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Prepared in cooperation with
U.S. Environmental Protection Agency

Concentrations and Loads of Cadmium, Zinc, and Lead in the Main Stem Coeur d'Alene River, Idaho—March, June, September, and October 1999

Open-File Report 01–34

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By Paul F. Woods

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CONVERSION FACTORS AND OTHER ABBREVIATED UNITS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic yard (yd^3)	0.7645	cubic meter
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
mile (mi)	1.609	kilometer
pound (lb)	0.4536	kilogram
pound per day (lb/d)	0.4536	kilogram per day
square mile (mi^2)	2.590	square kilometer

Other abbreviated units:

L . . . . . liter
µg/L. . . . . microgram per liter
µm . . . . . micrometer
mg/L . . . . . milligram per liter
mm . . . . . millimeter

Concentrations and Loads of Cadmium, Zinc, and Lead in the Main Stem Coeur d'Alene River, Idaho—March, June, September, and October 1999

By Paul F. Woods

Abstract

The Remedial Investigation/Feasibility Study conducted by the U.S. Environmental Protection Agency within the Spokane River Basin of northern Idaho and eastern Washington included extensive data-collection activities in numerous studies to determine the nature and extent of trace-element contamination within the basin. The objective of this particular study was to improve our understanding of the effects of different river discharges and lake levels of Coeur d'Alene Lake on the transport of cadmium, zinc, and lead within the main stem Coeur d'Alene River. In particular, water-quality data and loads during a broad range of hydrologic conditions were examined to determine if the river channel, flood plain, and associated ground water along the main stem Coeur d'Alene River acted as sources or sinks of trace elements. Water-quality samples were collected at six riverine stations and one lake station along a 35-mile reach during March, June, September, and October of 1999. Samples were analyzed for whole-water recoverable, filtered (0.45 micrometer), and dissolved (0.01 micrometer) concentrations of cadmium, zinc, and lead.

Concentrations and loads of cadmium and zinc measured during the four sampling trips were predominately in the filtered and dissolved fraction, rather than particulate. The smallest concentrations were measured during the June sampling trip when flows were high and snowmelt runoff diluted riverine concentrations. Conversely, the largest concentrations were measured during the latter two sampling trips when flows were low because a larger proportion of the river's discharge was contributed by ground-water inflow. During each sampling trip, cadmium and zinc concentrations generally decreased in a downstream direction, even as discharge increased in a downstream direction.

Spatial and temporal trends exhibited by lead concentrations and loads during the four sampling trips were different from those of cadmium and zinc because of the propensity for lead to adsorb to sediment particles. Whole-water recoverable lead concentrations and loads during the four sampling trips were predominantly in the particulate fraction, with filtered and dissolved concentrations and loads composing a much smaller proportion of the recoverable fraction compared to cadmium and zinc. Filtered lead concentrations generally increased at a faster rate in the downstream direction than dissolved lead concentrations; thus, colloidal lead either was being formed by complexation reactions or being added by sediment erosion in the downstream direction.

INTRODUCTION

Mining and ore-processing activities conducted since the late 1880s in the South Fork Coeur d'Alene River Basin have produced extensive deposits of trace-element-contaminated sediments throughout the South Fork Coeur d'Alene River valley and its tributaries, the channel and 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 transport and redistribute trace-element-contaminated sediments throughout the 6,680-mi^2 Spokane River Basin of northern Idaho and eastern Washington (fig. 1, back of report).

The U.S. Environmental Protection Agency (EPA) has recently (1998) initiated a Remedial Investigation/Feasibility Study (RI/FS) of the Spokane River Basin under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, which requires EPA to evaluate contaminant release, fate, and transport. The Remedial Investigation (RI) phase involves data collection to characterize site conditions, development of conceptual models, determination of the nature and extent of trace-element contamination, and risk assessment for human health and the environment. The RI phase is followed by the Feasibility Study (FS) phase where remedial action alternatives are developed and evaluated. In March of 1998, the U.S. Geological Survey (USGS) was requested by EPA to collect data characterizing hydrology and water quality in support of the RI/FS of the Spokane River Basin. The study described in this report was conducted by the USGS as Task 7 (Evaluation of suspended and bedload sediment transport within the Coeur d'Alene River Basin and affected areas—Subtask A) and an amendment to Task 2 (Additional geochemical analytes and fourth sampling trip for segment 3 stations) of Interagency Agreements DW14957278–01–0 and DW14957278–01–2 with EPA.

The objective of the study was to determine whether the river channel, bank sediments, adjacent flood-plain sediments, and associated ground water along the main stem Coeur d'Alene River acted as sources or sinks of trace elements between the USGS gaging station near Cataldo (station 12413500) and the river's mouth at Coeur d'Alene Lake. Water-quality samples were collected for analysis of cadmium, zinc, and lead at six riverine stations and one lake station (fig. 1) during March, June, September, and October of 1999.

DESCRIPTION OF STUDY AREA

The study area was situated within the flood plain of the main stem Coeur d'Alene River. The flood plain is a broad, flat river valley bounded by steep hillslopes; the width of the flood plain ranges from 0.2 to 3 mi. The river-mile distance between the upstream boundary of the study area and the river's mouth at Coeur d'Alene Lake is about 35 mi. The upstream boundary receives drainage from about 1,230 mi^2; at the river's mouth, the drainage area is about 1,480 mi^2. The primary source of inflow to the study area is from the North and South Forks of the Coeur d'Alene River. During the 1999 water year, mean daily discharges for the North Fork and South Fork were 2,240 and 687 ft^3/s, respectively (Woods, 2001). Numerous small tributary streams enter the main stem Coeur d'Alene River; none provide substantial inflow volumes. Eleven lateral lakes and associated wetlands lie within the flood plain; most have surface-water connections to the Coeur d'Alene River.

The main stem Coeur d'Alene River is free flowing in its upper reach to about station S2 (fig. 1). Downstream from S2, the river's gradient is low, about 0.019 percent (Bender, 1991). The low gradient, in combination with the lake-surface elevation of Coeur d'Alene Lake, creates backwater conditions throughout much of the study reach. The lake-surface elevation of Coeur d'Alene Lake is controlled by Post Falls Dam, situated on the Spokane River near Post Falls (fig. 1). The annual variation in lake-surface elevation also affects river stage in much of the study reach. Thus, the river's banks are alternately inundated and dewatered during the year by variations in lake-surface elevation.

The flood plain and river channel of the main stem Coeur d'Alene River are mostly covered with trace-element-contaminated alluvial sediments of varying thickness, which were derived from the mixing of tailings and mining-related wastes with uncontaminated materials (Bookstrom and others, 1999). The active riverbed of the main stem Coeur d'Alene River has been estimated to contain about 176,000,000 yd^3 of mining-waste-contaminated alluvium (A.A. Bookstrom, U.S. Geological Survey, written commun., 2000).

The transport of mining-waste contaminants through the study reach was evident from annual loads of whole-water recoverable (WWR) cadmium, lead, and zinc reported by Woods (2001) for the following three USGS gaging stations within the study reach: Coeur d'Alene River near Cataldo (station 12413500), Coeur d'Alene River at Rose Lake (station 12413810), and Coeur d'Alene River near Harrison (station 12413860). Large downstream increases in WWR loads were measured for the three trace elements between the Cataldo and Harrison stations. At the Cataldo station, annual loads of WWR cadmium, lead, and zinc were as follows: cadmium, 9,860 lb; lead, 200,000 lb; and zinc, 1,300,000 lb. The loads of lead and zinc had increased to 246,000 lb and 1,500,000 lb, respectively,

at the Rose Lake gaging station; the cadmium load had decreased to 8,790 lb. At the downstream gaging station near Harrison, the loads had increased to 10,400 lb, 590,000 lb, and 1,570,000 lb for cadmium, lead, and zinc, respectively.

The majority of the load of WWR cadmium and zinc was composed of the fraction that passes a filter with a pore size of 0.45 µm; however, only about 10 percent of the load of WWR lead was transported in the filtered fraction (Woods, 2001). Therefore, the majority of the WWR lead load was transported in association with suspended sediment. On the basis of a study reported by Clark and Woods (2001), the majority of suspended sediment in transport within the main stem Coeur d'Alene River was as fine-grained particles (<63 µm diameter) at discharges less than 15,000 ft^3/s. The particle size of sediment carried as bedload at the Rose Lake gaging station was dominated by fine-grained sediments less than 1 mm in diameter; an absence of bedload transport was measured at the Harrison gaging station (Clark and Woods, 2001).

APPROACH

Sampling Design

Four sampling trips were designed to evaluate trace-element transport in the main stem Coeur d'Alene River over a broad range of hydrologic conditions during 1999. Two sampling trips occurred during low lake stages; one on the recession of a winter discharge event (March 9) and the other during base-flow discharge near the end of the autumn reduction in lake stage (October 19–20). The other two sampling trips occurred during high lake stages; one on the recession of the annual snowmelt peak (June 8) and the other at the initiation of lake-stage reduction following several months of high stage (September 21–22). Dates of the four sampling trips are plotted on a graph showing the relation of lake stage to stream stage at three USGS gaging stations that bracketed the river reach sampled in this study (fig. 2, back of report).

Locations of Data-Collection Stations

Listed in table 1 (back of report) are USGS station numbers and names for the seven stations sampled in this study. The locations of the stations are illustrated in figure 1 in relation to the number preceding the USGS station number listed in table 1.

Collection of Discharge Data

Discharge data for the six riverine stations were obtained in two ways. Discharge measurements were made at USGS gaging stations near Cataldo (station 12413500), at Rose Lake (station 12413810), and near Harrison (station 12413860). The Cataldo gaging station was contiguous with station 17; the Rose Lake and Harrison gaging stations were within 0.6 mi of stations S3 and S6, respectively. Estimated discharges at the intervening stations (S2, S4, and S5) were interpolated from the measured discharges, as shown in table 1. Discharge measurements were made from bridges or cableways using standardized USGS methods for collection of streamflow data, computation of discharge, and quality assurance procedures which are described in six USGS Techniques of Water-Resources Investigations reports (Buchanan and Somers, 1968, 1969; Riggs, 1968; Carter and Davidian, 1968; Kennedy, 1983, 1984).

Collection and Analysis of Water-Quality Data

Depth-integrated water-quality samples were collected from the estimated centroid of flow by pumping with a high-volume peristaltic pump. The pumped sample was composited in a churn sample splitter from which subsamples were withdrawn for laboratory analyses. Samples destined for WWR analyses were withdrawn initially; filtered samples were then withdrawn via a peristaltic pump and through a nonmetallic filtration apparatus having a filter pore size of 0.45 µm (Gelman capsule filters). This pore size is the traditional size used to define "dissolved," but recent data indicate that colloidal material may pass through. Therefore, an additional 2-L sample of filtered water was obtained for later processing for analysis of colloidal-bound trace elements. The "dissolved" sample, as defined in this study, was obtained by filtering the 2-L filtered (0.45 µm) sample through a tangential micro/ultrafiltration system (Millipore Minitan II) equipped with filter plates having a filter pore size of 0.01 µm. All trace-

element samples were preserved with 2 mL of Ultrex nitric acid. Water-quality sample preparation, collection, and field processing were conducted using "clean" protocols that ensure noncontamination at the parts-per-billion level, as described in Horowitz and others (1994). Samples were shipped in plastic coolers to the USGS National Water-Quality Laboratory in Denver, Colorado, using chain-of-custody procedures and documentation.

Water-quality samples were analyzed for WWR, filtered (0.45 µm), and dissolved (0.01 µm) concentrations of cadmium, zinc, and lead, as well as hardness. All analyses were performed at the USGS National Water-Quality Laboratory using low-level detection limit methods described by Fishman and Friedman (1989) and quality assurance/quality control procedures described by Pritt and Raese (1995). The water-quality data collected during this study are presented in tables 2–5 (back of report).

Calculation of Loads

Trace-element concentration data were combined with discharge data to compute instantaneous loads of cadmium, zinc, and lead at each riverine station for the four sampling trips (tables 2–5). Instantaneous loads, in pounds per day, were computed by multiplying the following four variables: instantaneous discharge, in cubic feet per second; constituent concentration, in milligrams per liter; a conversion factor of 0.0027 to convert flow and concentration units; and a conversion factor of 2,000 to convert tons to pounds.

SPATIAL AND TEMPORAL PATTERNS IN TRACE ELEMENTS

Cadmium Concentrations and Loads

The March 9, 1999, sampling trip was during mid-level lake stage for Coeur d'Alene Lake and near the end of a recession of a rain-on-snow runoff event in the Coeur d'Alene River (fig. 2). Discharge increased downstream along the main stem Coeur d'Alene River from 2,280 ft^3/s at station 17 to 3,600 ft^3/s at station S6 (fig. 3, back of report). Mean cross-sectional velocities at stations S3 and S6 were slow, 0.5 ft/s and 0.7 ft/s, respectively. At the six river stations, concentrations of WWR, filtered (0.45 µm), and dissolved (0.01 µm) cadmium, in µg/L, ranged from 1.6 to 1.9, from 1.6 to 2.0, and from 0.40 to 1.5, respectively. Concentrations of WWR and filtered cadmium were nearly equal and declined about 0.3 µg/L between station 17 and the lake station (fig. 3). Dissolved cadmium represented about 20 percent of WWR cadmium at station 17 (fig. 3). At station S3, the percent contribution of dissolved cadmium had increased to about 75 percent; from station S5 to station S7, the percentage had increased to about 90. The downstream increase in the percentage of WWR cadmium composed by the dissolved fraction indicates that cadmium was desorbing from colloidal material, resulting in an increased dissolved concentration and a smaller difference between the 0.45- and 0.01-µm fractions. The load of the WWR, filtered, and dissolved cadmium increased in the downstream direction, primarily in response to downstream increases in discharge (fig. 3). Because WWR and filtered cadmium concentrations declined slightly between stations 17 and S5, loads of these fractions did not increase as rapidly as those for dissolved cadmium, whose concentrations increased through this reach.

The next sampling trip on June 8, 1999, was near the end of the recession of the annual snowmelt peak. In contrast to the March sampling trip, lake stage was near its annual maximum (fig. 2). Discharge ranged from 5,130 ft^3/s at station 17 to 7,640 ft^3/s at station S6 (fig. 4, back of report). Mean cross-sectional velocities at stations S3 and S6 were 1 ft/s and 1.3 ft/s, respectively—about twice as fast as those measured during the March 9 sampling trip. Concentrations of WWR, filtered, and dissolved cadmium, in µg/L, ranged from 0.74 to 0.84, from 0.66 to 0.79, and from 0.56 to 0.75, respectively. Concentrations of WWR and filtered cadmium differed by less than 0.1 µg/L and decreased in a generally similar pattern between station 17 and the lake station, S7 (fig. 4). At stations 17, S2, and S3, dissolved cadmium represented about 90 percent of WWR cadmium; by station S5, the percentage had declined to about 75 (fig. 4). As with WWR and filtered cadmium, dissolved cadmium concentrations tended to decline in a downstream direction, but at a more rapid rate than WWR or filtered concentrations, indicating that colloidal material was more prevalent in the lower reach of the river. Loads of WWR and filtered cadmium generally increased in the downstream direction in response to increased discharge, whereas the decrease in dissolved cadmium load between stations S3 and S5 was

attributable to the decrease in dissolved concentration in that river reach (fig. 4).

