WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Cadmium, Lead, and Zinc in the Spokane River

Recommendations for Total Maximum Daily Loads and Waste Load Allocations

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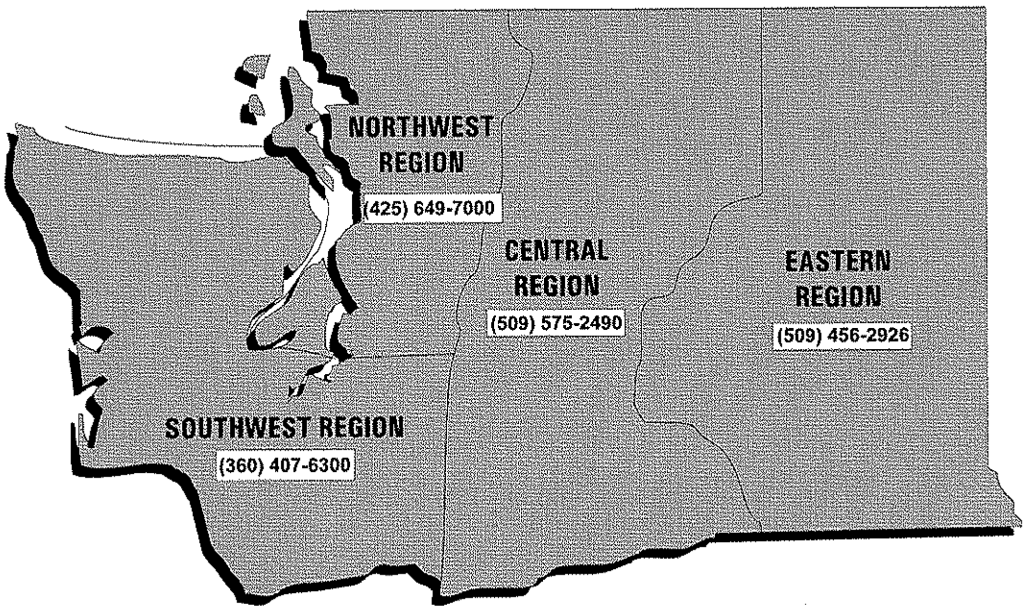

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Recommendations for Total Maximum Daily Loads and Waste Load Allocations

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Abstract

The Spokane River regularly violates water quality standards for zinc. Standards for lead and cadmium are also exceeded frequently, especially at higher flows. A procedure for determining Waste Load Allocations (WLAs) for all NPDES point source discharges to the Spokane River was developed based on meeting aquatic life criteria in the effluent. Permit limits for NPDES dischargers will be developed in the future for each individual discharger under Ecology's current schedule for permit cycles. Effluent limits for cadmium, lead, and zinc will be determined by comparing existing concentrations of metals in effluent, where adequate data exist, with the water quality criteria associated with the effluent hardness. Whichever results in the lower permit limits will be chosen.

This method should not result in any unreasonable compliance issues and minimizes the addition of metals to a system that is already exceeding the criteria. It is also an alternative to developing very stringent water quality-based effluent limits that are severely restricted due to excessive upstream and out-of-state metal sources. This approach is consistent with the intent of the anti-degradation policy of the federal Clean Water Act and the policy enunciated in the Washington State Water Pollution Control Act (RCW 90.48) requiring "... all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state ...(AKART)".

Waste Load Allocations are established as a maximum discharge concentration (micrograms per liter) rather than a discharge loading (pounds per day). The federal Clean Water Act allows for the use of allocations in mass per time or other appropriate measure. In this case, a concentration measure is appropriate, because the relationship between the effluent-based criterion and receiving water quality holds for all effluent and river flow rates.

The Spokane River at the state line is the upstream boundary for the present Total Maximum Daily Load (TMDL) in Washington. The proposed TMDL and analysis to address point source discharges and other sources of metals in the Spokane River requires that the Spokane River will meet Washington state's water quality standards, at a point where the river enters Washington State, within a reasonable period of time. The ultimate success and appropriateness of this TMDL/WLA depends solely on whether the Idaho Department of Environmental Quality or EPA develops and implements an adequate TMDL/WLA and management plan that will result in meeting Washington's water quality standards at the upstream end of the Spokane River.

Introduction

Objective

The Spokane River regularly has elevated levels of zinc, and frequently has elevated levels of lead and cadmium. The river does not meet water quality standards for these metals. The Washington State Department of Ecology, Idaho's Division of Environmental Quality (IDEQ), and the U. S. Environmental Protection Agency (EPA) are evaluating regulatory actions to address this issue. The various entities that are permitted under NPDES to discharge to the Spokane River have also been active in proposing approaches to regulate water quality in the Spokane River.

The objective of this report is to propose an approach for regulating point source dischargers in Washington under a Total Maximum Daily Load (TMDL), instead of developing unreasonably stringent water quality-based effluent limits on a case-by-case basis when upstream concentrations of metals already exceed criteria. At the same time, Idaho and EPA are developing a TMDL to control pollution sources in Idaho. One of the necessary objectives of the Idaho and EPA TMDLs is to meet Washington's water quality criteria in the Spokane River. This TMDL by Ecology addresses NPDES discharges in Washington, and uses an approach that will preferably be similar to EPA's proposed regulation of NPDES dischargers in Idaho.

Spokane River Dischargers and Hydrology

The source of the Spokane River is Lake Coeur d'Alene located in Idaho (Figure 1). The river flows in a westerly direction from Lake Coeur d'Alene, across the state line, to the city of Spokane. From Spokane, the river flows in a northwesterly direction to its confluence with the Columbia River. In Idaho, the following wastewater treatment plants (in order proceeding downstream from the river source) are permitted to discharge to the river:

- City of Coeur d'Alene Advanced Wastewater Treatment Plant (AWTP)
- Hayden Area Regional Sewer Board (HARSB) Publicly-owned Treatment Works (POTW)
- City of Post Falls POTW (also serves the City of Rathdrum)

Continuing downstream, the dischargers in Washington are as follows:

- Liberty Lake POTW
- Kaiser Aluminum Industrial Wastewater Treatment Plant (IWTP)
- Inland Empire Paper Company IWTP
- City of Spokane AWTP

The current and projected effluent design flows from the NPDES dischargers are presented in Table 1 (SRDG, 1997).

