Alene River at Cataldo	Apr. 1911–Dec. 1912, July 1920–Sept. 1972, Oct. 1986–present	Stage / discharge	EPA
7	12413810	Coeur d'Alene River at Rose Lake	Oct. 1994–present	NR	EPA
8	12413860	Coeur d'Alene River near Harrison	Jan. 1991–present	NR	EPA
9	12413875	St. Joe River at Red Ives Ranger Station near Avery	Oct. 1997–present	NR	NROK
10	12414500	St. Joe River at Calder	Apr. 1911–Sept. 1912, July 1920–present	Stage / discharge, precipitation	ISWNc + Biology
11	12414900	St. Maries River near Santa	Oct. 1965–present	Stage / discharge	—
12	12415500	Coeur d'Alene Lake at Coeur d'Alene	Apr. 1903–present	Stage (via phone line)	—
13	12419000	Spokane River near Post Falls	Oct. 1912–present	NR	ISWNa + Biology, EPA, NROK
14	[2]12419500	Spokane River above Liberty Bridge near Otis Orchards, WA	1930–36, 1938–40, 1942, 1944–46, 1951–79	NR	—
15	12422500	Spokane River at Spokane, WA	Apr. 1891–present	NR	NROK
16	12432500	Long Lake at Long Lake, WA	Oct. 1913–present	NR	—
17	[3]12433000	Spokane River at Long Lake, WA	Apr. 1939–present	Stage	—
18	12431000	Little Spokane River at Dartford, WA	Apr. 1929–Sept. 1932, Dec. 1946–present	Stage / discharge	—
19	12431500	Little Spokane River at Painted Rocks near Spokane, WA	Apr. 1948–Mar. 1952, Oct. 1997–present	NR	—
20	12424000	Hangman Creek at Spokane, WA	Apr. 1948–Sept. 1977, Oct. 1978–present	Precipitation	—

[1] EPA: Sampled for hardness and trace elements by the USGS 9 to 12 times annually; cadmium, lead, and zinc loads estimated.
ISWNa: Idaho Surface-Water Quality Ambient Monitoring Network site, sampled monthly Apr.–Sept., every year.
ISWNc: Idaho Surface-Water Quality Ambient Monitoring Network, sampled monthly Apr.–Sept., every year.
ISWN + Biology: Fish / macroinvertebrate community assessment and tissue (contaminant) analyses (in addition to regularly scheduled water-column sampling) every 3 years, beginning in 1998.
NROK: USGS Northern Rockies Intermontane Basins National Water-Quality Assessment (planned basic or intensive fixed site, sampled 12 to 18 times annually, 1999–2001).

[2] Former USGS cableway streamflow gaging station, now operated for educational purposes by Spokane Community College, Water Resources Technology Program.

[3] Operated by Washington Water Power Company, Inc.

trast, lead is transported primarily as particulate material eroded from the bed, banks, and flood plain of the main-stem Coeur d'Alene River. Annual loads of some trace elements at Rose Lake are substantially larger than at either Cataldo or Harrison, indicating entrainment in the reach between Cataldo and Rose Lake and subsequent loss or deposition in the reach between Rose Lake and Coeur d'Alene Lake (Beckwith and others, 1997). Combined with the USGS hydraulic models developed to estimate streamflow, these findings could serve as the basis for more detailed studies of sediment and trace-element transport needed for designing, implementing, and assessing the effectiveness of environmental remediation actions in the main-stem Coeur d'Alene River.

Link with U.S. Geological Survey Northern Rockies Intermontane Basins National Water-Quality Assessment

Several gaging stations in the Spokane River Basin are under consideration for inclusion in the NROK NAWQA as fixed sampling sites or as aquatic biological sampling sites. They include the South Fork Coeur d'Alene River near Pinehurst, the St. Joe River at Red Ives Ranger Station, the Spokane River near Post Falls, and the Spokane River at Spokane, Wash. (sites 4, 9, 13, and 15, fig. 1). Several other sites are under consideration for intensive aquatic biological, bed-sediment, and tissue-contaminant assessments.