The third sampling trip on September 21–22, 1999, was at the end of about 3 months of sustained high lake stage and 3 months of low-discharge conditions, which were representative of the summer/fall recession (fig. 2). Although discharge increased over the entire study reach by about 90 ft^3/s, discharge decreased between stations 17 and S3 by about 60 ft^3/s (fig. 5, back of report). Mean cross-sectional velocities at stations S3 and S6 were slow, 0.06 ft/s and 0.09 ft/s, respectively. The loss in discharge in the upper portion of the river indicates movement of surface water into ground water within the adjacent flood plain, presumably through bank-storage effects associated with high lake stage. Concentrations of WWR, filtered, and dissolved cadmium, in µg/L, ranged from 1.1 to 2.9, from 0.96 to 3.0, and from 0.92 to 3.0, respectively. Essentially all of the cadmium in the river was carried in the dissolved fraction. Concentrations declined in a downstream direction by about 2 µg/L (fig. 5). This level of concentration decrease was greater than that measured in the March and June sampling trips. The decrease in dissolved cadmium load between stations 17 and S3 (fig. 5) is attributable to the decrease in both concentration and discharge, which presumably results from the movement of surface water into ground water. In contrast, the increase in discharge downstream from station S3, concurrent with decreasing dissolved cadmium concentrations, indicates an inflow of dilute ground water from bank-storage releases and the alluvial aquifer.

The final sampling trip of October 19–20, 1999, also was during the low-discharge conditions of the summer/fall recession; however, the stage of Coeur d'Alene Lake had been reduced by about 4 ft compared to June's maximum stage (fig. 2). The spatial trends and magnitudes of discharge (fig. 6, back of report) were similar to those observed during the September sampling trip. Mean cross-sectional velocities at stations S3 and S6 were slow, 0.06 ft/s and 0.09 ft/s, respectively. Concentrations of WWR, filtered, and dissolved cadmium, in µg/L, ranged from 1.7 to 2.9, from 1.8 to 2.8, and from 1.7 to 2.8, respectively. Also similar to September, cadmium concentrations declined downstream from station 17 (fig. 6). Unlike September, an increase in cadmium concentration, nearly all in the dissolved fraction, was measured at station S6. This increase may indicate the release of bank storage and a corresponding inflow of dissolved cadmium from the riverbanks and adjacent flood plain in response to removal of the hydraulic head generated by the river at a high lake stage. Outflow from Blue Lake, a lateral lake upstream from station S5, was discounted as the source of dissolved cadmium because samples at station S5 did not indicate increased cadmium concentrations.

Cadmium concentrations and loads measured during the four sampling trips were predominantly in the filtered and dissolved fraction. The smallest concentrations were measured on June 8 because snowmelt runoff diluted riverine concentrations. Conversely, the highest cadmium concentrations were measured during the latter two sampling trips because a larger proportion of the river's discharge was contributed by ground-water inflow. The downstream pattern during each sampling trip was for cadmium concentrations to decrease, even as discharge increased in a downstream direction. The first two sampling trips were conducted at discharges much higher than those during the last two trips; thus, cadmium concentrations were dominated by surface-water inflow. In contrast, ground water exerted more influence on cadmium concentrations during the last two low-flow sampling trips. In the reach that lost surface water to the adjacent ground water during September and October (station 17 to station S3), cadmium concentrations also declined slightly. This pattern suggests that dissolved and filtered cadmium migrated into the ground-water system. Downstream from the losing reach, cadmium concentrations continued to decrease as discharge increased. The increases in discharge during base-flow conditions indicate an influx of ground water into the river; the concurrent decreases in cadmium concentrations indicate dilution by that ground-water inflow.

Zinc Concentrations and Loads

The spatial and temporal patterns exhibited by WWR, filtered, and dissolved zinc during the four sampling trips (figs. 7–10, back of report) were similar to those described in the preceding section for WWR, filtered, and dissolved cadmium (figs. 3–6). The major difference between the two trace elements was that zinc concentrations were substantially higher than cadmium concentrations. Concentrations of WWR, filtered, and dissolved zinc, in µg/L, for the four sampling trips

ranged from 110 to 540, from 110 to 550, and from 65 to 530, respectively.

As with cadmium, zinc concentrations and loads were dominated by the filtered and dissolved fractions. During each sampling trip, zinc concentrations decreased in a downstream direction as discharge increased, with the exception of dissolved zinc in March, which increased between stations 17 and S5. The interaction of surface and ground water affected zinc concentrations in a manner analogous to that of cadmium concentrations.

Lead Concentrations and Loads

The spatial and temporal trends exhibited by WWR, filtered, and dissolved lead during the four sampling trips (figs. 11–14, back of report) were different from those of cadmium (figs. 3–6) and zinc (figs. 7–10). Much of the difference is attributable to the propensity for lead to adsorb to sediment particles, whereas cadmium and zinc are much more soluble in water.

Coeur d'Alene Lake was at a mid-level lake stage and the Coeur d'Alene River was near the end of a recession of a rain-on-snow runoff event during the March 9 sampling trip (fig. 2). Concentrations of WWR, filtered, and dissolved lead, in µg/L, ranged from 5.3 to 17, from 1.3 to 3.0, and from <1 to 0.40, respectively. The increase in discharge through the main stem Coeur d'Alene River occurred in concert with increased concentrations and loads of WWR lead down the river, except between stations S3 and S4 (fig. 11). Concentrations of WWR lead decreased 3.5 µg/L between stations S3 and S4, possibly due to deposition of sediment-associated lead. Concentrations of filtered and dissolved lead increased slightly between stations 17 and S7 (fig. 11). Filtered lead concentrations represented between 14 and 25 percent of WWR lead concentrations among the stations. Dissolved lead represented only 2 percent of WWR lead at station S6; percentages at the other stations could not be computed because dissolved lead was reported as less than 1.0 µg/L.

The June 8 sampling trip occurred near the end of the recession of the annual snowmelt peak; lake stage was near its annual maximum (fig. 2). Discharge through the entire study reach ranged from 5,130 ft^3/s at station 17 to 7,640 ft^3/s at station S6 (fig. 12); these were the largest discharges measured during the four sampling trips. Mean cross-sectional velocities at stations S3 and S6 were 1 ft/s and 1.3 ft/s, respectively; these were the largest measured over the four sampling trips. Suspended sediment concentrations were also the largest measured over the four sampling trips. The range in suspended sediment concentration on June 8 was 44 to 56 mg/L; the maximum concentration measured on the other three sampling trips was 2.3 mg/L (tables 2–5). Concentrations of WWR, filtered, and dissolved lead, in µg/L, ranged from 13 to 20, from 1.5 to 4.0, and from <1 to 0.36, respectively. Concentrations of WWR lead decreased slightly (2.6 µg/L) between stations 17 and S4 and then increased by more than 7 µg/L to 20 µg/L at station S7 (fig. 12). Filtered lead concentrations increased 2.8 µg/L in the downstream direction but represented only 10 to 21 percent of WWR lead concentrations, which was substantially less than the filtered proportion of WWR cadmium and zinc. Dissolved lead represented 1.9 percent of WWR lead at station S6; percentages at the other stations could not be computed because dissolved lead was reported as less than 1.0 µg/L. Lead loads for the three fractions generally followed the same pattern as that for concentrations.

Three months of sustained high lake stage and 3 months of low-discharge conditions preceded the September 21–22 sampling trip (fig. 2). Although discharge increased through the entire study reach by about 90 ft^3/s, discharge decreased in the upper reaches (stations 17 to S3) by about 60 ft^3/s (fig. 13). Concentrations of WWR, filtered, and dissolved lead, in µg/L, ranged from 5.7 to 21, from 2.1 to 4.9, and from <1 to 0.56, respectively. Despite low-discharge conditions, concentrations of WWR lead increased almost fourfold between stations 17 and S5 (fig. 13), whereas filtered and dissolved concentrations changed only about twofold. This increase in the particulate fraction of WWR concentrations indicates resuspension of sediment-associated lead. Concentrations of filtered lead represented between 22 and 37 percent of WWR lead concentrations among the stations. Dissolved lead represented between 1.2 and 3.5 percent of WWR lead at stations S5 and 17, respectively; percentages at the other stations either were within that range or could not be computed because dissolved lead was reported as less than 1.0 µg/L.

The final sampling trip of October 19–20, 1999, also occurred during the low-discharge conditions of the summer/fall recession; however, the stage of Coeur d'Alene Lake had been reduced by about 4 ft (fig. 2).

Concentrations of WWR, filtered, and dissolved lead, in µg/L, ranged from 4.6 to 22, from 1.0 to 6.5, and from <1 to 1.1, respectively. As was observed in the previous sampling trip, WWR lead concentrations increased between stations 17 and S3 even though discharge declined between those stations (fig. 14). Concentrations of filtered and dissolved lead also increased slightly in a downstream direction until they declined downstream from station S5 (fig. 14). Filtered lead concentrations represented between 20 and 32 percent of WWR lead concentrations. Dissolved lead concentrations at six of the seven stations represented between 3.1 and 12.9 percent of WWR lead concentrations. Lead concentrations and loads in October were very similar in magnitude and spatial pattern to those measured in September, thereby indicating that the 4-ft lowering of lake stage had minimal effect on the sources and transport of lead during base-flow conditions.

During the four sampling trips, WWR lead concentrations and loads were predominantly in the particulate (>0.45 µm) fraction. The spatial variations in WWR lead were largely attributable to its propensity to be associated with sediment particles and being subjected to the physical processes of erosion and deposition.

Filtered and dissolved lead concentrations during the four sampling trips were much lower than WWR lead concentrations. The downstream pattern generally was for filtered lead concentrations to increase at a faster rate than dissolved lead concentrations; thus, it is hypothesized that colloidal lead was being formed or supplied by instream sources in the downstream direction. Colloidal lead was presumably being produced by several processes, one of which was ground-water inflow of dissolved lead and subsequent complexation with iron and manganese. A second source of colloidal lead was erosion of very fine riverbed and riverbank sediments. A third process was desorption; lead associated with sediment particles was released and entered the dissolved fraction and was then complexed with iron and manganese to form colloidal lead. This third process was evident when increases in filtered lead paralleled decreases in WWR lead, indicative of desorption (June 8, stations 17 to S4). The interplay of these three processes complicated the interpretation of the spatial and temporal behavior of filtered and dissolved lead throughout the main stem Coeur d'Alene River. For example, a portion of the dissolved lead input to the river via ground water might shift to the filtered fraction via complexation with iron and manganese, and then settle to the riverbed in areas of slow velocity during low-discharge conditions. Lead deposited in the river channel may then later be eroded from the riverbed sediments by increased riverine turbulence and be transported downstream. During transport, the lead might desorb from its colloidal complex and reenter the dissolved fraction.

EXCHANGE OF TRACE ELEMENTS BETWEEN RIVER AND FLOOD PLAIN

The objective of this study was to determine whether sediments in the river's channel and banks and adjacent flood-plain sediments along the main stem Coeur d'Alene River act as sources or sinks for trace elements. Four sampling trips were designed to address the objective by measuring spatial and temporal patterns in trace-element concentrations and loads under several combinations of lake levels and riverine discharges. The basic premise was that as lake levels and associated hydraulic heads were reduced, ground water and (or) bank-storage water would be more readily discharged into the river. This discharge to the river was postulated to be retarded or reversed when lake levels were at their summer high and inundated much of the riverbank. The low lake-level scenario was addressed by sampling trips conducted on March 9 and October 19–20. The sampling trip of September 21–22 addressed the sustained high lake-level scenario. The second sampling trip, on June 8, occurred during high flow on the recession of the annual snowmelt peak and thereby reflected a transient situation in which lake levels were briefly higher than the normal summer high.

The initial sampling trip on March 9 occurred during mid-level lake stage and near the end of a recession of a rain-on-snow runoff event. During the previous 3 months, the lake's level had increased and decreased several times in response to rain-on-snow runoff events (fig. 2); therefore, the riverbanks had alternating episodes of inundation and dewatering. The relatively large downstream increases in dissolved cadmium and zinc concentrations between stations 17 and S4 indicate these two trace elements may have moved into the river from the adjacent ground-water system (which includes bank storage). Ground water and bank-storage water moving through flood-plain sediments enriched in soluble trace elements conceivably could pick up cadmium and zinc, thereby transporting them to the

river when the hydraulic gradient favored discharge to the river. However, part of the increase in dissolved concentrations of cadmium and zinc may have been due to desorption from colloidal complexes because filtered concentrations tended to decrease in the downstream direction in conjunction with increased discharge while dissolved concentrations tended to increase. Dissolved and filtered lead concentrations continued to increase slightly in the downstream direction below station S4, suggesting either the ground-water system as a potential source of dissolved lead or additional desorption from the colloidal to the dissolved phase. The limited spatial variability for filtered and dissolved lead, however, does not permit a definitive answer to the question of whether the river receives dissolved lead from the adjacent ground-water system or desorption from colloidal material. Increases in discharge generally paralleled increases in WWR lead concentration and load, more so than for filtered and dissolved lead, which was indicative of the predominance of particulate lead, presumably caused by the erosion of sediment-associated lead from the river channel and riverbanks.

The June 8 sampling trip was during the final recession of the annual snowmelt peak, when lake stage was about 1 ft above its normal summer level (fig. 2). Compared to the March 9 sampling trip, WWR, filtered, and dissolved concentrations of cadmium and zinc on June 8 had been reduced by about 50 percent because of dilution by the large volume of snowmelt runoff that preceded this sampling trip. More notably, the spatial pattern for dissolved cadmium and zinc essentially reversed between the March and June sampling trips, changing from a downstream increase in March to a downstream decrease in June. The downstream decrease in dissolved cadmium and zinc was maintained for the next two sampling trips in September and October. The high discharge generated by snowmelt runoff had a noticeable effect on the partitioning of WWR concentrations of cadmium and zinc among the particulate, filtered, and dissolved fractions, as evidenced by decreased percentages of dissolved and filtered concentrations composing the WWR concentrations. It is speculated that the shift in partitioning occurred because colloidal-bound cadmium and zinc had solubilized, thereby causing increased dissolved concentrations during high flow from stations 17 to S3. Downstream from S3, colloidal cadmium and zinc apparently reformed as dissolved concentrations decreased. Spatial patterns for WWR lead concentrations in June indicated possible deposition of particulate lead between stations 17 and S4 and erosion of particulate lead between stations S4 and S6.

The third sampling trip on September 21–22, 1999, was at the end of about 3 months of high lake stage and at low-discharge conditions representative of the summer/fall recession (fig. 2). Because of the high lake stage, cadmium and zinc were likely transported with river water into the adjacent ground-water system or bank storage between stations 17 and S3, a losing reach. Between stations S3 and S6, streamflow increased, probably due to ground-water inflow. Although WWR cadmium and zinc concentrations decreased in a downstream direction, spatial changes in the partitioning among particulate and soluble phases were not evident because essentially all cadmium and zinc concentrations were in the filtered and dissolved fractions throughout the entire study reach. Filtered and WWR lead concentrations increased through the losing reach, indicating a possible source of colloidal and particulate lead in this reach that is not associated with ground-water inflow. This pattern of concentration increase suggests that lead-enriched sediments containing a colloidal fraction were entrained into the river's flow. Dissolved lead concentrations were very low and showed little spatial variation. Downstream from station S3, WWR lead concentrations continued to increase as filtered concentrations stabilized, indicating additional sediment inputs. Decreases in WWR and filtered lead concentrations downstream from station S5 may indicate deposition of both particulate and colloidal lead.