Substantial inflows of groundwater enter the river beginning downstream from the Liberty Lake outfall. The groundwater inflows significantly increase the river flow rate, especially when surface water flows are low. Table 2 presents the equations used to estimate the aquifer inflow and outflow to the river based on the compilation of data used for the phosphorus attenuation model of the basin (Patmont *et al.*, 1985; Patmont *et al.*, 1987).

Aquifer inflows and outflows were assumed to be correlated to river flows up to a flow of 4,000 cfs from Lake Coeur d'Alene based on the evaluations by Patmont *et al.* The total net aquifer inflows range between about 500 to 800 cfs depending on river flow. For comparison, the combined effluent flow from all current NPDES dischargers is about 128 cfs. The *lowest* 7-day average flow with a 10-year recurrence for the Spokane River at the upstream end near Post Falls (river mile 100.7) is approximately 187 cfs; the *highest* 7-day average flow with a 10-year recurrence is approximately 36,000 cfs; and the annual average flow is approximately 6,300 cfs.

A recent groundwater modeling study by CH2M-Hill suggests that aquifer exchange may be less than previous estimates (CH2M-Hill, 1998). However, the results of the CH2M-Hill study were not used for this study because their reach definitions were not as detailed, and their findings are still under review. Also, if future review of the aquifer exchange rates results in confirmation of CH2M-Hill estimates, then the recommended effluent limits to meet criteria for cadmium, lead, and zinc will not change because the concentrations of metals in the aquifer are much lower than water quality standards, and therefore the recommended effluent limits do not depend on the aquifer exchange rates. However, for future evaluations of limits for other constituents that are a function of available dilution (*e.g.* ammonia), it may be preferable to use the revised aquifer exchange rates by CH2M-Hill.

TMDL Boundaries

Cadmium, lead, and zinc concentrations in the Spokane River at the state line often exceed water quality standards. The Bunker Hill Superfund site is the largest source to discharge heavy metals in the Idaho sub-basin (IDEQ, 1998). More than a century of deep-shaft mining activities for sulfide-based heavy metals has elevated levels of cadmium, lead, arsenic, and zinc in the South Fork Coeur d'Alene River, which discharges into Lake Coeur d'Alene. Although measures have been taken to dramatically reduce loading to the South Fork, existing concentrations of some metals are still above those in most surface waters of the nation.

IDEQ is currently developing a TMDL for metals and is initiating projects to further reduce metals loads to the South Fork. That TMDL also must have the objective of eventually meeting Washington's water quality standards in the Spokane River. The EPA is working closely with the IDEQ to ensure that progress in reducing loads of metals continues in Idaho.

Ecology is also monitoring the trend in water quality at the state line to detect expected decreases in metals concentrations.

The outlet of Lake Coeur d'Alene is a logical upstream boundary for a separate TMDL analysis to address point source discharges and other sources of metals in the Spokane River, provided that IDEQ develops an adequate TMDL and management plan to meet Washington's water quality standards at the border. However, delays in TMDL development in Idaho have caused Washington State to proceed with a TMDL/WLA which begins with the upstream reach of the Spokane River beginning at the Idaho-Washington state line, and the downstream boundary located below the outfall for the City of Spokane's AWTP. Spokane is the most downstream NPDES discharger, and is therefore considered to be the most downstream potential contributor of significant concentrations of cadmium, lead, and zinc.

Data Analysis and Modeling

Water Quality Criteria for Cadmium, Lead, and Zinc

Water quality criteria to protect aquatic life (established in WAC 173-201A-040) apply to the dissolved fraction for cadmium, lead, and zinc and are calculated with the following equations for chronic (4-day average concentration in micrograms per liter not to be exceeded more than once every three years) and acute (one-hour average concentration in micrograms per liter not to be exceeded more than once every three years based on hardness in milligrams per liter as $CaCO_3$):

Dissolved Cadmium

Chronic ≤ (1.101672-((LN(hardness))*(0.041838)))*EXP(0.7852*(LN(hardness))-3.49)
Acute ≤ (1.136672-((LN(hardness))*(0.041838)))*EXP(1.128*(LN(hardness))-3.828)

Dissolved Lead

Chronic ≤ (1.46203-((LN(hardness))*(0.145712)))*EXP(1.273*(LN(hardness))-4.705)
Acute ≤ (1.46203-((LN(hardness))*(0.145712)))*EXP(1.273*(LN(hardness))-1.46)

Dissolved Zinc

Chronic ≤ 0.986*EXP(0.8473*(LN(hardness))+0.7614)
Acute ≤ 0.978*EXP 0.8473*(LN(hardness))+0.8604)

Figures 2 and 3 depict two hypothetical waters in relation to the water quality criterion curve for cadmium, lead and zinc. If one were to mix the two waters, the resulting mixed concentration of metals and hardness would always fall on a straight line between the two points. Assuming Point A is the Spokane River, meeting the water quality criteria as it exits Lake Coeur d'Alene, a discharge (Point B) at or below the effluent-based criterion would result in a mixture that falls below the criterion curve. Because of the concave shape (bending downward) of the cadmium and zinc criteria curves, any combination of cadmium, zinc, and hardness for the discharge that falls below the curve will mix with river water (A) to form a mixture that also falls below the curve. Therefore, in this situation, the effluent-based criterion approach is protective of state water quality standards.

However, for lead, the criterion curve is convex, or bending upward, leaving open the possibility that a mixture could exceed the criterion even when the waters individually fall below the criterion (a straight line between two points on the criterion curve will fall above the curve). If discharges do not exceed the lead concentration on the tangent line associated with the effluent hardness, the lead criterion will not be exceeded in the mixture of effluent and river water (Figure 3 and Appendix A). This approach is recommended to assure that limits are protective of state water quality standards.