During 1999–2001, NAWQA fixed sites will be sampled 12 to 18 times per year, with emphasis on sampling extreme streamflow conditions such as snowmelt runoff. In addition to continuous streamflow data, chemical and physical data will be collected at these sites. Synoptic sampling will be conducted at many other stream and river sites throughout the study area to improve spatial coverage or to address specific water-quality or hydrologic issues. Extensive information on aquatic biological conditions (algal, invertebrate, and fish communities and habitats), bed-sediment chemistry, bank and channel morphometry, and riparian characteristics also will be collected.

NAWQA fixed sampling sites are further characterized as indicator or integrator sites. Indicator sites characterize water-quality conditions resulting from relatively homogeneous land types or particular land uses. Integrator sites characterize conditions resulting from multiple land types and uses, typically at the mouths of large drainage areas. The St. Joe River at Red Ives Ranger Station (site 9, fig. 1) will serve as an indicator of water-quality and aquatic biological conditions in relatively undisturbed, forested, mid-elevation, mountainous areas in the Northern Rocky Mountains physiographic province. The South Fork Coeur d'Alene River near Pinehurst (site 4, fig. 1) will serve as an indicator of mining effects. The Spokane River near Post Falls and at Spokane (sites 13 and 15, fig. 1) probably will serve as indicator or integrator sites, reflecting the influences of Coeur d'Alene Lake and the Spokane metropolitan area, respectively. However, monitoring of in-lake processes will not be conducted as part of the NAWQA Program.

Ambient Surface-Water Quality Monitoring

A conceptual monitoring network and sampling strategy for the Spokane River Basin are presented in table 4. Essentially, they are an expansion of the USGS streamflow, hardness, and trace-element monitoring currently conducted in cooperation with the EPA at seven gaging stations in the Coeur d'Alene River system in Idaho, to include the entire Spokane River Basin.

The conceptual monitoring network incorporates other ongoing and planned efforts such as the NROK study of the USGS NAWQA Program and the ISWN conducted by the USGS in cooperation with the IDEQ. The conceptual network emphasizes sampling during periods of high streamflow; procedures that ensure representative samples from the stream cross section; standardized filtration, sample-processing, and quality-assurance protocols; and consistent data-interpretation methods. Nutrient sampling at selected gaging stations allows for the monitoring of nutrient loads to the Spokane River and Coeur d'Alene and Long Lakes. Streamflow and trace-element and nutrient loads could be estimated for any time period desired. An aquatic biological monitoring component patterned after the USGS NAWQA Program and ISWN also is included. Key elements are discussed in the next section.

TRACE-ELEMENT TRANSPORT IN THE SOUTH FORK COEUR D'ALENE RIVER

The cooperative USGS and EPA monitoring effort currently underway at seven stations on the Coeur d'Alene and Spokane Rivers in Idaho and Washington could be expanded. Additional gaging stations and monitoring sites could be established at the mouths of tributaries to the South Fork Coeur d'Alene River for monitoring trace-element contributions to the river and potential effects of remediation actions.

Table 4. Conceptual ambient surface-water quality monitoring network and strategy for the Spokane River Basin

[Sites are in Idaho unless otherwise noted; WA, Washington; x/yr, time(s) per year; NROK, Northern Rockies Intermontane Basins; NAWQA, National Water-Quality Assessment Program; WY, water year; approx., approximately; ISWN, Idaho Surface-Water Quality Ambient Monitoring Network; S, suspended sediment; P, pesticides; V, volatile organic compounds]