The final sampling trip of October 19–20, 1999, also was during the low-discharge conditions of the summer/fall recession; however, the stage of Coeur d'Alene Lake had been reduced by about 4 ft (fig. 2). With the reduction of the river's hydraulic head, the potential for release of bank-storage water and delivery of trace elements from the adjacent ground-water system was more likely than in the previous three sampling trips. However, except for the reach between stations S5 and S6, spatial variations in cadmium and zinc concentrations were similar to those described for the September sampling trip. The increase in concentration of cadmium and zinc, nearly all in the dissolved fraction, coupled with the increase in discharge, resulted in the only notable load increase for cadmium and zinc between stations S5 and S6. This increase, attributable almost entirely to the dissolved fraction, indicates a ground-water source of dissolved cadmium and zinc

from the riverbanks and adjacent flood plain in response to reduction of the hydraulic head generated by the lowering of lake stage. Concentrations of filtered and dissolved lead were slightly higher during this sampling trip compared to those during higher lake stages, possibly indicative of ground water adding lead to the river. Some unquantified portion of the added dissolved load presumably was attributable to groundwater discharge into the river; however, desorption or erosion of colloidal-bound lead also probably contributed to the concentration increases.

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FIGURES 1–14

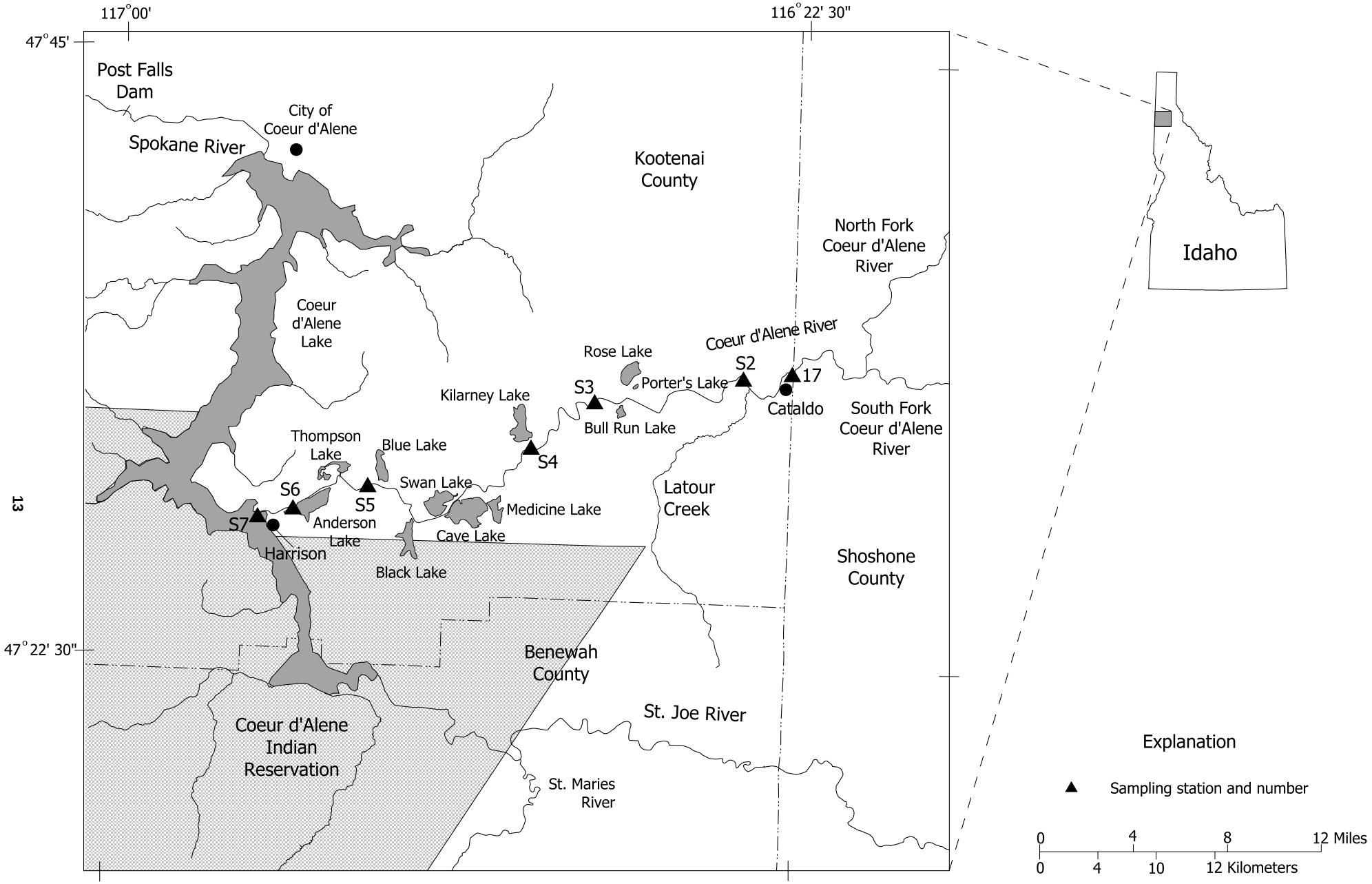


Figure 1. Locations of seven water-quality stations monitored for trace-element transport during March, June, September, and October 1999, main stem Coeur d'Alene River, Idaho.

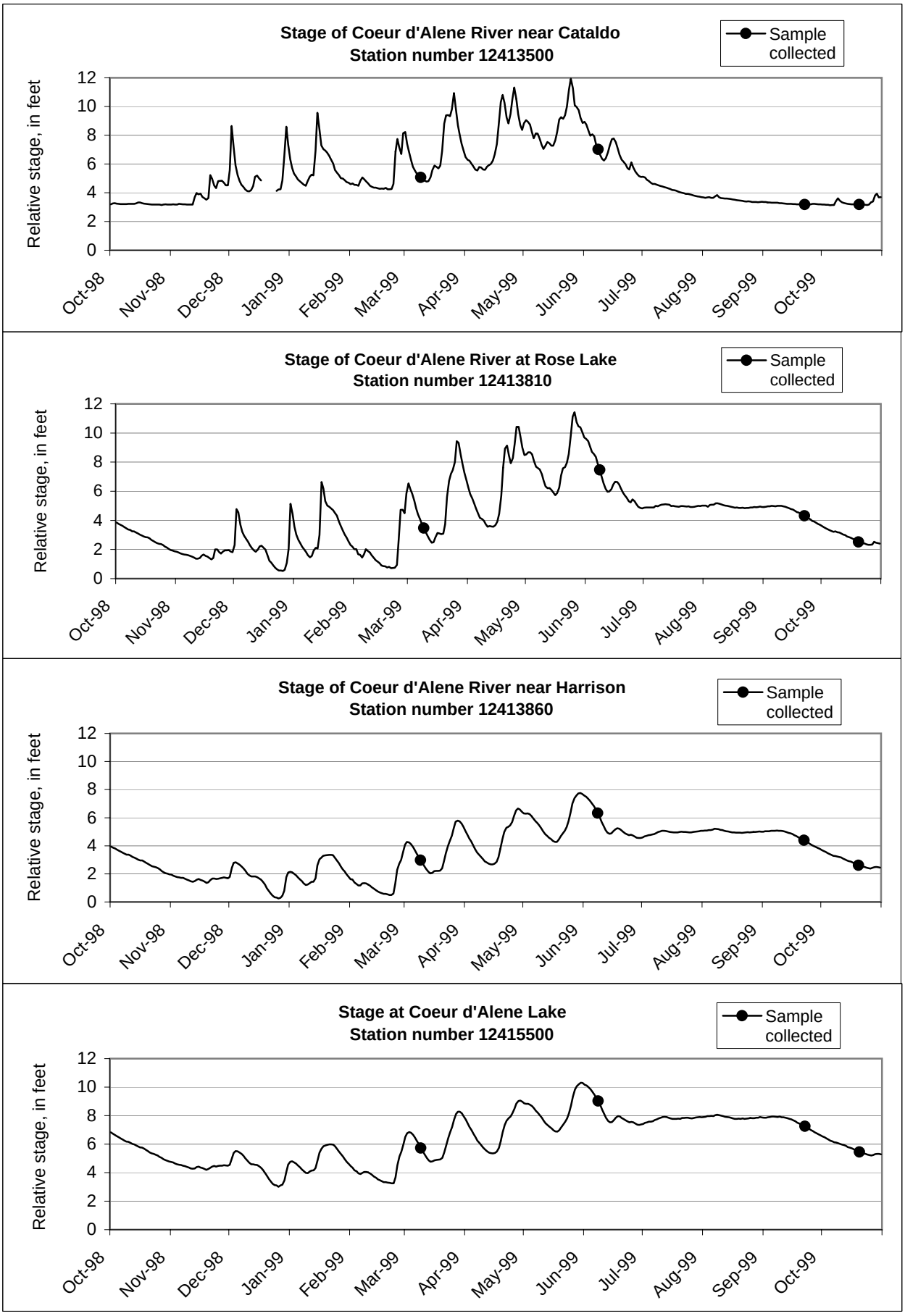
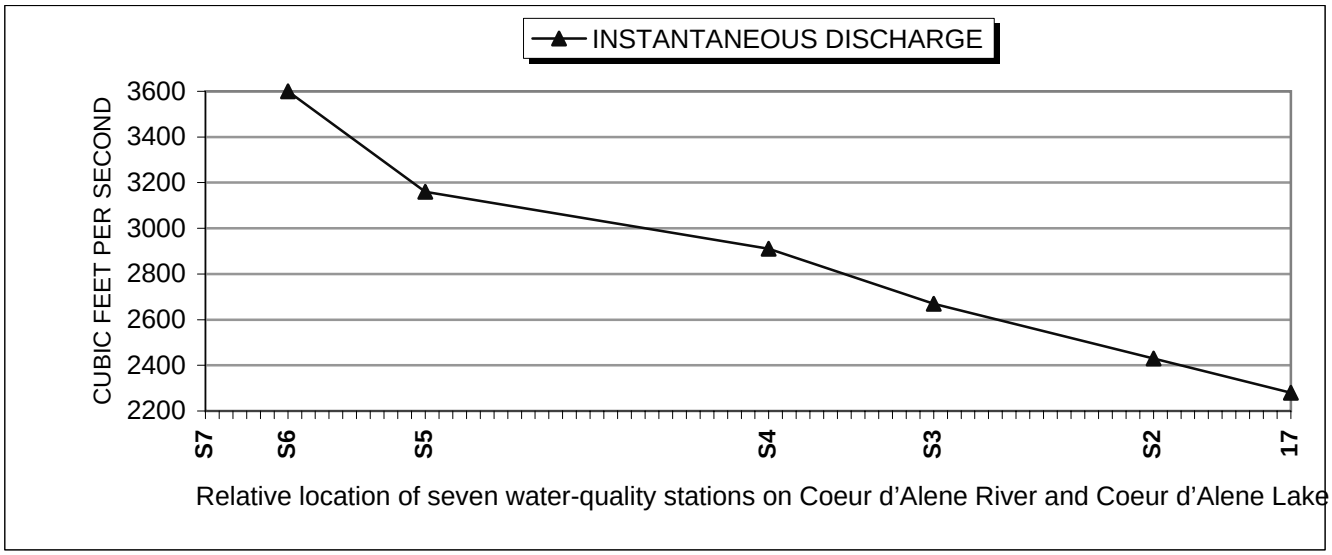
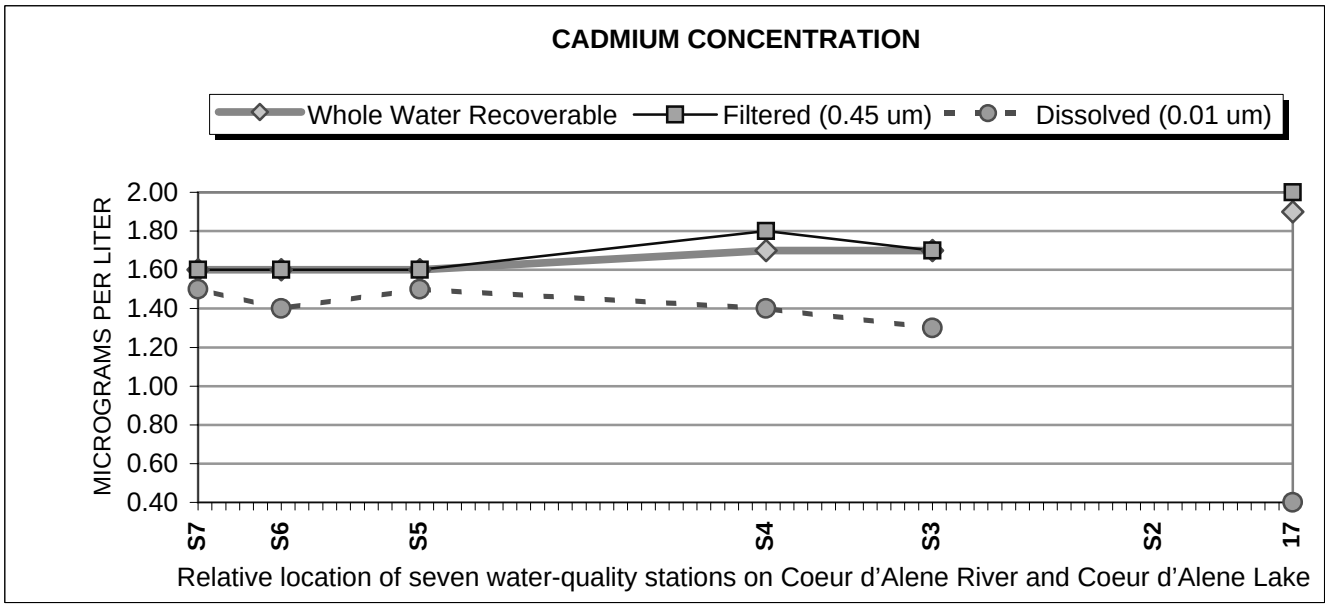


Figure 2. Variation in river or lake stage between October 1998 and October 1999 at four U.S. Geological Survey stations in the Coeur d'Alene River Basin, Idaho





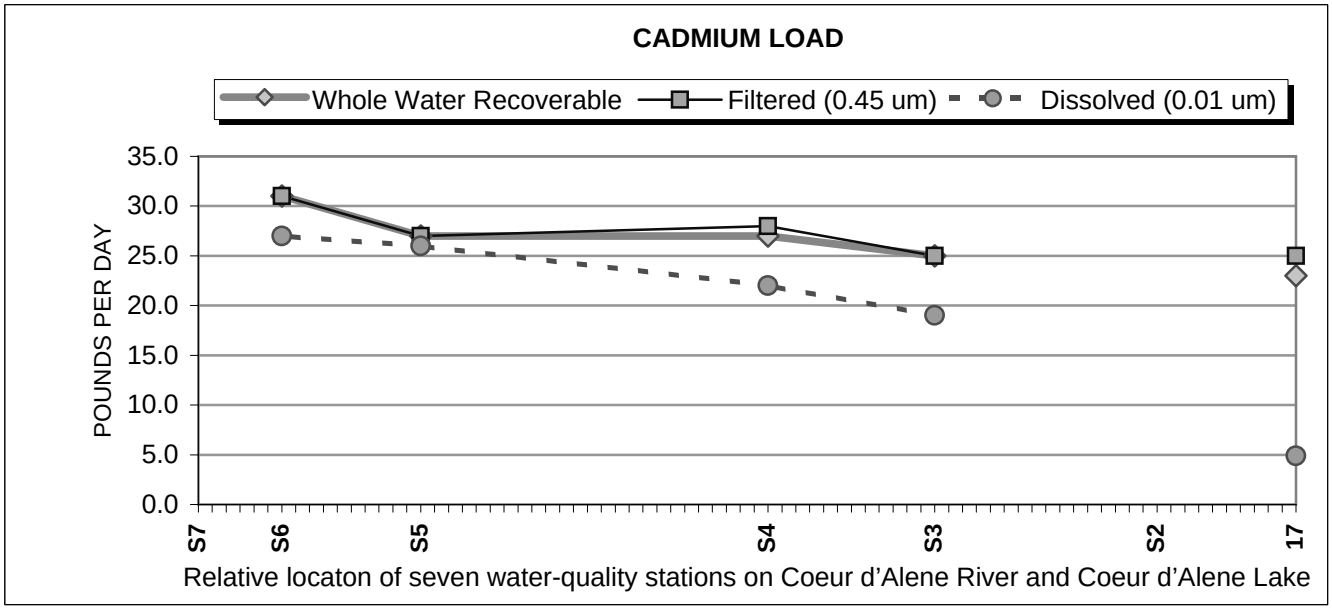


Figure 3. Instantaneous values for discharges and concentrations and loads of cadmium at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, March 9, 1999.