If other sources of water with greater hardness than the river are also added to the mixture, for example groundwater or tributaries, then the resulting mixture including these multiple sources would also meet the criteria provided that no single source exceeds the criteria for cadmium or zinc, or exceeds the tangent line for lead. If the effluent concentrations of metals are below aquatic life criteria, then the metal toxicity in the river below the outfall is reduced by the hardness affect, which allows the river to either be closer to meeting the water quality standard or creates a small safety buffer.

Effluent Data

Typical effluent data are presented in Appendix B. The Spokane River Dischargers Group (SRDG) is currently collecting samples to characterize effluent quality. Appendix B presents preliminary results from the November-December 1997 sampling, as well as sampling by the City of Spokane AWTP from July 1996 through April 1998. All samples of effluent from all dischargers have been found to meet the chronic aquatic life criteria for cadmium, lead, and zinc at the effluent hardness. Effluent lead has also been consistently below the tangent equation for lead shown in Figure 3.

River Modeling

A mass-balance model of the Spokane River was developed to evaluate the effect of different effluent loading on metals and hardness. The model includes a flow balance that accounts for inflow of water from the outlet of Lake Coeur d'Alene, inflow from NPDES dischargers, and inflow/outflow from the aquifer and Hangman Creek. The model divides the river into reaches as shown in Table 2. For each reach, the flow balance is calculated from the following equation:

$$Q_{down} = Q_{up} + Q_{npdes} + Q_{aquifer}$$

where:

Q_{down} = flow at the downstream end of the reach (cfs)
Q_{up} = flow at the upstream end of the reach (cfs)
Q_{npdes} = flow from NPDES dischargers (Table 1) (cfs)
$Q_{aquifer}$ = flow from or to the aquifer or tributary (Table 2) (cfs)

The mass balance for hardness was calculated from the following equation:

$$H_{down} = [\ Q_{up}\ H_{up} + Q_{npdes}\ H_{npdes} + Q_{aquifer}\ H_{aquifer}\ ]\ /\ Q_{down}$$

where:

H_{down} = hardness (mg/L as $CaCO_3$) at the downstream end of the reach
H_{up} = hardness at the upstream end (assumed to be H_{down} from previous reach)
H_{npdes} = hardness of NPDES effluent
$H_{aquifer}$ = hardness of aquifer (if aquifer inflow) or H_{up} (if aquifer outflow)

For metals, the mass balance was as follows:

$$M_{dis,down} = F_{down}[\ Q_{up}\ M_{trec,up} + Q_{npdes}\ M_{trec,npdes} + Q_{aquifer}\ M_{trec,aquifer}\ ]\ /\ Q_{down}$$

where:

$M_{dis,down}$ = dissolved metals (ug/L) at the downstream end of the reach
F_{down} = fraction of dissolved/total recoverable metals at downstream end of reach
$M_{trec,up}$ = total recoverable metals at upstream end of reach (=$M_{dis,down}$ / F_{down} from previous reach)
$M_{trec,npdes}$ = total recoverable metals of NPDES effluent
$M_{trec,aquifer}$ = total recoverable metals of aquifer (if aquifer inflow) or $M_{dis,up}$ (if aquifer outflow)

The fraction of dissolved/total recoverable metals was estimated to equal the conversion factor used to convert the total recoverable criteria to the dissolved criteria (EPA, 1996). It was not considered necessary to use site-specific ratios of dissolved/total recoverable metals because the conversion factors generally represent a worse-case scenario of higher fractions of dissolved metals, and the use of site-specific ratios was not expected to result in different conclusions provided that all sources meet water quality criteria at their respective hardness. Aquifer inflow of total recoverable metals to the river was assumed to equal the dissolved metals concentration estimated during model calibration.

Model Calibration

Calibration of the model to actual conditions in the river involved estimation of aquifer hardness and metals to match observed concentrations in the river. All other inputs in the flow and mass balance equations were directly estimated from available data:

- The effluent flow rates were assumed to be the current flows presented in Table 1.

- Aquifer inflow/outflow rates were estimated as presented in Table 2.

- Outflow from Lake Coeur d'Alene was assumed to be various values between the normal range of 300 to 20,000 cfs.

- Effluent hardness was assumed to be approximately 145 mg/L as $CaCO_3$ based on the 10^{th} percentile hardness for the Spokane AWTP (CH2M-Hill, 1997). Effluent hardness from Kaiser IWTP was assumed to be a lower value of 120 mg/L as $CaCO_3$ based on the mixture of river and groundwater used for the production process.

- Effluent total recoverable cadmium, lead, and zinc were assumed to be approximate maximum values reported by the SRDG (0.3 ug/L cadmium, 2.5 ug/L lead, and 100 ug/L zinc).

- The ratio of dissolved/total recoverable metals was assumed to equal the conversion factor for the chronic criteria evaluated at the hardness of the river water. The effluent was assumed to partition at the same ratio of dissolved/total recoverable metals as the river at the mixing zone boundaries and after completely mixing with river water.

- The hardness for the outflow from Lake Coeur d'Alene was assumed to be 20 mg/L as $CaCO_3$. This represents the seasonal 10^{th} percentiles for the low flow (July-February) and high flow (March-June) seasons (Pelletier, 1994), and also the 5^{th} percentile of hardness from all seasons. Hardness was not found to be correlated with flow at the upstream end of the Spokane River (Appendix C).

- The hardness at river mile 85.3 and 66 was assumed to equal the 10% prediction limits from the regression equations with flow presented in Appendix C.

- The dissolved cadmium, lead, and zinc in the outlet of Lake Coeur d'Alene was assumed to equal the upper 90% prediction limit from the regression equations with flow presented in Appendix C for river mile 96-100.7.

- The dissolved cadmium, lead, and zinc at river mile 63.5-69.9 was assumed to equal the upper 90% prediction limit from the regression equations with flow presented in Appendix C.

Relationships between hardness, metals, and flow are known at various locations in the Spokane River based on long-term ambient monitoring data (Appendix C). The model was calibrated for hardness by starting with the known upstream hardness and trying various values for groundwater hardness until the mass balance model predicted the observed downstream hardness. After the hardness was calibrated, the same approach was used to estimate the dissolved cadmium, lead, and zinc of the aquifer/tributary inflow. Appendix C presents the results of model calibration of aquifer hardness and metals.