Site No. (fig. 1)	Gaging station No.	Gaging station name	Dissolved and total recoverable trace elements and hardness[1]	Nutrients (nitrogen and phosphorus, low-detection level)[2]	Aquatic biology[3]	Potential other constituents
1	12411000	North Fork Coeur d'Alene River above Shoshone Creek near Prichard	1x / yr (during biological sampling)	1x / yr (during biological sampling)	Conduct	S
2	12413000	North Fork Coeur d'Alene River at Enaville	NROK NAWQA (WY 1999–2001) approx. 10 to 18x / yr	Add low-level nutrients	Included-ISWN site	S
3	12413210	South Fork Coeur d'Alene River at Elizabeth Park near Kellogg	6 to 8x / yr high flow; 2 to 4x / yr low flow		Conduct	S
4	12413470	South Fork Coeur d'Alene River near Pinehurst	NROK NAWQA (WY 1999–2001 approx. 10 to 18x / yr	Add low-level nutrients	Included-NROK and ISWN site	S
5	12413445	Pine Creek below Amy Gulch near Pinehurst	6 to 8x / yr high flow; 2 to 4x / yr low flow	2 to 4x / yr high flow; 1x / yr low flow	Conduct	S
6	12413500	Coeur d'Alene River at Cataldo	6 to 8x / yr high flow; 2 to 4x / yr low flow		Conduct	S
7	12413810	Coeur d'Alene River at Rose Lake	6 to 8x / yr high flow; 2 to 4x / yr low flow			S
8	12413860	Coeur d'Alene River near Harrison	6 to 8x / yr high flow; 2 to 4x / yr low flow	6 to 8x / yr high flow; 2 to 4x / yr low flow		S
9	12413875	St. Joe River at Red Ives Ranger Station near Avery	NROK NAWQA (WY 1999–2001) approx. 10 to 18x / yr	Add low-level nutrients	Included-NROK site	S
10	12414500	St. Joe River at Calder	2 to 4x / yr high flow; 1x / yr low flow	6 to 8x / yr high flow; 2 to 4x / yr low flow	Included-ISWN site	S
11	12414900	St. Maries River near Santa	2 to 4x / yr high flow; 1x / yr low flow	6 to 8x / yr high flow; 2 to 4x / yr low flow	Conduct	S
12	12415500	Coeur d'Alene Lake at Coeur d'Alene	See text, p. 17			
13	12419000	Spokane River near Post Falls	NROK NAWQA (WY 1999–2001) approx. 10 to 18x / yr	Add low-level nutrients		S, P, V
14	12419500	Spokane River above Liberty Bridge near Otis Orchards, WA	(4)	Conduct		
15	12422500	Spokane River at Spokane, WA	NROK NAWQA (WY 1999–2001) approx. 10 to 18x / yr	Add low-level nutrients	Included-NROK site	S, P, V
16	12432500	Long Lake at Long Lake, WA	See text, p. 17			
17	12433000	Spokane River at Long Lake, WA	6 to 8x / yr high flow; 2 to 4x / yr low flow	6 to 8x / yr high flow; 2 to 4x / yr low flow		S, P, V
18	12431000	Little Spokane River at Dartford, WA			Conduct; potential NROK site	S, P, V
19	12431500	Little Spokane River at Painted Rocks near Spokane, WA	2 to 4x / yr high flow; 1x / yr low flow	6 to 8x / yr high flow; 2 to 4x / yr low flow		S, P
20	12424000	Hangman Creek at Spokane, WA	2 to 4x / yr high flow; 1x / yr low flow	6 to 8x / yr high flow; 2 to 4x / yr low flow	Conduct; potential NROK site	S, P

[1] Cadmium, lead, zinc (perhaps arsenic, mercury); according to USGS "clean" sampling / processing / capsule filtration protocols.

[2] Phosphorus detection level, 1 to 3 micrograms per liter.

[3] Aquatic biology (fish and macroinvertebrate community assessment; tissue contaminants) according to USGS NAWQA / ISWN protocols; annually, during low-flow conditions.

[4] Potentially useful site for defining ground-water / surface-water interactions.

Potential monitoring sites include the mouths of Canyon and Ninemile Creeks. These creeks enter the South Fork Coeur d'Alene River at Wallace and are undergoing remediation. Water-quality monitoring at the station recently installed on Pine Creek near Pinehurst (site 5, table 3) also could be implemented; this would better define trace-element concentrations and loads attributable to the Bunker Hill Superfund site and begin recording information on the cumulative response of this drainage to ongoing and planned environmental remediation projects. Additional stations also could be established on the South Fork Coeur d'Alene River to monitor specific reaches and subreaches. Another site to consider is one upstream from the mining-affected areas to assess reference conditions, perhaps at Shoshone Park upstream from Mullan.

MONITORING THE SPOKANE AND LITTLE SPOKANE RIVERS

Existing gaging stations in Washington could be incorporated into the network to better define nutrient and trace-element concentrations and transport throughout the Spokane River Basin. Monitoring at these stations could be coordinated with, or supplement, WDOE monitoring activities. Samples collected at these sites could be analyzed for organic compounds such as pesticides, polychlorinated biphenyls, and volatile organic compounds associated with urban and industrialized settings.