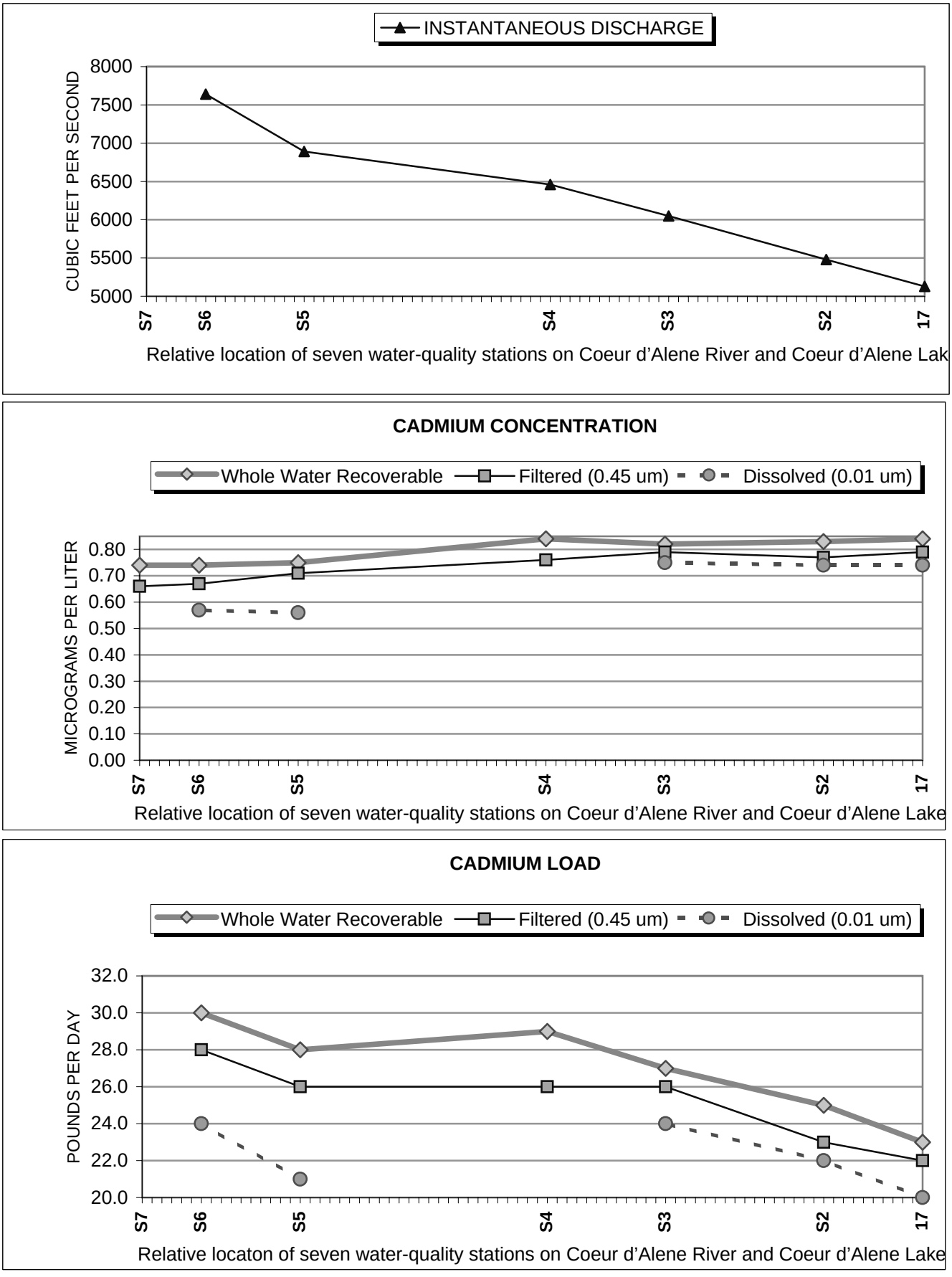
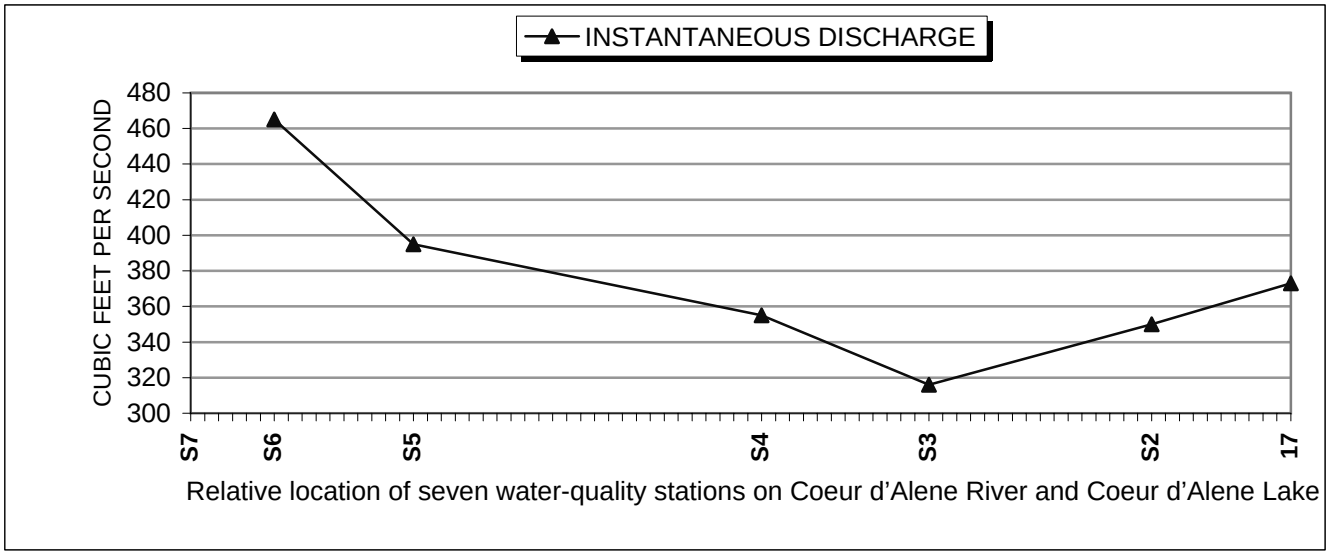
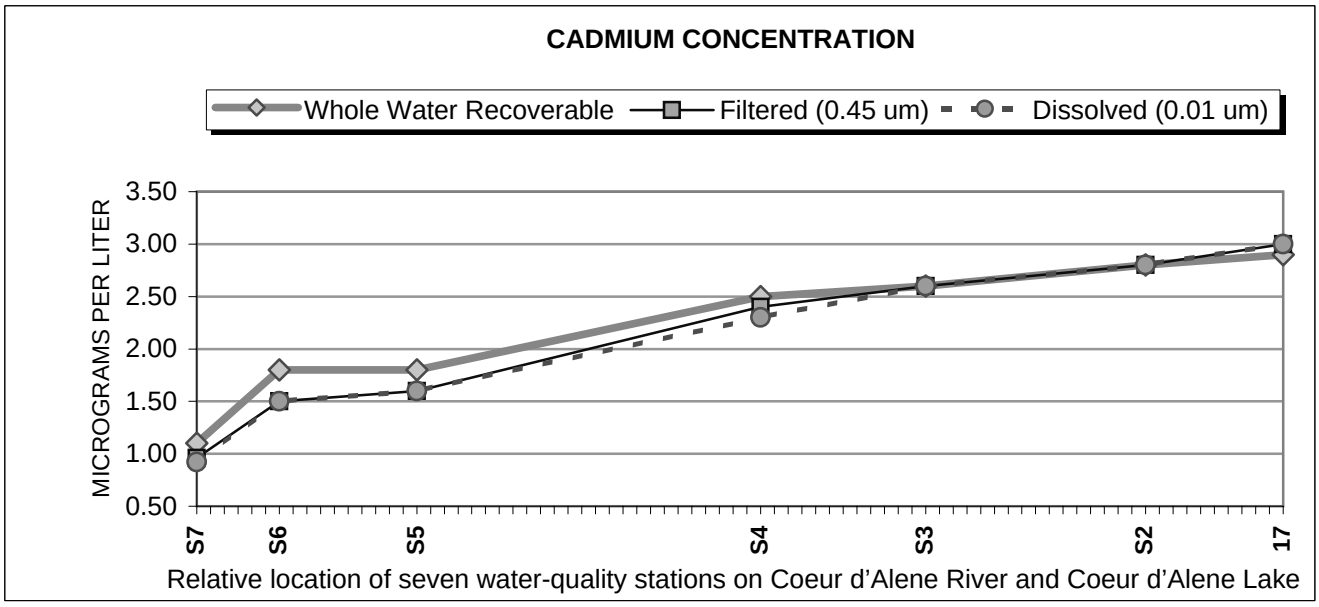


Figure 4. Instantaneous values for discharges and concentrations and loads of cadmium at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, June 8, 1999.





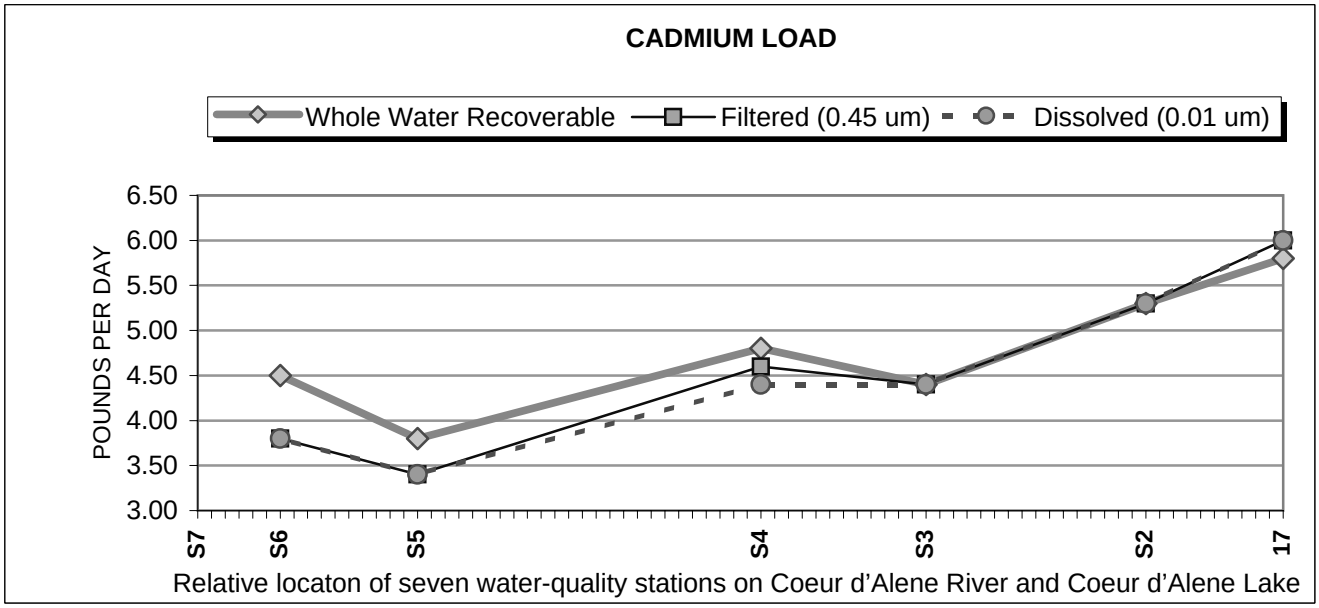
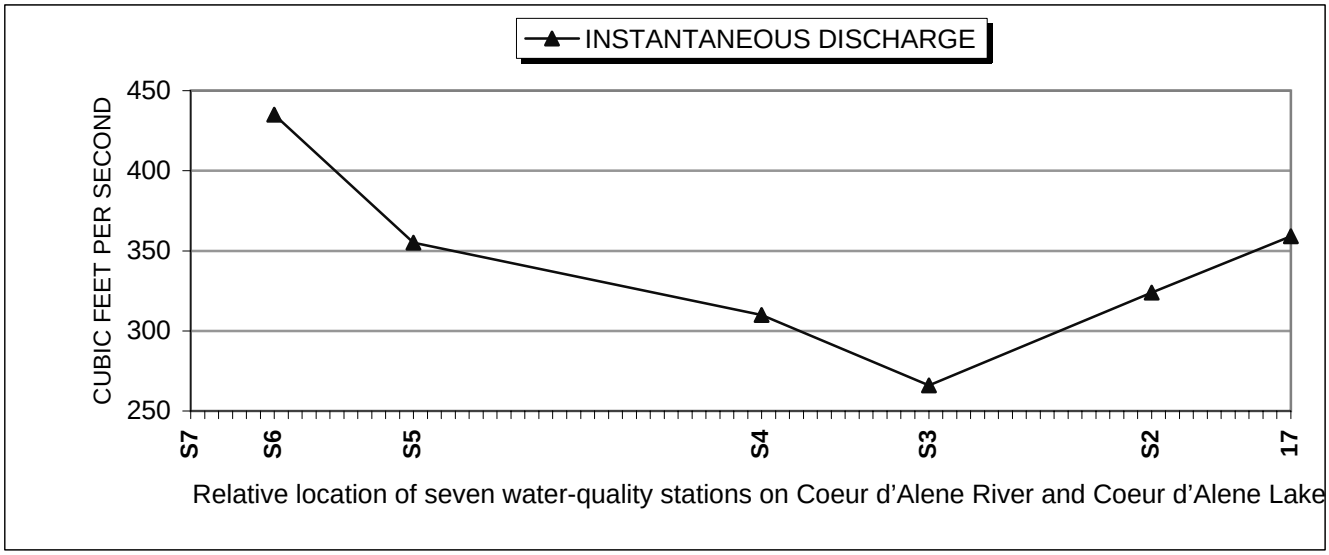
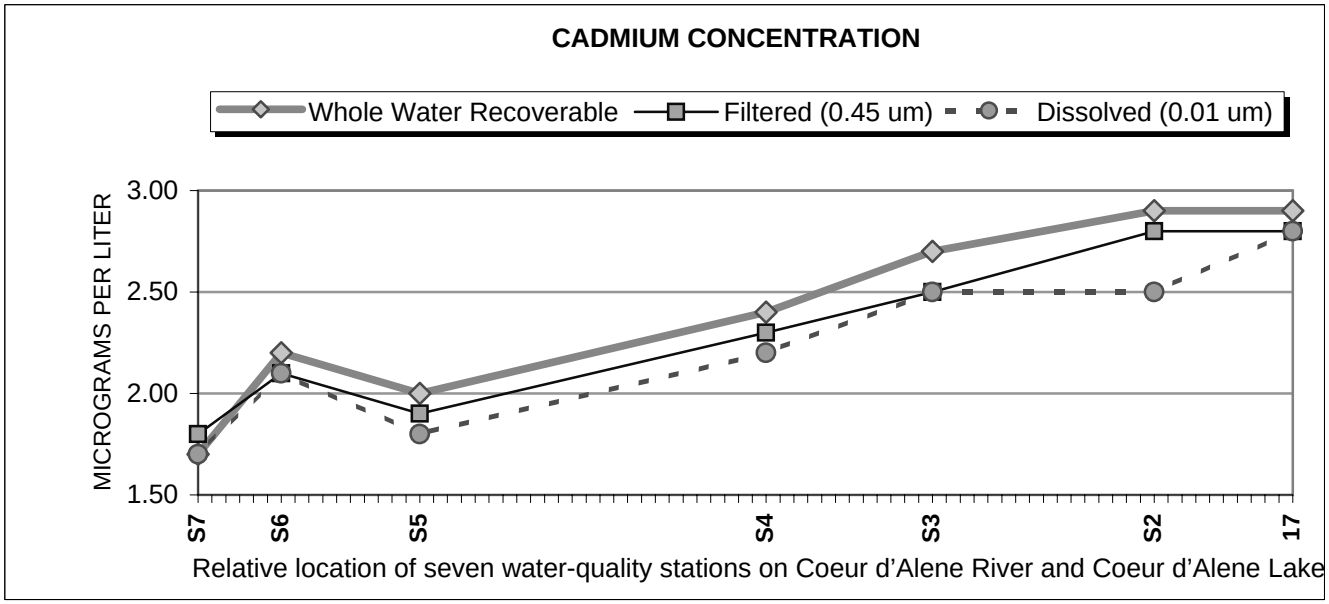


Figure 5. Instantaneous values for discharges and concentrations and loads of cadmium at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, September 21-22, 1999.