Model Application to Various Scenarios of Effluent and River Flows

The calibrated mass balance model was next used to estimate concentrations of metals in the river for a variety of river flows and effluent flows (Appendix D). The model was used to evaluate whether water quality standards would be violated in the river if the effluent meets end-of-pipe limits based on effluent hardness. The following assumptions were made:

- The hardness for the outflow from Lake Coeur d'Alene was assumed to equal 20 mg/L as $CaCO_3$.
- The dissolved cadmium, lead, and zinc in the outlet of Lake Coeur d'Alene were assumed to equal the chronic criteria for protection of aquatic life at the hardness of the river.
- The dissolved cadmium and zinc in the effluent from NPDES dischargers were assumed to equal the chronic criteria for protection of aquatic life for the hardness of the effluent (Figure 2).
- The ratio of dissolved/total recoverable cadmium and zinc was assumed to equal the conversion factor for the chronic criteria evaluated at the hardness of the effluent or river water. The ratio of dissolved/total recoverable metals in the effluent was used to test whether criteria were met in the effluent. The effluent was assumed to partition at the same ratio of dissolved/total recoverable metals as the river at the mixing zone boundaries and after completely mixing with river water.
- For lead, the convex shape of the criterion curve precludes the use of the conversion factor as a default translators to a total recoverable lead limit. Appendix E presents a spreadsheet illustrating the problem. Two hypothetical waters are mixed, and total recoverable lead is tracked. The use of the default translation causes the effluent to exceed the water quality criterion at certain dilutions. Therefore, the total recoverable lead in the effluent from NPDES dischargers was assumed to equal the value predicted from the tangent line for the chronic criteria for total recoverable lead shown in Figure 3. Appendix E presents a comparison of alternative methods for estimating the WLA for total recoverable lead.
- Aquifer inflow/outflow rates were estimated as presented in Table 2.

- Effluent hardness and aquifer hardness, dissolved cadmium, lead, and zinc were as estimated during calibration.

Various combinations of effluent and river flows were evaluated as follows:

- Current effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs.

- 20-year projected effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs (this scenario was run for zinc only because the conclusions for zinc were expected to be representative of cadmium and lead also).

- 50-year projected effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs (this scenario was run for zinc only because the conclusions for Zinc were expected to be representative of cadmium and lead also).

- 20-times current effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs. This scenario was chosen to show the potential effect of extremely high flow rates from NPDES dischargers.

The results of the model runs (Appendix D) show that the water quality standards for cadmium and zinc would not be exceeded in the river if the effluent meets end-of-pipe limits based on effluent hardness. The water quality criteria for lead would not be violated if the maximum concentration of total recoverable lead in the effluent does not exceed the value predicted from the tangent line for the equation for the chronic criteria for total recoverable lead shown in Figure 3. The relationship between effluent-based criteria and receiving water quality holds for all river and effluent flow rates.

Proposed TMDL Approach

Permit limits for all point source discharges to the Spokane River will be established by comparing potential limits based on meeting aquatic life criteria at effluent hardness with AKART limits based on maintaining existing concentrations of metals in effluent, where adequate data exist. Whichever method results in lower limits will be selected for the permit. AKART based limits would be reevaluated at each permit re-issuance. These limits may change over time, but could never exceed the aquatic life criteria based limits. This method should not result in any unreasonable compliance issues and minimizes the addition of metals to a system already exceeding the criteria due to pollutant loading from an upstream state. This is consistent with the intent of anti-degradation policy of the federal Clean Water Act and the policy enunciated in the Washington State Water Pollution Control Act (RCW 90.48) requiring "... all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state ...".

The use of effluent hardness in the criteria equations to determine the potential limits will be termed the "effluent-based criterion" approach. There are several ways to illustrate the effect of effluent hardness on river metals conditions. In simple terms, applying the effluent-based criterion is analogous to treating the effluent discharge as if it were a tributary that has higher hardness levels than the river. The tributary would be allowed to achieve less stringent (*i.e.*, higher) metals criteria by virtue of its elevated hardness levels. Similarly, the criteria applied to protect the mainstem would be more stringent due to its lower hardness levels. The focus of concern then becomes the point of mixing between the tributary and river.

The analogy to a tributary can be extended to selection of a load allocation (LA) for a tributary or a WLA for a point source. The LA for a tributary to a water quality-limited river would be the existing concentration in the tributary if it is lower than the criteria at the hardness of the tributary. Similarly, the permit limits for the NPDES dischargers will be either the potential limits based on meeting criteria at effluent hardness, or the potential limits based on maintaining existing concentrations (performance-based), whichever is more restrictive.

Waste load allocations (WLAs) are established as a maximum discharge concentration (micrograms per liter, or ug/L) rather than a discharge loading (pounds per day). TMDL regulations allow for the use of allocations in mass per time or "other appropriate measure" (40 CFR 130.2). In this case, a concentration measure is appropriate because the relationship between the effluent-based criterion and receiving water quality holds for all effluent flow rates. The use of effluent flow to establish a loading limit would not only be unnecessary, but also could be misconstrued to represent a restriction on effluent flow. Also, a loading limit could require unnecessary TMDL and permit modifications to change loading limits as communities grow and flows increase.

Waste Load Allocations (based on meeting the aquatic life criteria at effluent hardness)

For cadmium and zinc, potential limits based on aquatic life criteria for all point source discharges to the Spokane River are estimated from the water quality criteria associated with the effluent hardness. For lead, limits based on aquatic life criteria are estimated from the point on a line tangent to the lead criterion curve (intersecting the curve at the river hardness value) associated with the effluent hardness. Figure 4 shows the recommended equations for each metal.

The chronic aquatic life criteria are expressed as 4-day-average dissolved metal concentrations. The 5th percentile value of the effluent hardness for each facility should be used by permit writers to establish aquatic life criteria at effluent hardness for derivation of potential limits. Permit writers will also translate the dissolved criteria into total recoverable metal limitations pursuant to the NPDES regulations and Ecology's Permit Writer's Manual.