MONITORING NUTRIENT TRANSPORT AND LAKE/RESERVOIR EUTROPHICATION

Monitoring nutrient loads to and from Coeur d'Alene and Long Lakes could be accomplished by including nutrient sampling only at selected stations. For Coeur d'Alene Lake, nutrient inflow could be estimated by sampling for nitrogen and phosphorus at the Coeur d'Alene River near Harrison, St. Joe River at Calder, and St. Maries River near Santa gaging station (sites 8, 10, and 11, fig. 1); nutrient outflow could be estimated by sampling at the Spokane River near Post Falls gaging station (site 13, fig. 1). A nutrient budget could be estimated for Long Lake by sampling at gaging stations on Hangman Creek and the Spokane River at Spokane and the Little Spokane River at Painted Rocks, Wash. (sites 15, 19, and 20, fig. 1), adding the contribution of the Spokane wastewater treatment plant, and sampling Spokane River outflow below the Long Lake Dam.

Lake trophic response could be evaluated from bimonthly sampling for euphotic zone nutrient and chlorophyll concentrations in June, July, August, September, and October. Sampling sites could include four locations in Coeur d'Alene Lake (corresponding to limnological sampling stations 1, 3, 4, and 5 used in the 1990–94 USGS study [Woods and Beckwith, 1997]), and three locations in Long Lake (used in previous studies) at the upstream end, midway in the reservoir, and at the deepest point near the dam. Water-column physical and chemical characteristics (dissolved oxygen, pH, specific conductance, and temperature), as well as chlorophyll and chlorophyll-degradation product concentrations also could be determined using high-resolution, near-real time profiling instrumentation. Phytoplankton species and density in the euphotic zone sample could be determined. Samples also could be collected about 3 to 6 ft from the lake bottom at these sites and analyzed for nutrients and selected trace elements of concern.

Greater spatial resolution of nutrient loading throughout the basin for developing and (or) refining phosphorus-management strategies and load allocations could be attained by sampling for nutrients at additional sites. These include the North Fork Coeur d'Alene River at Enaville, South Fork Coeur d'Alene River near Pinehurst (sites 2 and 4, fig. 1), and at the outlet of Coeur d'Alene Lake in Idaho. However, this latter site, which is actually the source of the Spokane River, probably would require special sampling and streamflow-measurement techniques such as acoustic doppler current profiling. Nutrients also could be sampled on the Spokane River near Otis Orchards, Wash. (site 14, fig. 1), where a cableway is still in place; this former USGS gaging station is now operated by the Community College of Spokane, Water Resources Technology Program, for educational purposes. This station also could be of value in assessing ground- and surface-water interactions between the Spokane River and Spokane Valley / Rathdrum Prairie aquifer.

Aquatic Biological Monitoring

Aquatic organisms can be indicators of biologically available contaminants because some pesticides and trace elements can accumulate in their bodies at higher concentrations than in surrounding water (Crawford and Luoma, 1993). Monitoring contaminant concentrations in the tissues of aquatic organisms can allow an assessment of water-quality conditions over time. This information can be used to indicate potential risks to human health and wildlife, especially with regard to the consumption of contaminated fish and other organisms. The structure of the aquatic biological community (such as types and number of species present) can be an indicator of stream and river conditions, including changes in hydrologic conditions, habitat, and water chemistry (Gurtz, 1994; Meador and Gurtz, 1994).

Aquatic biological monitoring has received more attention recently in efforts to assess water-quality conditions and trends. The USGS NAWQA Program employs standardized protocols to assess aquatic biological communities, environmental contaminants in tissue and bed sediment, and associated water and habitat quality (Cuffney and others, 1993a, 1993b; Meador and others, 1993a, 1993b; Porter and others, 1993). Reference sites are sampled for the NAWQA Program to compare conditions in relatively unaffected areas with conditions in areas affected by land use or some other factor.

In 1996, the USGS added aquatic biological monitoring, according to NAWQA protocols, to the ISWN. Aquatic biological monitoring sites in the ISWN are co-located with USGS gaging stations where streamflow and water-chemistry data are collected. These sites are located at the downstream end of relatively large river and stream drainages where contamination is suspected or has been documented. A few sites in relatively unaffected areas will serve as reference sites. Aquatic biology is sampled every 3 years during low streamflow in late summer / early autumn.