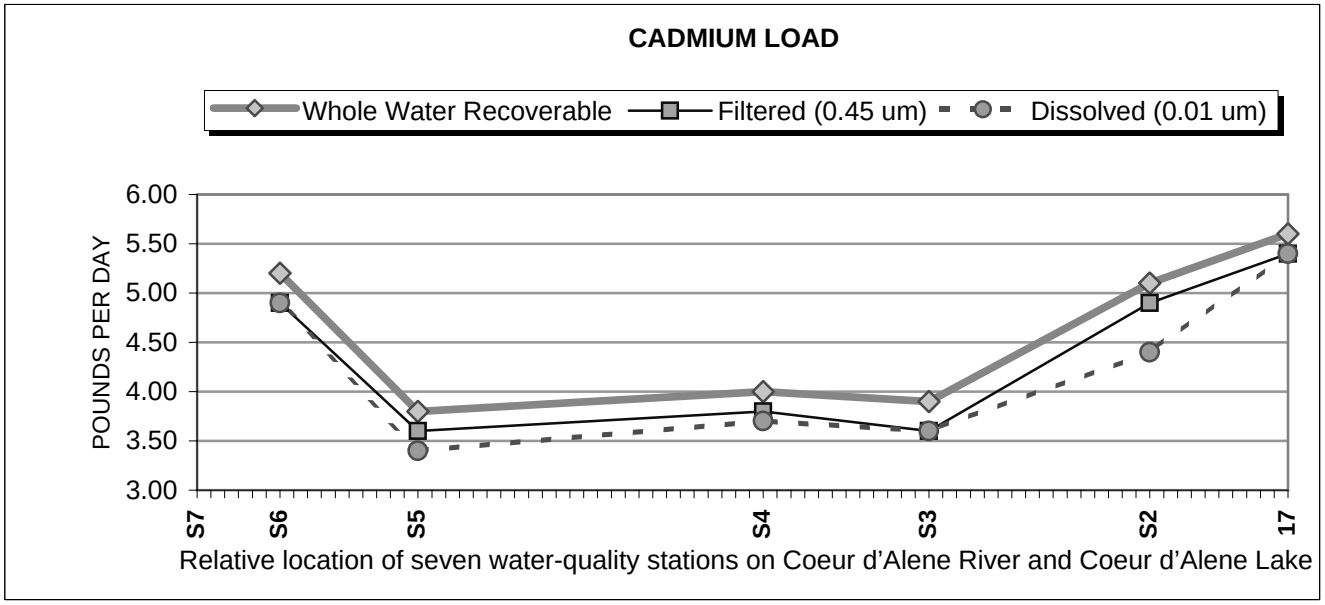


Figure 6. Instantaneous values for discharges and concentrations and loads of cadmium at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, October 19-20, 1999.

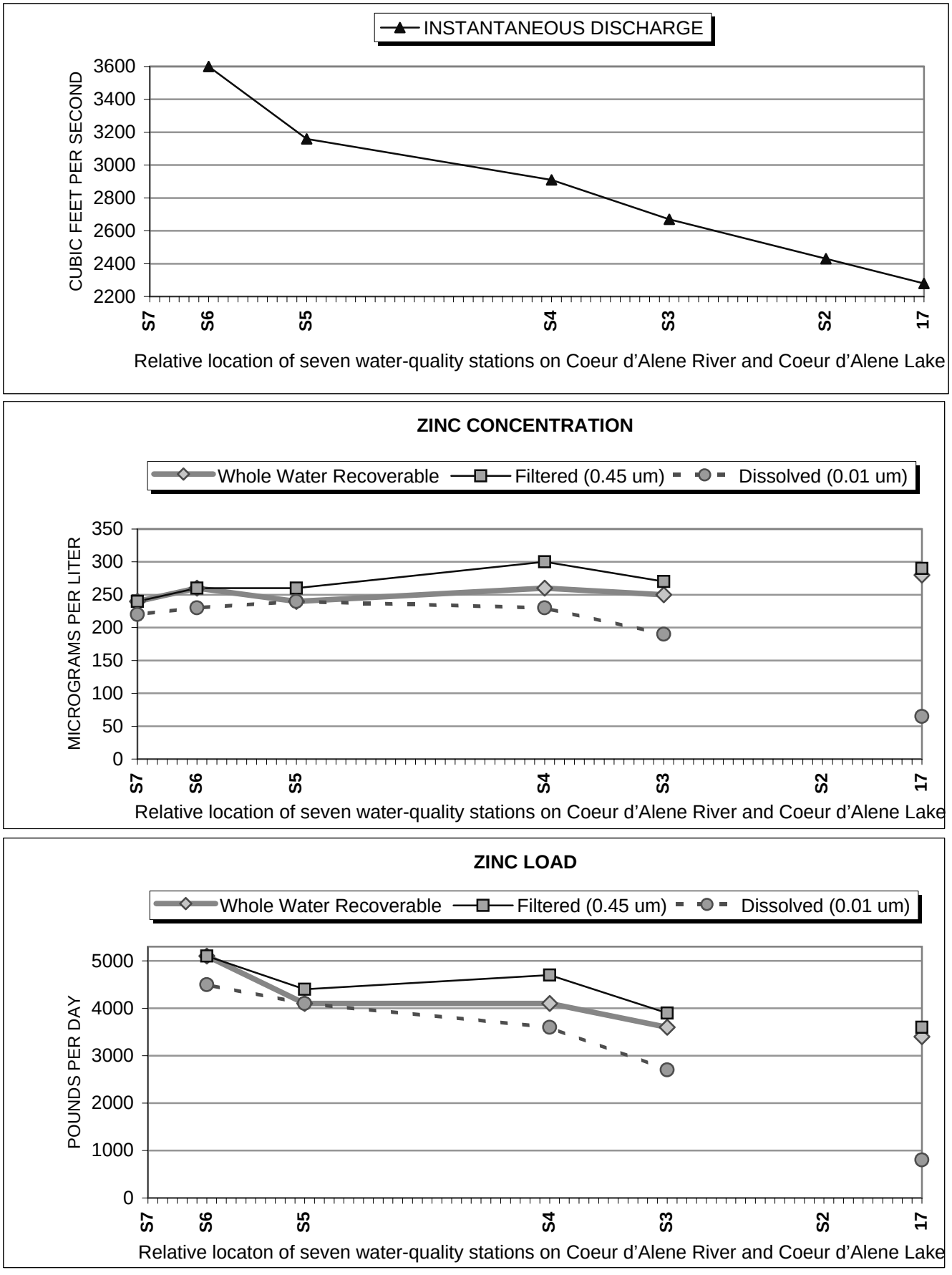
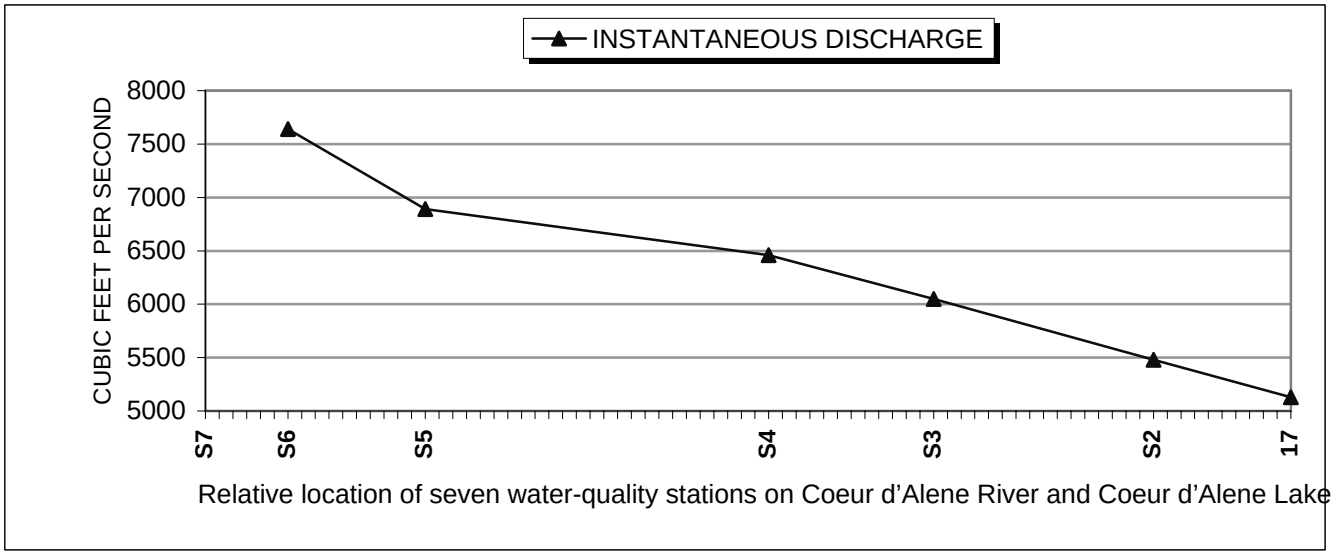
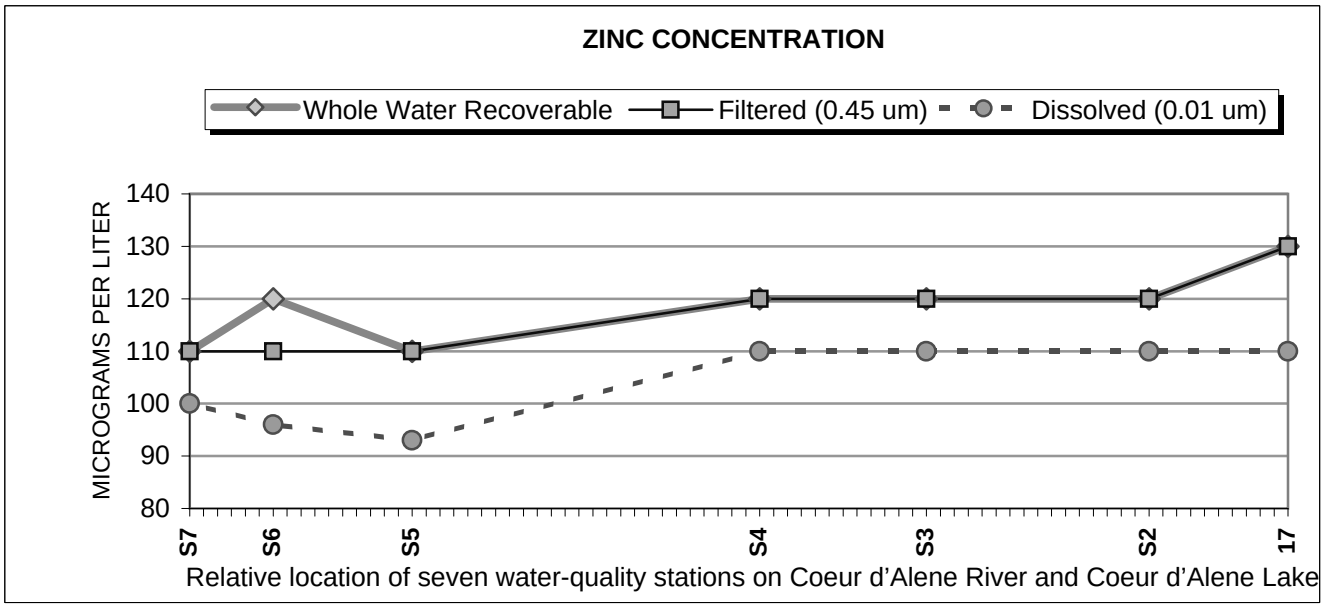


Figure 7. Instantaneous values for discharges and concentrations and loads of zinc at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, March 9, 1999.





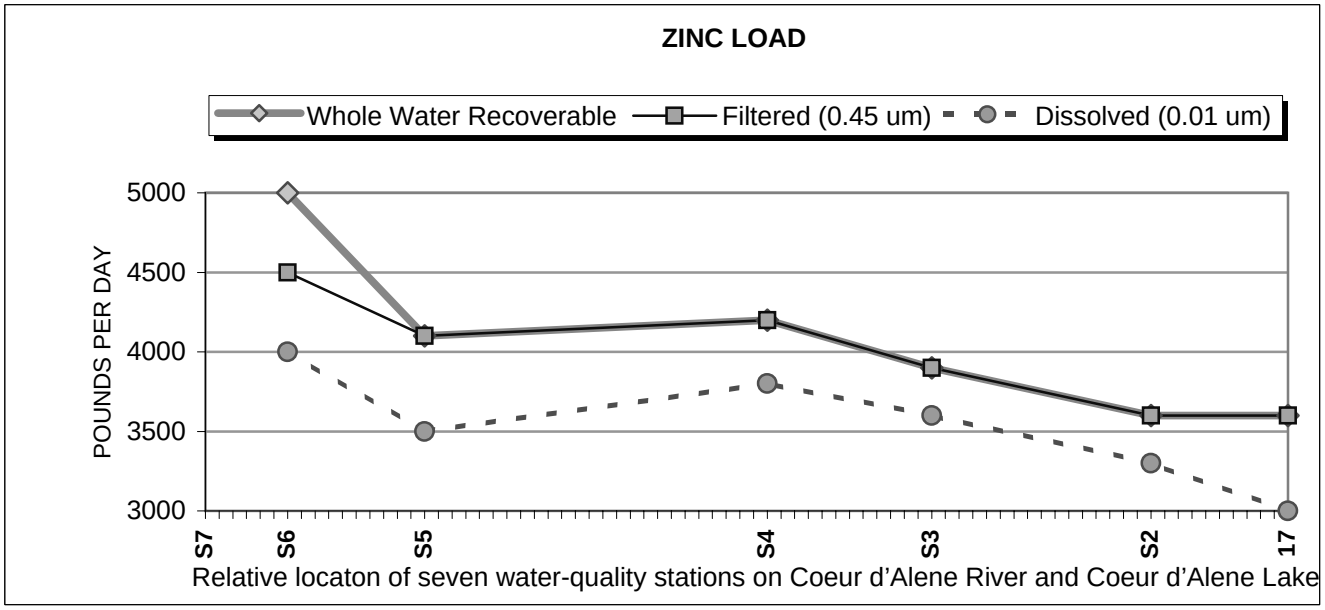


Figure 8. Instantaneous values for discharges and concentrations and loads of zinc at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, June 8, 1999.