The hardness of the wastewater effluent is significantly higher than the hardness of the Spokane River. The metals criteria for protection of aquatic life are based on hardness, because the toxicity of metals to aquatic life decreases as hardness increases. Thus, as the Spokane River flows downstream, its loading capacity (its total maximum daily load) for metals increases due to inflows of higher hardness water (mainly groundwater and to a lesser extent effluent discharges). While the loading capacity changes are relatively minor on the Idaho stretch of the river, changes in river hardness and flow due to groundwater inflows and effluent discharges result in significant loading capacity increases in Washington.

Because of the concave shape (bending downward) of the cadmium and zinc criteria curves (Figure 2), any combination of cadmium, zinc, and hardness for the discharge that falls below the curve will mix with river water to form a mixture that also falls below the curve. Therefore, in this situation, the effluent-based criterion approach is protective of state water quality standards. However, for lead, the criterion curve is convex, or bending upward, leaving open the possibility that a mixture could exceed the criterion even when the waters individually fall below the criterion (a straight line between two points on the criterion curve will fall above the curve). If discharges do not exceed the lead concentration on the tangent line associated with the effluent hardness, the lead criterion will not be exceeded in the mixture of effluent and river water (Figure 3).

The criterion curve for lead also affects the options available for translating a dissolved lead WLA into a total recoverable lead WLA for NPDES permitting. This issue is discussed later in this document in the "Example Calculations" section.

Potential Limits (based on performance)

Washington State law (RCW 90.48) requires that dischargers use all known available and reasonable methods to prevent and control the pollution of the waters of the state (AKART). A performance-based assessment of existing condition in the effluent is a good measure of what can be reasonably achieved using the existing technology. Performance-based limits would be established using the statistical methods in Ecology's Permit Writer's Manual (Ecology, 1998) and EPA's Technical Support Document (EPA, 1991). These performance-based limits would be reevaluated during each permit re-issuance.

Since many dischargers do not have adequate data to estimate the effluent concentration of metals, a monitoring program will need to be established. Ecology's Permit Writer's Manual recommends that greater than 10 samples are required to estimate effluent variability. Therefore, the recommended minimum sampling frequency is monthly sampling for at least 12 months to provide sufficient data to estimate effluent quality of metals. The sampling and analysis methods should be conducted under a Quality Assurance/Quality Control Project Plan (QAPP) that describes the methods to be used. EPA's 1600-series methods (EPA, 1995) are recommended for sampling trace metal concentrations that are less than detection limits for the usual 40 CFR Part 136 methods, unless the QAPP demonstrates that alternative methods are sufficient the measure the expected concentrations.

Implementation of WLAs in NPDES Permits

The WLAs will be implemented as permit limits in the NPDES permits for each facility. Using statistical permitting procedures, Ecology will determine whichever potential limits are more restrictive based on comparison of:

- Potential limits based on meeting aquatic life criteria at effluent hardness, or

- Potential limits based on maintaining existing concentrations of metals in effluent (AKART), where adequate data exist.

Whichever method results in lower limits will be selected for the permit limit.

Example Calculations: WLAs for the Spokane AWTP

The following calculations are provided as an example of the waste load allocation method for each facility. The example calculation is performed for the City of Spokane Advanced Wastewater Treatment Plant (SAWTP). During permit development, similar calculations would be performed for each facility, based on the effluent hardness and metals data available to the permit writers.

A Microsoft Excel spreadsheet was developed to perform the calculations (Appendix F). The equations used in the spreadsheet are presented in Appendix G. Appendices F and G should be consulted to follow the calculations presented in this example.

The equations that were used in the spreadsheet to calculate permit limits were taken from the EPA Technical Support Document for Water Quality-based Toxics Control (EPA, 1991), and have been widely used in the Ecology NPDES program (Ecology, 1998; *e.g.*, Ecology's PWSPREAD and TSDCALC7 spreadsheets).

WLAs (based on meeting the aquatic life criteria at effluent hardness)

1. *Estimated 5th percentile hardness*

   SAWTP has collected 234 samples of effluent hardness between 6/25/96 and 2/18/98. The 5th percentile hardness for this sample set is estimated to be 138 mg/L.

2. *Chronic aquatic life criteria*

   The following calculations were performed to establish the chronic aquatic life criteria (ALC) for cadmium, lead, and zinc for the SAWTP facility.

- Chronic ALC for dissolved cadmium = (1.101672-[ln(hardness)(.041838)]) * ($e^{(.7852[\ln(hardness)]-3.49)}$) = 1.31 ug/L

- Chronic ALC for dissolved lead = 0.02378(hardness) - 0.05505 = 3.23 ug/L dissolved Lead

- Chronic ALC for dissolved zinc = $.986e^{(.8473[\ln(hardness)]+.7614)}$ = 137 ug/L

3. *Ratio of total recoverable/dissolved metals, and*

4. *Chronic aquatic life criteria for total recoverable metals*

For cadmium and zinc, default conversion factors in the federal criteria can be used to translate dissolved criteria to total recoverable metals. The conversion factors are 1/(1.101672-[ln(hardness)*(.041838)]) for cadmium, and 1/.986 for zinc. For the SAWTP facility, with a hardness of 138 mg/L $CaCO_3$, the default translators are 1.12 for cadmium and 1.01 for zinc.

Development of effluent-specific translators is also allowable, using parallel total recoverable and dissolved effluent samples to derive a conservative ratio of total recoverable-to-dissolved metals. Translators based on ratios in the river should be used if they are more restrictive than ratios for effluent.
The chronic aquatic life criteria, in terms of total recoverable cadmium and zinc, for the SAWTP example are as follows:

- Chronic ALC for total recoverable cadmium = 1.46 ug/L
- Chronic ALC for total recoverable zinc = 139 ug/L

For lead, the convex shape of the criterion curve precludes the use of the conversion factor as a default translator to a total recoverable lead limit. The use of the default translation causes the effluent to exceed the water quality criterion at certain dilutions (Appendix E).