In both the NAWQA Program and ISWN, a fish community assessment (species, numbers, size ranges, and visible anomalies) is conducted at each site. Fish usually are sampled by electroshocking. In addition to analyses of water-column constituents collected monthly from April through September, tissue is analyzed for the 25 organic compounds and 22 trace elements shown in tables 1 and 2. Samples consist of 5 to 10 whole-body fish (generally bottom-dwelling species), composited for organic analyses, and 5 to 10 fish livers, composited for inorganic analyses when possible. If fish cannot be collected, a composite sample of aquatic insects such as the caddisflies *Hydropsychidae* are used instead for inorganic analyses. In cases where human health is a concern, gamefish fillets are analyzed.

Three to five semiquantitative samples of macroinvertebrates, such as insects and crustaceans, are collected from riffle areas with a Surber-type kick net and composited into a single sample per site. A qualitative sample representing macroinvertebrates from all habitats in the stream or river reach at a given site also is collected. Macroinvertebrates present in these samples are identified to the species level whenever possible.

Habitat in the sampled riffle(s) is assessed by measuring water depth and velocity and by visually characterizing the bottom substrate as to particle size and embeddedness, channel and bank properties, and riparian vegetation. Specific conductance, water temperature, dissolved oxygen, pH, and alkalinity are measured, and coliform bacteria counts are determined at the time of sampling. Stream temperature is recorded continuously every hour from June through September at aquatic biological monitoring sites.

Aquatic biological monitoring for the ISWN began in northern Idaho in 1998 at the following gaging stations: North Fork Coeur d’Alene River at Enaville, South Fork Coeur d’Alene River near Pinehurst, and St. Joe River at Calder (sites 2, 4, and 10, fig. 1). Aquatic biological monitoring for the NAWQA Program also will be conducted at the St. Joe River at Red Ives Ranger Station in Idaho (site 9, fig. 1); monitoring at the Spokane River and Hangman Creek at Spokane and Little Spokane River at Dartford in Washington (sites 12, 20, and 18, fig. 1) is being considered.

Aquatic biological monitoring methods and protocols could be employed at other sites throughout the Spokane River Basin as shown in table 4. Other sites of particular interest include the South Fork Coeur d’Alene River between Kellogg and Wallace, upstream from the mining-affected areas near Mullan, and at the mouths of tributaries such as Canyon and Ninemile Creeks near Wallace, where environmental remediation activities are ongoing or planned. The resulting data could be compared with those from sites such as the relatively undisturbed upper St. Joe River, or from similar environmental settings such as mining-affected areas in the upper Clark Fork in Montana, and with other regional and national data sets collected using equivalent methods and protocols.

Effectiveness Monitoring

Effectiveness monitoring, or monitoring the effects of specific environmental remediation projects on water quality, must be a component of remediation projects or management actions in the basin. Effectiveness monitoring can be the most challenging and resource intensive of all monitoring activities. As with other monitoring activities, effectiveness monitoring will provide the greatest return if it is soundly designed and competently conducted. Effectiveness monitoring must be based on well-defined objectives for providing specific information and be supported by adequate resources to meet those objectives. Because trends might not become evident for several years, data collection incorporating consistent methodology over an extended time period is essential.

Hydrology-based sampling would be the most appropriate approach to effectiveness monitoring. Although this approach is resource intensive and most likely will have to be applied at multiple locations over substantial pre- and post-project timeframes, it accounts for streamflow, which is the major factor influencing constituent transport. Use of this approach would improve the ability to identify trends and reduce the possibility of drawing invalid conclusions about cause-and-effect relations. Data collected using less robust approaches might not adequately identify the effectiveness of a remediation project. Without sound, hydrology-based water-quality monitoring data, project effectiveness perhaps could be described only in qualitative terms or in physical terms of project plans or design criteria such as the amount of contaminated material removed from a given distance of stream channel.

For example, recent remediation projects in the East Fork Ninemile and Canyon Creek drainages (which enter the South Fork Coeur d'Alene River at Wallace, Idaho) removed mining-contaminated material from stream channels, banks, and adjacent flood plains to make it unavailable for transport by the stream. Project effectiveness was monitored primarily by comparing trace-element concentrations upstream and downstream from the project areas during expected high- and low-flow conditions, averaging the concentrations, and comparing the averages from pre-project years to those from post-project years. This approach ignores the effect of streamflow on constituent concentrations and transport.