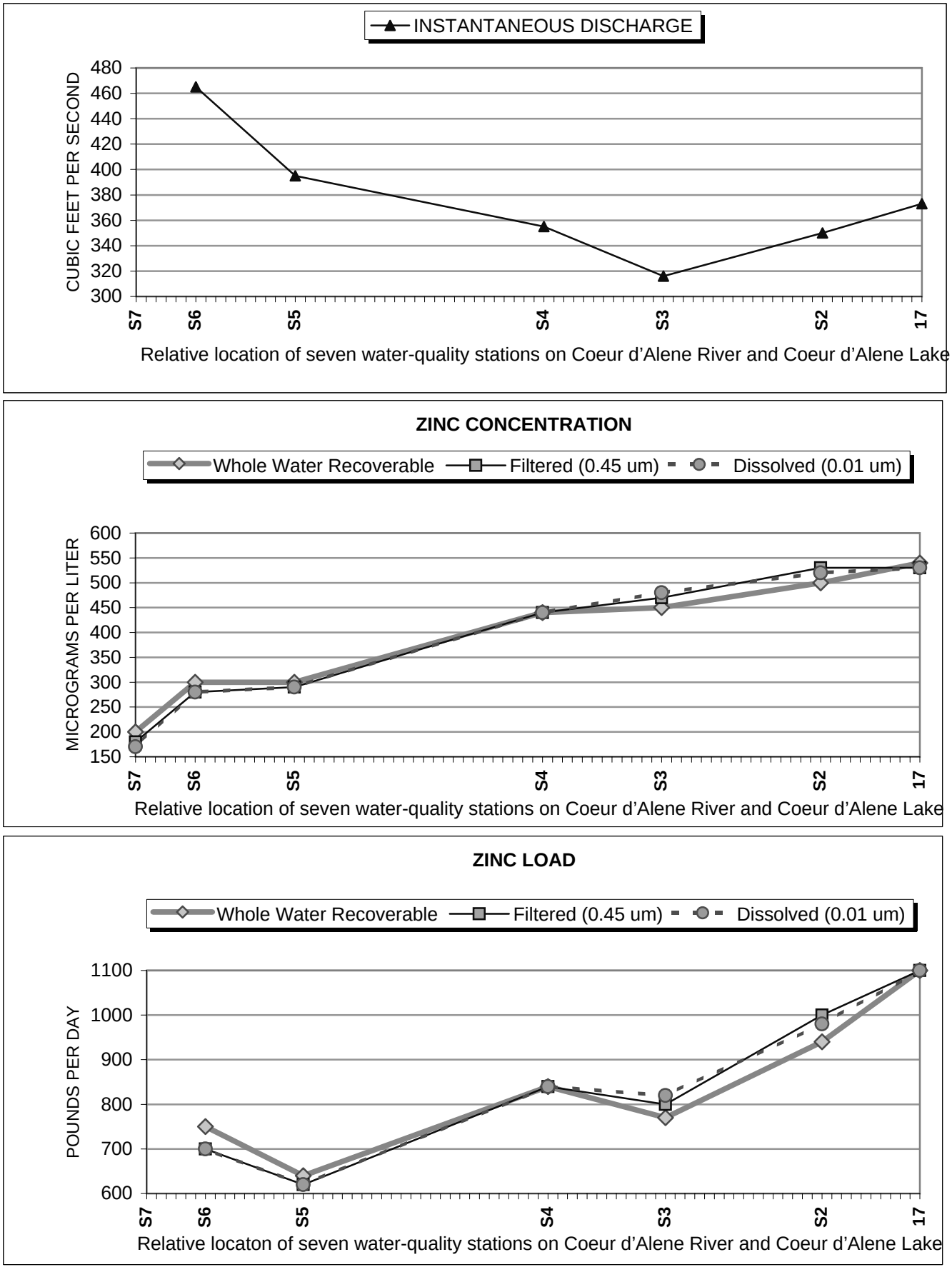


Figure 9. Instantaneous values for discharges and concentrations and loads of zinc at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, September 21-22, 1999.

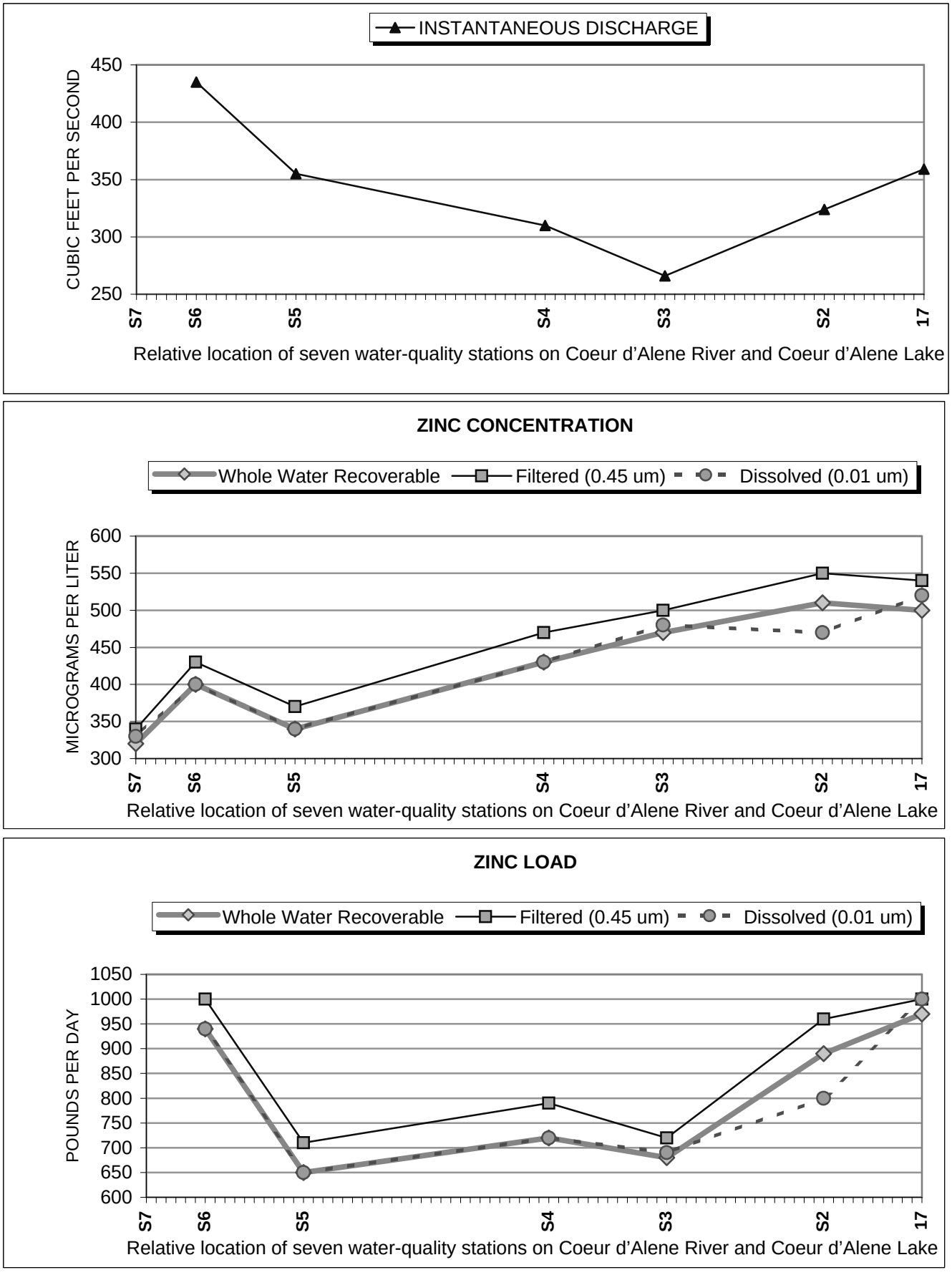


Figure 10. Instantaneous values for discharges and concentrations and loads of zinc at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, October 19-20, 1999.

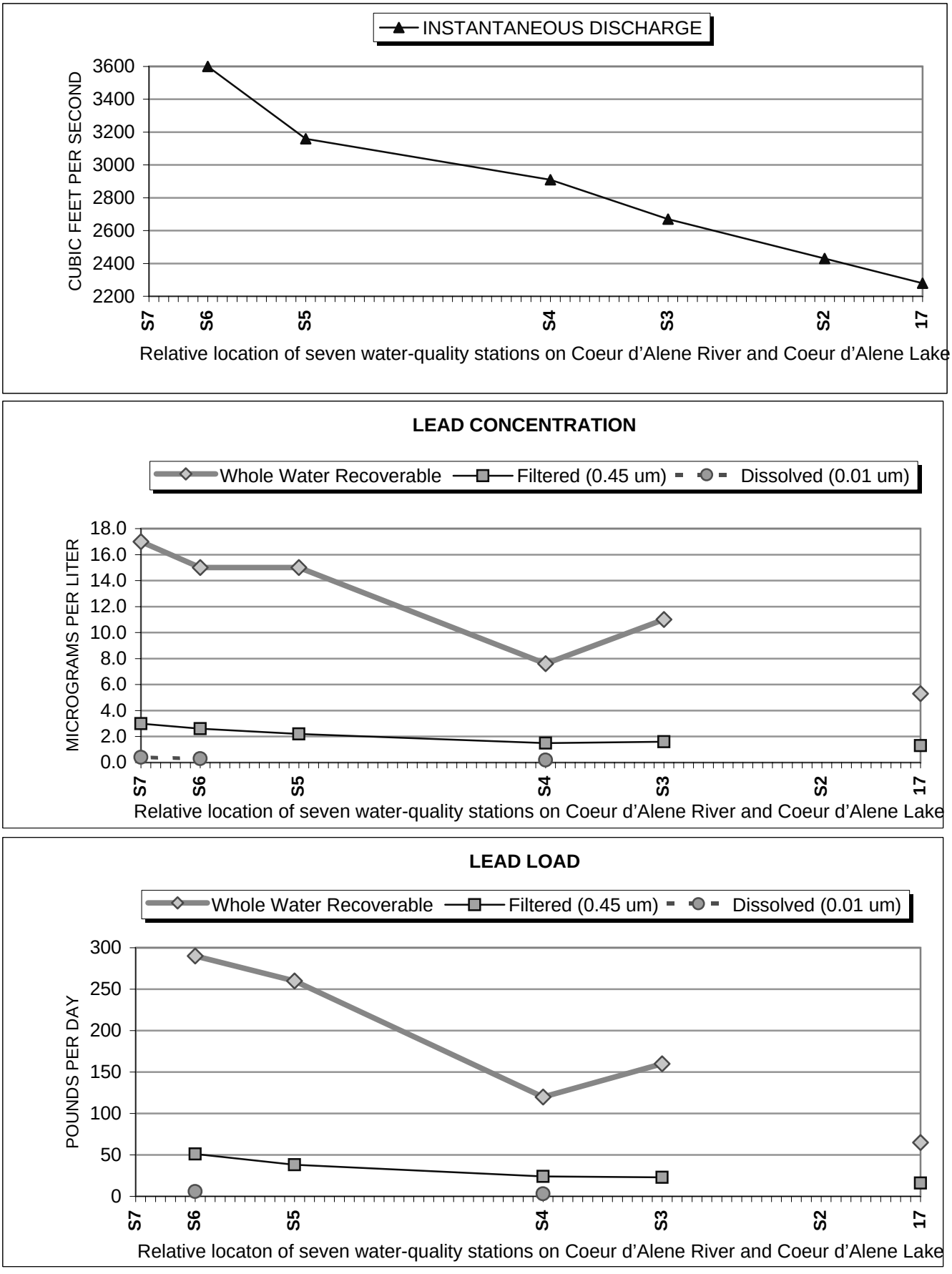
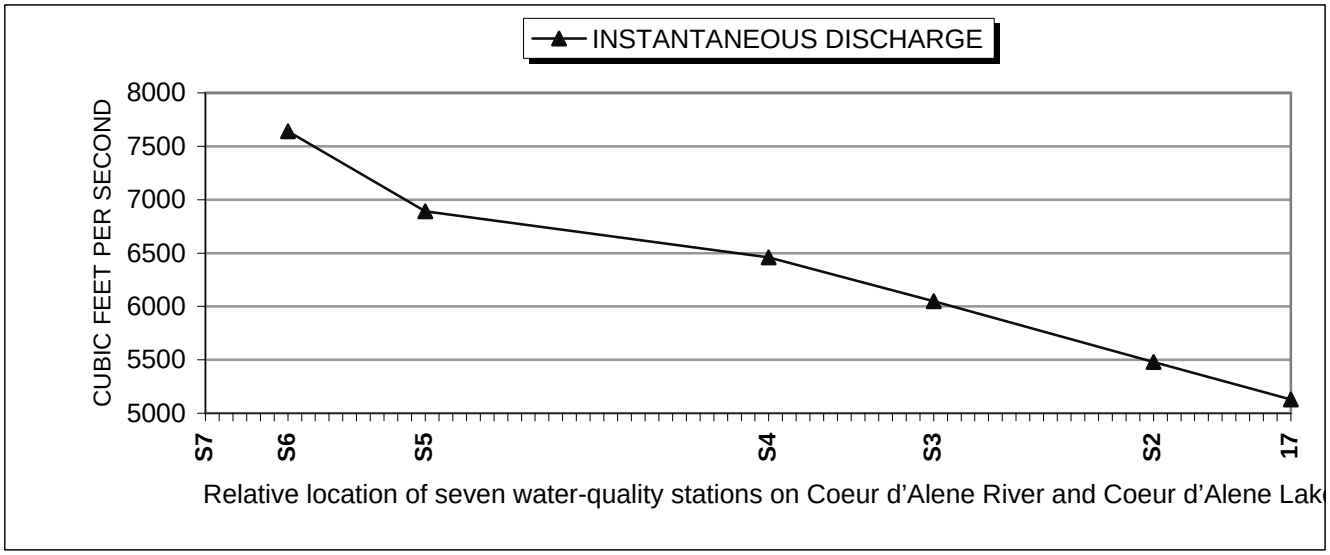
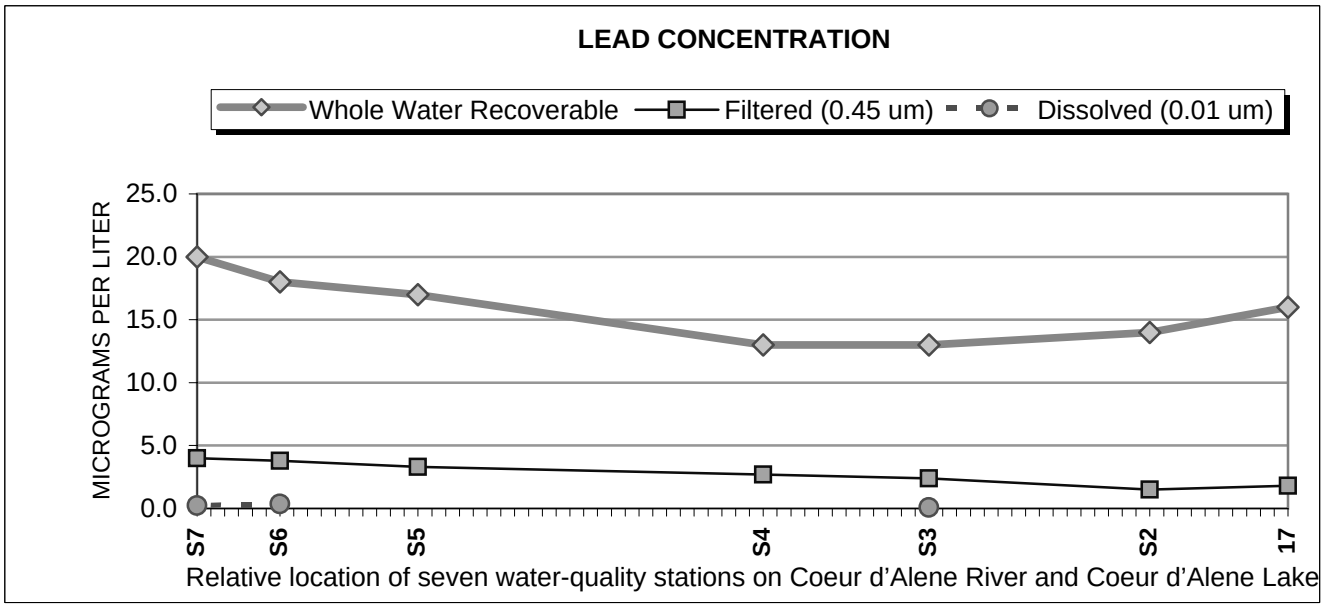


Figure 11. Instantaneous values for discharges and concentrations and loads of lead at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, March 9, 1999.