As with cadmium and zinc, an effluent-specific translator is allowable. Development of this translator will require characterization of total recoverable and dissolved concentrations at a number of points between 0 and 100% effluent (diluted with ambient water, sampled at the same time) to ensure that the translator is protective of the dissolved criterion at all points of mixing.

Another option for developing total recoverable lead limits is to convert the dissolved criterion curve to the associated total recoverable criterion curve using the default conversion factor (see Figure 3). Then a tangent line to this curve at the river hardness value is used as the chronic aquatic life criterion for total recoverable lead, rather than using the dissolved criterion tangent (Figure 4) and an effluent-specific translator.

Using this approach and Figure 3 in the SAWTP example, the chronic aquatic life criterion for total recoverable Lead is:

- Chronic ALC for total recoverable lead = 3.49 ug/L total recoverable lead

5. *Number of samples (n2) required per month for compliance monitoring*

For the SAWTP example, 2 samples per month were assumed as a requirement for compliance monitoring. This number could be changed to any reasonable value between once per month and daily sampling.

6. *Coefficient of variation for effluent metals*

Effluent samples for metals were collected by SAWTP between 7/12/96 and 4/2/98. The coefficients of variation for cadmium, lead, and zinc were estimated from the 31 samples collected:

- CV for total recoverable cadmium = 0.431
- CV for total recoverable lead = 0.335
- CV for total recoverable zinc = 0.283

7. *Calculate maximum daily and average monthly permit limits from the aquatic life criteria*

The statistical method for calculating permit limits from the aquatic life criteria is presented in the EPA's Technical Support Document for Water Quality-based Toxics Control (EPA, 1991). A spreadsheet was developed to simplify the calculation procedure (Appendix F). Equations for the spreadsheet are presented in Appendix G.

The first step is to back-calculate a long-term average (LTA) concentration of metals that corresponds to the chronic aquatic life criteria (ALC). The LTAs for cadmium, lead, and zinc are as follows:

- LTA for total recoverable cadmium = 0.91 ug/L
- LTA for total recoverable lead = 2.4 ug/L
- LTA for total recoverable zinc = 101 ug/L

The next step is to calculate the maximum daily limit (MDL). The maximum daily limits (MDLs) for cadmium, lead, and zinc are as follows:

- MDL for total recoverable cadmium = 2.2 ug/L
- MDL for total recoverable lead = 4.9 ug/L
- MDL for total recoverable zinc = 186 ug/L

The last step is to calculate the average monthly limits (AML). The average monthly limits (AMLs) for cadmium, lead, and zinc are as follows:

- AML for total recoverable cadmium = 1.4 ug/L
- AML for total recoverable lead = 3.4 ug/L
- AML for total recoverable zinc = 138 ug/L

Potential Limits Based on Performance

A performance-based assessment of the existing condition in the effluent is a good measure of what can be reasonably achieved using the existing technology. Performance-based limits would be established using the statistical methods in Ecology's Permit Writer's Manual (Ecology, 1998) and EPA's Technical Support Document (EPA, 1991). This evaluation would occur during each permit re-issuance cycle and would be documented in the Fact Sheet. The Fact Sheet is the basis document for each permit. While these performance-based limits may change over time they could never exceed the aquatic life criteria based limits.

Since many dischargers do not have adequate data to estimate the effluent concentration of metals, a monitoring program will need to be established. Ecology's Permit Writer's Manual recommends that greater than 10 samples are required to estimate effluent variability. Therefore, the recommended minimum sampling frequency is monthly sampling for at least 12 months to provide sufficient data to estimate effluent quality of metals.

Waste Load Allocations (the most restrictive of limits based on aquatic life criteria or performance)

The last step is to assign permit limits in terms of maximum daily and average monthly limits for the NPDES permits. The potential limits based on steps I and II above will be compared, and the most restrictive values will be chosen. This would be documented in the Fact Sheet during each permit re-issuance cycle.

References

CH2M-Hill, 1997. Steady-state metal limit calculations Spokane AWTP. Technical Memorandum No. 2. Prepared by Jerry Bills and Dave Reynolds, CH2M-Hill, Seattle, WA. Prepared for Gale Olrich, City of Spokane. November 15, 1997.

CH2M-Hill, 1998. City of Spokane Wellhead Protection Program Phase I-Technical Assessment Report, Draft #3. CH2M-Hill. October, 1997

Ecology, 1998. Water Quality Program Permit Writer's Manual. Washington State Department of Ecology. Water Quality Program. Publication 92-109. Olympia, WA.

EPA, 1991. Technical Support Document for Water Quality-based Toxics Control. U.S. Environmental Protection Agency. Office of Water. EPA/505/2-90-001.

EPA, 1995. Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels. U.S. Environmental Protection Agency. Office of Water. EPA 821-R-95-034.

EPA, 1996. The metals translator: guidance for calculating a total recoverable permit limit from a dissolved criterion. U.S. Environmental Protection Agency. Office of Water. EPA 823-B-96-007.

Hopkins, B. and A. Johnson, 1997. Metals concentrations in the Spokane River during spring 1997. Technical Memorandum. From Brad Hopkins and Art Johnson, Department of Ecology, to Jay Manning, Office of the Attorney General, and Carl Nuechterlein, Department of Ecology. Washington State Department of Ecology, Olympia, WA. August 26, 1997.

IDEQ, 1998. Coeur d'Alene Lake-Spokane River Water Quality Assessments and Total Maximum Daily Load to Address Trace (Heavy) Metals Criteria Exceedences. Idaho Department of Environmental Quality. January 16, 1998.

Patmont, C. R., G. J. Pelletier, M. E. Harper, 1985. Phosphorus Attenuation in the Spokane River. Final Report, Contract No. C0084076. Washington State Department of Ecology, Olympia, WA.

Patmont, C. R., G. J. Pelletier, L. R. Singleton, R. A. Soltero, W. T. Trial, and E. B. Welch, 1987. The Spokane River: Allowable Phosphorus Loading. Final Report, Contract No. C0087074. Washington State Department of Ecology, Olympia, WA.