Concentrations of soluble substances such as zinc often are diluted by high streamflow, whereas sediment-associated substances such as lead often are mobilized by high streamflow. Higher streamflow generally results in increased transport for both constituents. Lower streamflow in years following a remediation project would be expected to produce smaller loads, not because of project effectiveness, but because of reduced streamflow. Conversely, increased streamflow would be expected to produce larger loads, not as a result of the project, but as the result of streamflow conditions. This likely is the reason that downstream trace-element concentrations appear to be larger at the mouth of East Fork Ninemile Creek in some years following the projects, especially during high streamflow. Pre- and post-project hydrology-based data, especially if expressed as the total amount of trace elements transported in relation to the total volume of water discharged at various locations throughout the project areas over given pre- and post-project time periods, might have shown that the projects actually reduced trace-element loading and thus were effective in improving water quality.

Although streamflow data are inadequate for the recent effectiveness monitoring efforts in East Fork Ninemile and Canyon Creeks, it might be possible to synthesize an annual or seasonal hydrologic record using data from a nearby stream having similar characteristics. A USGS streamflow-gaging station was operated from November 1967 to November 1997 on nearby Placer Creek, which enters the South Fork Coeur d'Alene River from the south immediately downstream from Ninemile and Canyon Creeks in the town of Wallace. Hydrologic data from Placer Creek could serve as a surrogate for estimating a streamflow record for East Fork Ninemile Creek, as well as for other ungaged tributaries to the South Fork Coeur d'Alene River. If streamflow data were combined with the IDEQ concentration data, loading estimates from before and after the remediation projects in East Fork Ninemile and Canyon Creeks could be compared and project effectiveness could thereby be assessed. However, the potential errors and uncertainty associated with this approach would be larger than if a hydrology-based approach had been employed initially.

The effectiveness of remediation projects at improving water quality also could be inferred from aquatic biological monitoring. Establishment of an aquatic macroinvertebrate community at a site where none previously existed or significant changes in populations and species composition could be used to demonstrate water-quality effects.

Changes in the chemical composition of bed sediments collected from depositional zones over time could be used as well. Yearly samples could be collected at specific sites and assessed for changes in total trace-element concentrations. Aquatic biological and bed-sediment monitoring are integral components of the NAWQA Program and the long-term monitoring network in the upper Clark Fork Basin. Equivalent methods applied in the Spokane River Basin would allow for comparison with regional and national data.

It might not be possible to accurately assess the effectiveness of recent environmental remediation actions in tributaries draining the Bunker Hill Smelter area and in the South Fork Coeur d'Alene River because pre-project conditions were inadequately characterized, streamflow data generally are lacking, and concentration data are not representative of the full range of hydrologic conditions. Instituting effectiveness monitoring in these areas now might not be cost effective because relatively little information would be gained.

Moon Gulch is another mining-affected tributary to the South Fork Coeur d'Alene River where remediation activities are planned by the U.S. Forest Service. Instituting effectiveness monitoring in this area, using the principles discussed throughout this report, offers a unique opportunity to (1) adequately characterize preremediation conditions, (2) quantify the effects of remediation actions on surface- and ground-water quality, and (3) apply the experience and resulting information to other mining-affected areas. Monitoring potential water-quality effects of these and similar projects will require (1) installing streamflow gaging stations upstream and downstream from the project areas, (2) evaluating potential changes in surface-water constituent loads over extended time periods, and (3) accurately determining how much of the load(s) can be attributed to ground-water sources.

Ground-Water Quality Monitoring

Although considerable amounts of ground-water-related data have been collected, the role of ground water in affecting Spokane River Basin water-quality conditions remains poorly understood. An extensive network of existing wells have been sampled at least quarterly and, in some cases, more frequently, by county health agencies in Idaho and Washington for more than 20 years, but few data have been interpreted (K. Lustig, Idaho Panhandle Health District, oral commun., 1997; S. Miller, Spokane County Engineers Office, oral commun., 1997). Considerable interaction probably occurs between the Spokane River and the Spokane Valley / Rathdrum Prairie aquifer in the vicinity of the Idaho-Washington State line (B. Painter, Idaho Department of Environmental Quality, oral commun., 1997).