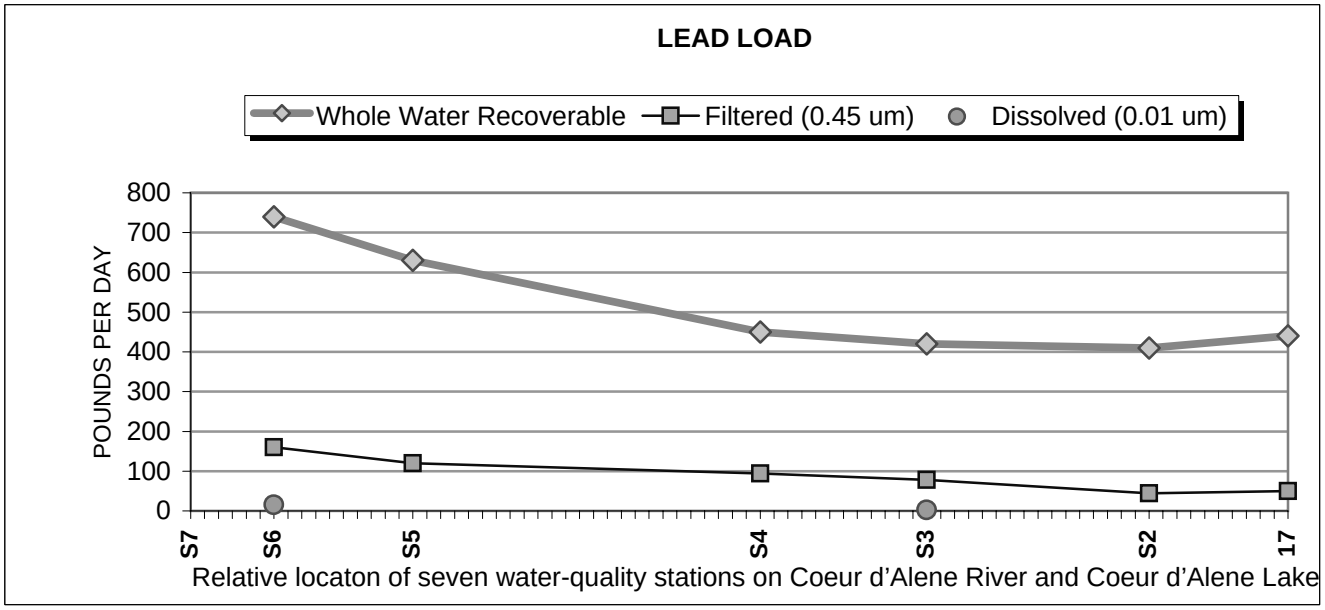
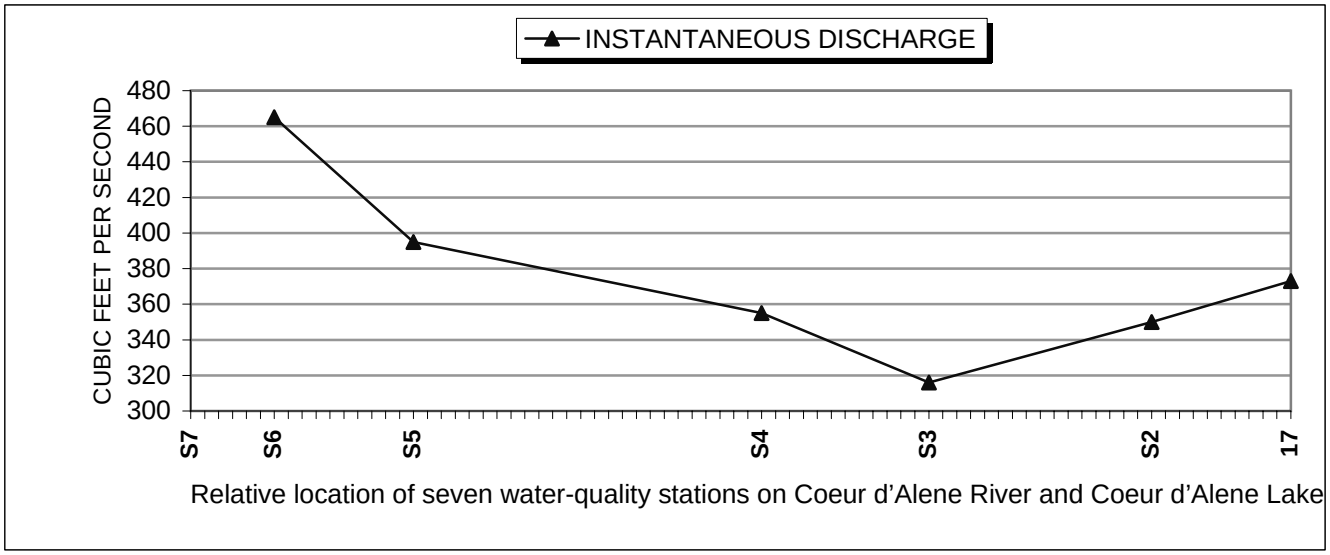
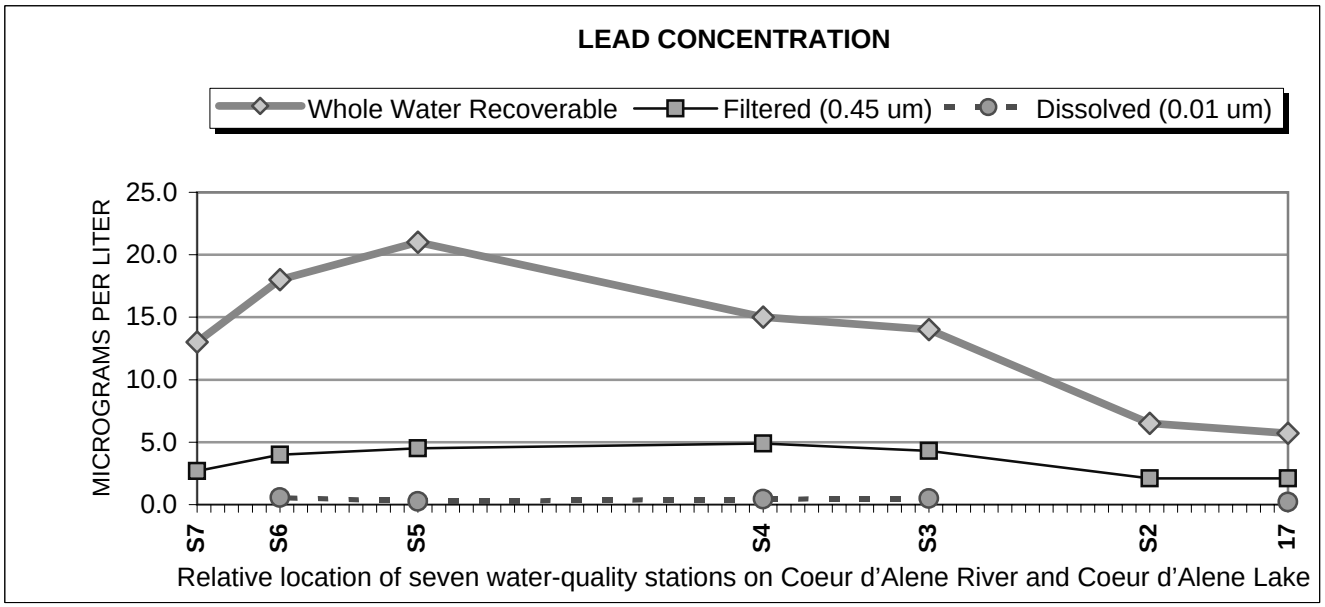


Figure 12. Instantaneous values for discharges and concentrations and loads of lead at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, June 8, 1999.





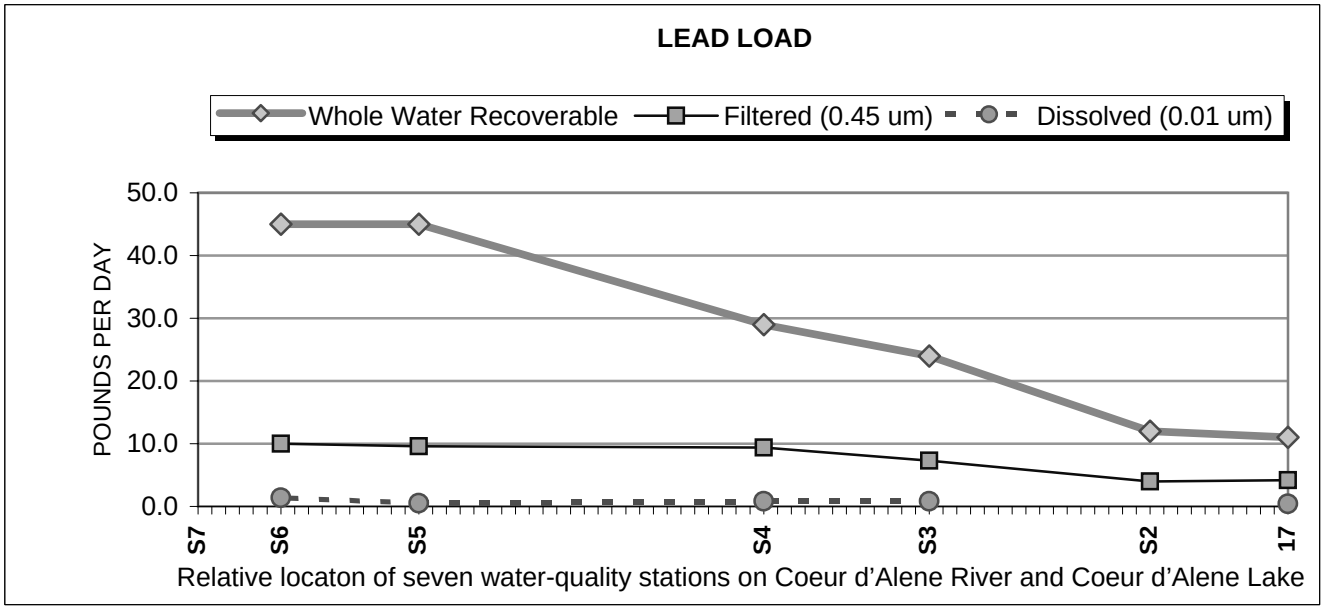


Figure 13. Instantaneous values for discharges and concentrations and loads of lead at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, September 21-22, 1999.

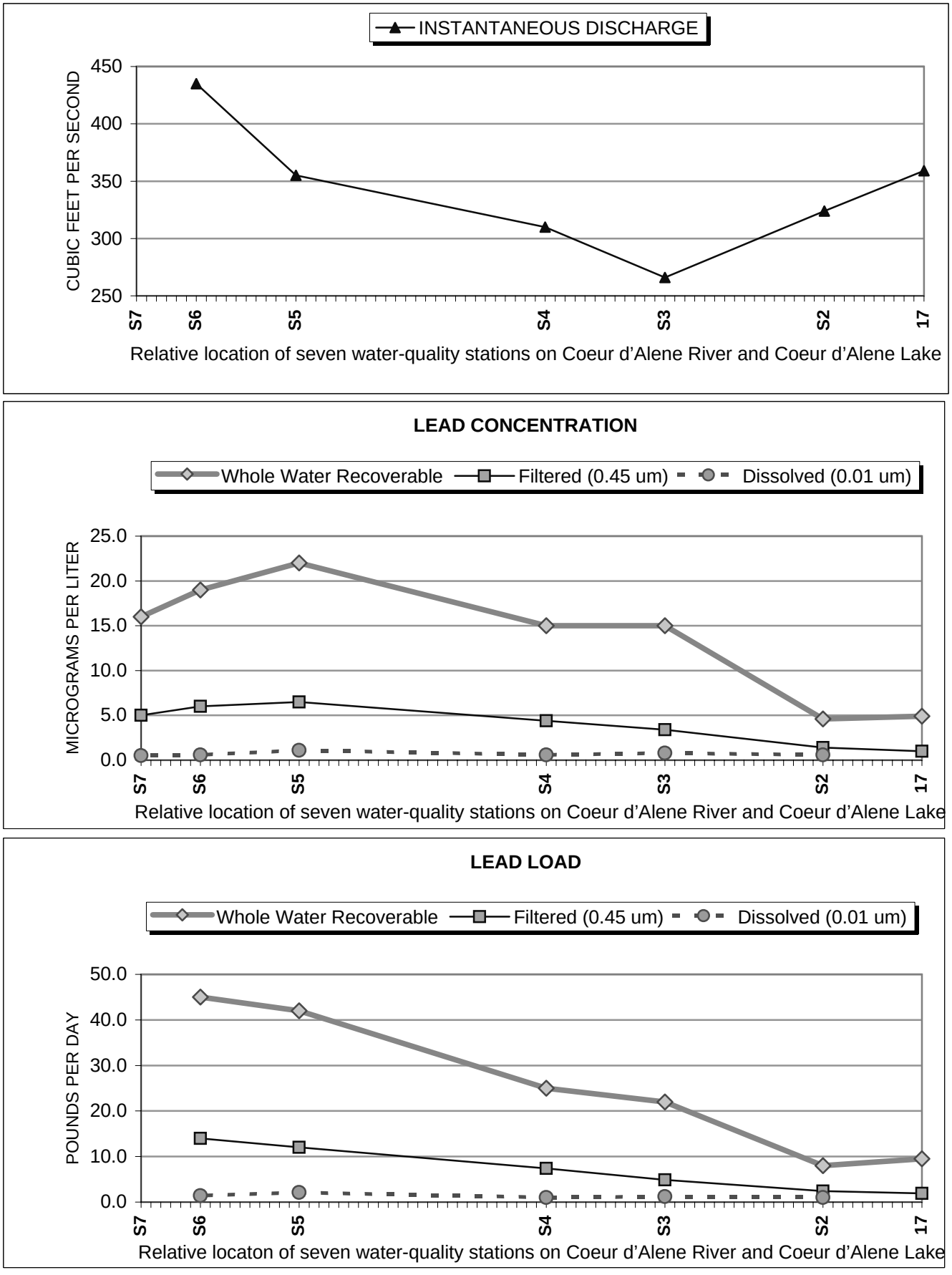


Figure 14. Instantaneous values for discharges and concentrations and loads of lead at seven water-quality stations on the main stem Coeur d'Alene River, Idaho, October 19-20, 1999.