Considerable amounts of data also exist for wells near the Bunker Hill Superfund site and other mining-affected areas in the South Fork Coeur d'Alene River drainage. Ground-water seepage from piles of abandoned mine tailings, waste rock, and contaminated flood-plain sediments has been identified as sources of zinc in East Fork Ninemile Creek, in Moon Creek (which enters the South Fork Coeur d'Alene River about 3 mi east of Kellogg), near Osburn Flats (on the South Fork Coeur d'Alene River about 5 mi east of Kellogg), and in and around the Bunker Hill Central Impoundment Area at the Superfund site (Paulson, 1994; S.E. Box and others, U.S. Geological Survey, written commun., 1997). A large source of dissolved trace elements entering the main-stem Coeur d'Alene River could be ground-water discharge to the South Fork near Smelterville Flats upstream from the Pinehurst gaging station (site 4, fig. 1) and the confluence with the North Fork Coeur d'Alene River (S.E. Box and others, U.S. Geological Survey, written commun., 1997). Likewise, leaching from mining-contaminated sediments in the banks, flood plains, lateral lakes, and wetlands along the lower Coeur d'Alene River could be an important source of trace elements to this river reach and ultimately to Coeur d'Alene Lake and the Spokane River. The magnitude of these inputs and the geochemical and geohydrologic processes controlling them remain largely unstudied, although seasonal fluctuations in lake and river levels could be an important factor in trace-element transport.

If the role ground water plays in determining surface-water quality (and vice versa) is not understood, considerable resources could be spent on environmental remediation activities that are not completely effective. For example, proposals have been made in the past to armor the banks of the lower Coeur d'Alene River for most of its length. However, if ground-water discharge or leaching of trace elements from the banks and flood plains are the primary sources of trace elements entering the river, then simply armoring the riverbank could have little effect on reducing trace-element transport.

Ground-water quality assessment activities can be resource intensive. Assessment often involves sampling wells installed specifically for monitoring and can require complex mathematical modeling techniques. However, it might be possible to define ground- and surface-water interactions on the basis of dilution studies of conservative substances such as chloride or other soluble tracers, thus reducing costs (A.J. Paulson, U.S. Bureau of Mines, written commun., 1994; Kimball, 1997).

Flowpath studies could be employed to address specific environmental issues related to ground-water / surface-water interactions. These studies generally are designed to measure chemical changes that occur as water enters the ground-water flow system, travels along a flowpath, and eventually discharges to a stream or river. Typically, wells are installed at various depths along a flowpath and sampled for selected chemical constituents and physical characteristics. Determining the age of ground water by using established and experimental techniques, such as analysis of isotopic ratios and concentrations of human-derived tracers, is an important tool used in flowpath studies. Well-designed and executed flowpath studies, in conjunction with surface-water monitoring, could be useful in designing, implementing, and assessing the effectiveness of remediation actions, especially those in restricted geologic and geographic settings such as tributary canyons and at the downstream end of the South Fork Coeur d'Alene River valley.

A first step in designing ground-water studies in the Spokane River Basin is to conduct a comprehensive technical review of existing ground-water data and formulate a conceptual understanding or model of the role that ground water plays in determining surface-water quality (and vice versa). Study plans having well-defined objectives to meet specific information needs then could be developed and implemented.

Other Monitoring Issues

Hydrologic and channel modifications over time are also issues of concern in the Spokane River Basin. For example, stream-channel morphometry and stability might have been affected by more than a century of timber harvest activities, particularly in the North Fork Coeur d'Alene and lower St. Joe River drainages. Assertions have been made in recent years that widespread road construction and clearcutting, in addition to direct sediment inputs, have altered the frequency, magnitude, and timing of peak floods and flows by directly exposing large, snow-covered areas to warm rain during winter storms and to direct sun. This alteration of the hydrologic regime might have further destabilized streambanks, channels, and flood plains, leading to increased bedload transport and filling of pools and, thus, degraded aquatic and riparian habitat and other adverse effects. Increased erosion and transport of mining-contaminated sediments also might be related to these postulated modifications in hydrologic conditions.

These issues of hydrologic modification and channel destabilization as a consequence of land-use activities remain largely unstudied, especially at the basin or subbasin scale. Hydrologic data from several long-term USGS gaging stations probably are sufficient to assess potential changes over time in the magnitude and timing of peak flows and floods by using statistical hydrologic data analysis techniques. Candidate stations include the North Fork Coeur d'Alene River near Prichard and at Enaville, Coeur d'Alene River at Cataldo, and St. Joe River at Calder (sites 1, 2, 6, and 10, fig. 1). Long-term changes in channel morphometry also might be revealed by studying historical photographs, and changes in stream-channel cross sections could be determined by using archived data such as streamflow measurement and survey (level) notes and other gaging station records (R.B. Jacobson, U.S. Geological Survey, written commun., 1994).

Interest in studies of erosion and changes in channel and flood-plain morphometry in the lower Coeur d'Alene River Basin has increased recently because these issues have direct bearing on the design and implementation of environmental remediation strategies. The USGS originally proposed such studies as part of the Coeur d'Alene River NRDA and assessed potentially suitable sediment transport models (C.E. Berenbrock, U.S. Geological Survey, oral commun., 1994). The data and hydraulic models used to estimate streamflow in the backwater-affected lower Coeur d'Alene River could serve as the basis for sediment transport and erosion models. Numerous channel cross sections between Cataldo and Harrison were surveyed during development of the hydraulic streamflow models; these data also could serve as the basis for subsequent investigations of bank and channel morphometry and stability.

The Geologic Division of the USGS is investigating channel and flood-plain morphometry and sedimentation / erosional processes in the lower South Fork and main-stem Coeur d'Alene Rivers. In addition to hydrologic processes, boat traffic might be an important mechanism for sediment and trace-element transport in the lower Coeur d'Alene River. Similar work investigating the effects of hydrologic conditions, boat wakes, and other processes on bank erosion and sediment transport in the Kenai River in Alaska has been completed by USGS researchers (Dorava and Moore, 1997); the methods used in that study could be applied to the Coeur d'Alene and St. Joe Rivers.

Potential suppression of primary productivity by trace elements, primarily by zinc but also perhaps by copper, in aquatic systems was first noted in the Spokane River Basin in the mid-1970's (Shiroyama and others, 1976; Greene and others, 1978). This effect could have significant implications for regulatory strategies for managing nutrient loads and controlling eutrophication. For example, less stringent controls on nutrient loading might be permissible because of elevated trace-element concentrations. Alternatively, the need for controlling trace elements could be reduced to counteract primary productivity caused by large nutrient loads. A more likely scenario is that if efforts to reduce trace-element concentrations in the Spokane River Basin are successful, nutrient loads also might have to be reduced concurrently and aggressively to prevent eutrophication.

There has been speculation that Coeur d'Alene Lake and River water-column zinc concentrations have decreased in recent years and that this decrease could result in increased eutrophication. However, the apparent decrease in zinc concentrations simply might be an artifact of changes in analytical techniques over the past two decades; potential trends in zinc concentrations in the Spokane River Basin have not been verified. As part of the Coeur d'Alene Lake study, the USGS performed bioassays by using native algae and methods that minimized interfering effects. Significant suppression of primary productivity by zinc was confirmed, but the threshold at which this effect occurred was not determined (Kuwabara and others, 1994). Definition of this threshold by using the advanced bioassay methods would be of considerable value in nutrient and trace-element management decisions for the Spokane River and Coeur d'Alene and Long Lakes.

SUMMARY

A large amount of streamflow, water-quality, and aquatic biological information exists for the Spokane River Basin, but its collective usefulness is limited by its inconsistent nature. Interpretation and synthesis of this information, which would result in a more coherent understanding of water-quality conditions, trends, controlling factors, and processes, would be a difficult and challenging task but would be of considerable value. Likewise, a considerable monitoring infrastructure exists and could be expanded to produce more comprehensive information. This existing monitoring infrastructure, much of it operated and maintained by the USGS, could form the basis for an integrated water-quality monitoring network. Such a monitoring network also could integrate local, State, and Federal efforts and produce the high-quality information needed for sound water-quality and natural-resource management decisions throughout the Spokane River Basin in a cost-effective and efficient manner.

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