TABLES 1–5

Table 1. Identification numbers and names of seven U.S. Geological Survey water-quality stations monitored during March, June, September, and October 1999 on the main stem Coeur d'Alene River, Idaho

[USGS, U.S. Geological Survey; na, not applicable; CDR, Coeur d'Alene River; ID, Idaho]

Station number on figure 1	USGS station number	USGS station name	Source of discharge data			
			Measured (M) or Interpolated (I)	Interpolated discharges		
				Upstream measured station	Downstream measured station	Ratio of distance of interpolated station to distance between upstream and downstream measured stations
17	12413500	CDR near Cataldo, ID	M	na	na	na
S2	12413755	CDR below Latour Creek near Cataldo, ID	I	17	S3	0.38
S3	12413815	CDR below Rose Creek near Rose Lake, ID	M	na	na	na
S4	12413825	CDR above Killarney Lake outlet near Rose Lake, ID	I	S3	S6	0.26
S5	12413858	CDR below Blue Lake near Harrison, ID	I	S3	S6	0.79
S6	12413862	CDR at Harrison bridge near Harrison, ID	M	na	na	na
S7[1]	472721116480100	Coeur d'Alene Lake between Harrison and Harlow Point near Harrison, ID	na	na	na	na

[1] Lake station

Table 2. Concentrations and instantaneous loads of cadmium, zinc, and lead measured on March 9, 1999, at six water-quality stations on the Coeur d'Alene River and one lake station near the mouth of the Coeur d'Alene River, Idaho

[CDR, Coeur d'Alene River; CDA, Coeur d'Alene; Inst. Q, instantaneous discharge; ft ^{3}/s, cubic feet per second; USGS, U.S. Geological Survey; ug/L, micrograms per liter; WWR, whole-water recoverable; F, filtered; D, dissolved; mg/L, milligrams per liter; <, less than; ns, not sampled; na, not applicable]

Station number on figure 1	USGS station name	Sample date	Inst. Q[1] (ft^3/s)	Suspended-sediment concentration (mg/L)	Cadmium concentration (µg/L)			Cadmium load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	3/9/99	2,280	1.9	1.9	2.0	0.40	23	25	4.9
S2	CDR below Latour Creek	3/9/99	2,430	ns	ns	ns	ns	ns	ns	ns
S3	CDR below Rose Creek	3/9/99	2,670	1.0	1.7	1.7	1.3	25	25	19
S4	CDR above Killarney Lake Outlet	3/9/99	2,910	1.0	1.7	1.8	1.4	27	28	22
S5	CDR below Blue Lake	3/9/99	3,160	1.9	1.6	1.6	1.5	27	27	26
S6	CDR at Harrison Bridge	3/9/99	3,600	0.6	1.6	1.6	1.4	31	31	27
S7	CDA Lake at mouth of CDR	3/9/99	na	ns	1.6	1.6	1.5	na	na	na
					Zinc concentration (µg/L)			Zinc load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	3/9/99	2,280	1.9	280	290	65	3400	3600	800
S2	CDR below Latour Creek	3/9/99	2,430	ns	ns	ns	ns	ns	ns	ns
S3	CDR below Rose Creek	3/9/99	2,670	1.0	250	270	190	3600	3900	2700
S4	CDR above Killarney Lake Outlet	3/9/99	2,910	1.0	260	300	230	4100	4700	3600
S5	CDR below Blue Lake	3/9/99	3,160	1.9	240	260	240	4100	4400	4100
S6	CDR at Harrison Bridge	3/9/99	3,600	0.6	260	260	230	5100	5100	4500
S7	CDA Lake at mouth of CDR	3/9/99	na	ns	240	240	220	na	na	na
					Lead concentration (µg/L)			Lead load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	3/9/99	2,280	1.9	5.3	1.3	<1	65	16	na
S2	CDR below Latour Creek	3/9/99	2,430	ns	ns	ns	ns	ns	ns	ns
S3	CDR below Rose Creek	3/9/99	2,670	1.0	11	1.6	<1	160	23	na
S4	CDR above Killarney Lake Outlet	3/9/99	2,910	1.0	7.6	1.5	0.20	120	24	3.1
S5	CDR below Blue Lake	3/9/99	3,160	1.9	15	2.2	<1	260	38	na
S6	CDR at Harrison Bridge	3/9/99	3,600	0.6	15	2.6	0.30	290	51	5.8
S7	CDA Lake at mouth of CDR	3/9/99	na	ns	17	3	0.40	na	na	na

[1] Discharge measured at stations 17, S3, and S6. Discharge estimated by interpolation at stations S2, S4, and S5.

[2] Weak-acid digestion performed on water, suspended-sediment mixture at U.S. Geological Survey's National Water-Quality Laboratory.

[3] Filtrate passing a 0.45-micrometer capsule filter.

[4] Filtrate passing a 0.01-micrometer tangential flow filter.

Table 3. Concentrations and instantaneous loads of cadmium, zinc, and lead measured on June 8, 1999, at six water-quality stations on the Coeur d'Alene River and one lake station near the mouth of the Coeur d'Alene River, Idaho

[CDR, Coeur d'Alene River; CDA, Coeur d'Alene; Inst. Q, instantaneous discharge; ft ^{3}/s, cubic feet per second; USGS, U.S. Geological Survey; ug/L, micrograms per liter; WWR, whole-water recoverable; F, filtered; D, dissolved; mg/L, milligrams per liter; <, less than; ns, not sampled; na, not applicable]

Station number on figure 1	USGS station name	Sample date	Inst. Q[1] (ft^3/s)	Suspended-sediment concentration (mg/L)	Cadmium concentration (µg/L)			Cadmium load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	6/8/99	5,130	56	0.84	0.79	0.74	23	22	20
S2	CDR below Latour Creek	6/8/99	5,480	52	0.83	0.77	0.74	25	23	22
S3	CDR below Rose Creek	6/8/99	6,050	51	0.82	0.79	0.75	27	26	24
S4	CDR above Killarney Lake Outlet	6/8/99	6,460	51	0.84	0.76	<1	29	26	na
S5	CDR below Blue Lake	6/8/99	6,890	44	0.75	0.71	0.56	28	26	21
S6	CDR at Harrison Bridge	6/8/99	7,640	52	0.74	0.67	0.57	30	28	24
S7	CDA Lake at mouth of CDR	6/8/99	na	ns	0.74	0.66	<1	na	na	na
					Zinc concentration (µg/L)			Zinc load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	6/8/99	5,130	56	130	130	110	3600	3600	3000
S2	CDR below Latour Creek	6/8/99	5,480	52	120	120	110	3600	3600	3300
S3	CDR below Rose Creek	6/8/99	6,050	51	120	120	110	3900	3900	3600
S4	CDR above Killarney Lake Outlet	6/8/99	6,460	51	120	120	110	4200	4200	3800
S5	CDR below Blue Lake	6/8/99	6,890	44	110	110	93	4100	4100	3500
S6	CDR at Harrison Bridge	6/8/99	7,640	52	120	110	96	5000	4500	4000
S7	CDA Lake at mouth of CDR	6/8/99	na	ns	110	110	100	na	na	na
					Lead concentration (µg/L)			Lead load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	6/8/99	5,130	56	16	1.8	<1	440	50	na
S2	CDR below Latour Creek	6/8/99	5,480	52	14	1.5	<1	410	44	na
S3	CDR below Rose Creek	6/8/99	6,050	51	13	2.4	0.08	420	78	2.6
S4	CDR above Killarney Lake Outlet	6/8/99	6,460	51	13	2.7	<1	450	94	na
S5	CDR below Blue Lake	6/8/99	6,890	44	17	3.3	<1	630	120	na
S6	CDR at Harrison Bridge	6/8/99	7,640	52	18	3.8	0.36	740	160	15
S7	CDA Lake at mouth of CDR	6/8/99	na	ns	20	4.0	0.22	na	na	na

[1] Discharge measured at stations 17, S3, and S6. Discharge estimated by interpolation at stations S2, S4, and S5.

[2] Weak-acid digestion performed on water, suspended-sediment mixture at U.S. Geological Survey's National Water-Quality Laboratory.

[3] Filtrate passing a 0.45-micrometer capsule filter.

[4] Filtrate passing a 0.01-micrometer tangential flow filter.

Table 4. Concentrations and instantaneous loads of cadmium, zinc, and lead measured on September 21-22, 1999, at six water-quality stations on the Coeur d'Alene River and one lake station near the mouth of the Coeur d'Alene River, Idaho

[CDR, Coeur d'Alene River; CDA, Coeur d'Alene; Inst. Q, instantaneous discharge; ft ^{3}/s, cubic feet per second; USGS, U.S. Geological Survey; ug/L, micrograms per liter; WWR, whole-water recoverable; F, filtered; D, dissolved; mg/L, milligrams per liter; <, less than; ns, not sampled; na, not applicable]

Station number on figure 1	USGS station name	Sample date	Inst. Q[1] (ft^3/s)	Suspended-sediment concentration (mg/L)	Cadmium concentration (µg/L)			Cadmium load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	9/22/99	373	ns	2.9	3.0	3.0	5.8	6.0	6.0
S2	CDR below Latour Creek	9/22/99	350	0.8	2.8	2.8	2.8	5.3	5.3	5.3
S3	CDR below Rose Creek	9/22/99	316	ns	2.6	2.6	2.6	4.4	4.4	4.4
S4	CDR above Killarney Lake Outlet	9/22/99	355	1.5	2.5	2.4	2.3	4.8	4.6	4.4
S5	CDR below Blue Lake	9/22/99	395	ns	1.8	1.6	1.6	3.8	3.4	3.4
S6	CDR at Harrison Bridge	9/21/99	465	1.8	1.8	1.5	1.5	4.5	3.8	3.8
S7	CDA Lake at mouth of CDR	9/21/99	na	ns	1.1	0.96	0.92	na	na	na
					Zinc concentration (µg/L)			Zinc load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	9/22/99	373	ns	540	530	530	1100	1100	1100
S2	CDR below Latour Creek	9/22/99	350	0.8	500	530	520	940	1000	980
S3	CDR below Rose Creek	9/22/99	316	ns	450	470	480	770	800	820
S4	CDR above Killarney Lake Outlet	9/22/99	355	1.5	440	440	440	840	840	840
S5	CDR below Blue Lake	9/22/99	395	ns	300	290	290	640	620	620
S6	CDR at Harrison Bridge	9/21/99	465	1.8	300	280	280	750	700	700
S7	CDA Lake at mouth of CDR	9/21/99	na	ns	200	180	170	na	na	na
					Lead concentration (µg/L)			Lead load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	9/22/99	373	ns	5.7	2.1	0.20	11	4.2	0.40
S2	CDR below Latour Creek	9/22/99	350	0.8	6.5	2.1	<1	12	4.0	na
S3	CDR below Rose Creek	9/22/99	316	ns	14	4.3	0.48	24	7.3	0.82
S4	CDR above Killarney Lake Outlet	9/22/99	355	1.5	15	4.9	0.43	29	9.4	0.82
S5	CDR below Blue Lake	9/22/99	395	ns	21	4.5	0.25	45	9.6	0.53
S6	CDR at Harrison Bridge	9/21/99	465	1.8	18	4.0	0.56	45	10	1.4
S7	CDA Lake at mouth of CDR	9/21/99	na	ns	13	2.7	<1	na	na	na

[1] Discharge measured at stations 17, S3, and S6. Discharge estimated by interpolation at stations S2, S4, and S5.

[2] Weak-acid digestion performed on water, suspended-sediment mixture at U.S. Geological Survey's National Water-Quality Laboratory.

[3] Filtrate passing a 0.45-micrometer capsule filter.

[4] Filtrate passing a 0.01-micrometer tangential flow filter.

Table 5. Concentrations and instantaneous loads of cadmium, zinc, and lead measured on October 19-20, 1999, at six water-quality stations on the Coeur d'Alene River and one lake station near the mouth of the Coeur d'Alene River, Idaho

[CDR, Coeur d'Alene River; CDA, Coeur d'Alene; Inst. Q, instantaneous discharge; ft ^{3}/s, cubic feet per second; USGS, U.S. Geological Survey; ug/L, micrograms per liter; WWR, whole-water recoverable; F, filtered; D, dissolved; mg/L, milligrams per liter; <, less than; ns, not sampled; na, not applicable]

Station number on figure 1	USGS station name	Sample date	Inst. Q[1] (ft^3/s)	Suspended-sediment concentration (mg/L)	Cadmium concentration (µg/L)			Cadmium load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	10/20/99	359	ns	2.9	2.8	2.8	5.6	5.4	5.4
S2	CDR below Latour Creek	10/20/99	324	0.5	2.9	2.8	2.5	5.1	4.9	4.4
S3	CDR below Rose Creek	10/20/99	266	ns	2.7	2.5	2.5	3.9	3.6	3.6
S4	CDR above Killarney Lake Outlet	10/20/99	310	1.5	2.4	2.3	2.2	4.0	3.8	3.7
S5	CDR below Blue Lake	10/20/99	355	ns	2.0	1.9	1.8	3.8	3.6	3.4
S6	CDR at Harrison Bridge	10/19/99	435	2.3	2.2	2.1	2.1	5.2	4.9	4.9
S7	CDA Lake at mouth of CDR	10/19/99	na	ns	1.7	1.8	1.7	na	na	na
					Zinc concentration (µg/L)			Zinc load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	10/20/99	359	ns	500	540	520	970	1000	1000
S2	CDR below Latour Creek	10/20/99	324	0.5	510	550	470	890	960	800
S3	CDR below Rose Creek	10/20/99	266	ns	470	500	480	680	720	690
S4	CDR above Killarney Lake Outlet	10/20/99	310	1.5	430	470	430	720	790	720
S5	CDR below Blue Lake	10/20/99	355	ns	340	370	340	650	710	650
S6	CDR at Harrison Bridge	10/19/99	435	2.3	400	430	400	940	1000	940
S7	CDA Lake at mouth of CDR	10/19/99	na	ns	320	340	330	na	na	na
					Lead concentration (µg/L)			Lead load (pounds/day)		
					WWR[2]	F[3]	D[4]	WWR[2]	F[3]	D[4]
17	CDR near Cataldo	10/20/99	359	ns	4.9	1.0	<1	9.5	1.9	na
S2	CDR below Latour Creek	10/20/99	324	0.5	4.6	1.4	0.6	8.0	2.4	1.0
S3	CDR below Rose Creek	10/20/99	266	ns	15	3.4	0.8	22	4.9	1.2
S4	CDR above Killarney Lake Outlet	10/20/99	310	1.5	15	4.4	0.6	25	7.4	1.0
S5	CDR below Blue Lake	10/20/99	355	ns	22	6.5	1.1	42	12	2.1
S6	CDR at Harrison Bridge	10/19/99	435	2.3	19	6.0	0.6	45	14	1.4
S7	CDA Lake at mouth of CDR	10/19/99	na	ns	16	5.0	0.5	na	na	na

[1] Discharge measured at stations 17, S3, and S6. Discharge estimated by interpolation at stations S2, S4, and S5.

[2] Weak-acid digestion performed on water, suspended-sediment mixture at U.S. Geological Survey's National Water-Quality Laboratory.

[3] Filtrate passing a 0.45-micrometer capsule filter.

[4] Filtrate passing a 0.01-micrometer tangential flow filter.