Pelletier, G. J., 1994. Cadmium, Copper, Mercury, Lead, and Zinc in the Spokane River: Comparisons with Water Quality Standards and Recommendations for Total Maximum Daily Loads. Publication #94-99.

SRDG, 1997. Proposed Zinc TMDL Approach for the Spokane River. December 11, 1997 Letter from Idaho and Washington Spokane River NPDES Dischargers to Chuck Clark, Regional Administrator, USEPA Region 10, c/o Sid Frederickson, Wastewater Utility Division, City of Coeur d'Alene, ID.

Figures

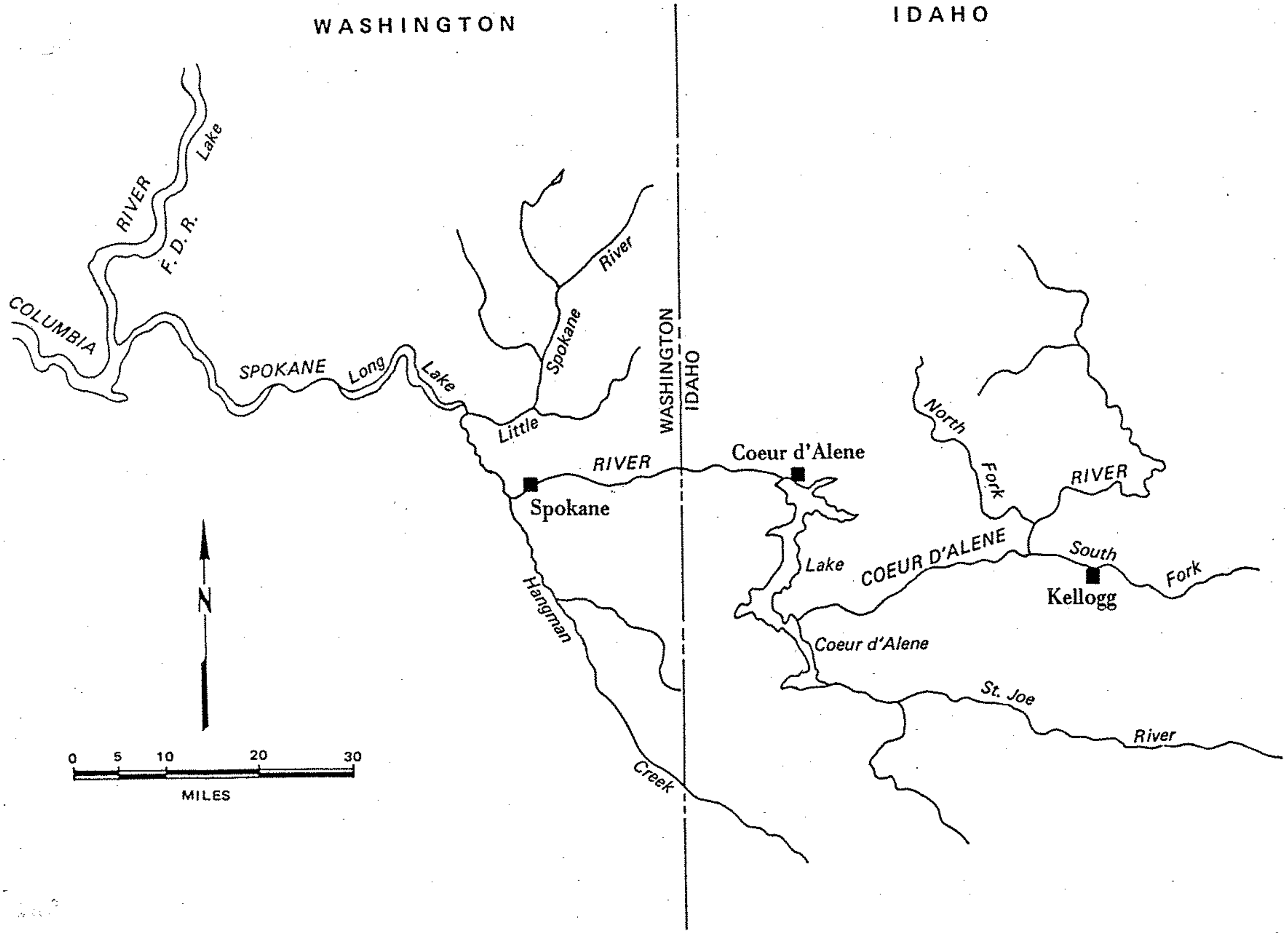


Figure 1. SPOKANE RIVER DRAINAGE SYSTEM

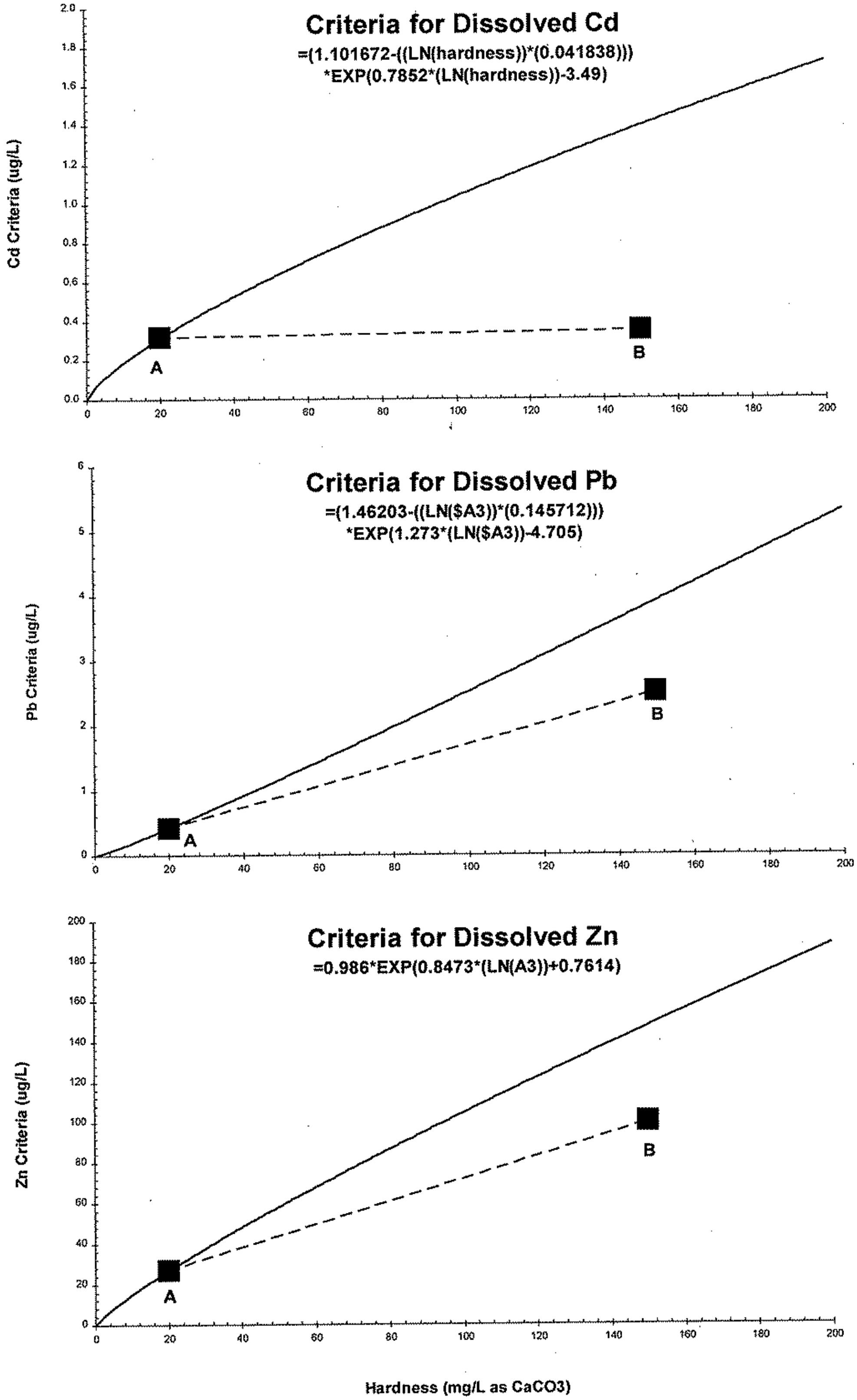


Figure 2. Chronic aquatic life criteria for dissolved Cd, Pb, and Zn.

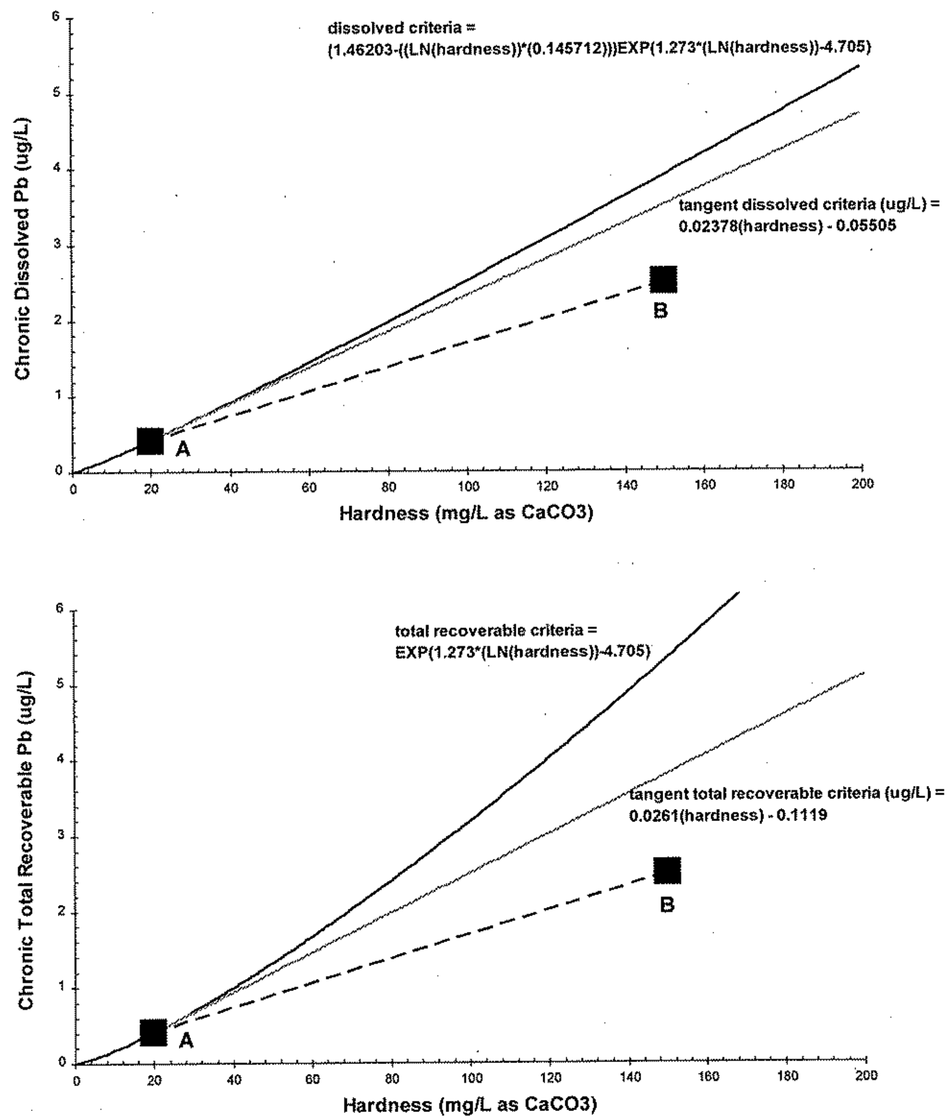


Figure 3. Chronic aquatic life criteria for dissolved Pb and total recoverable Pb (assuming the translator equals the conversion factor).

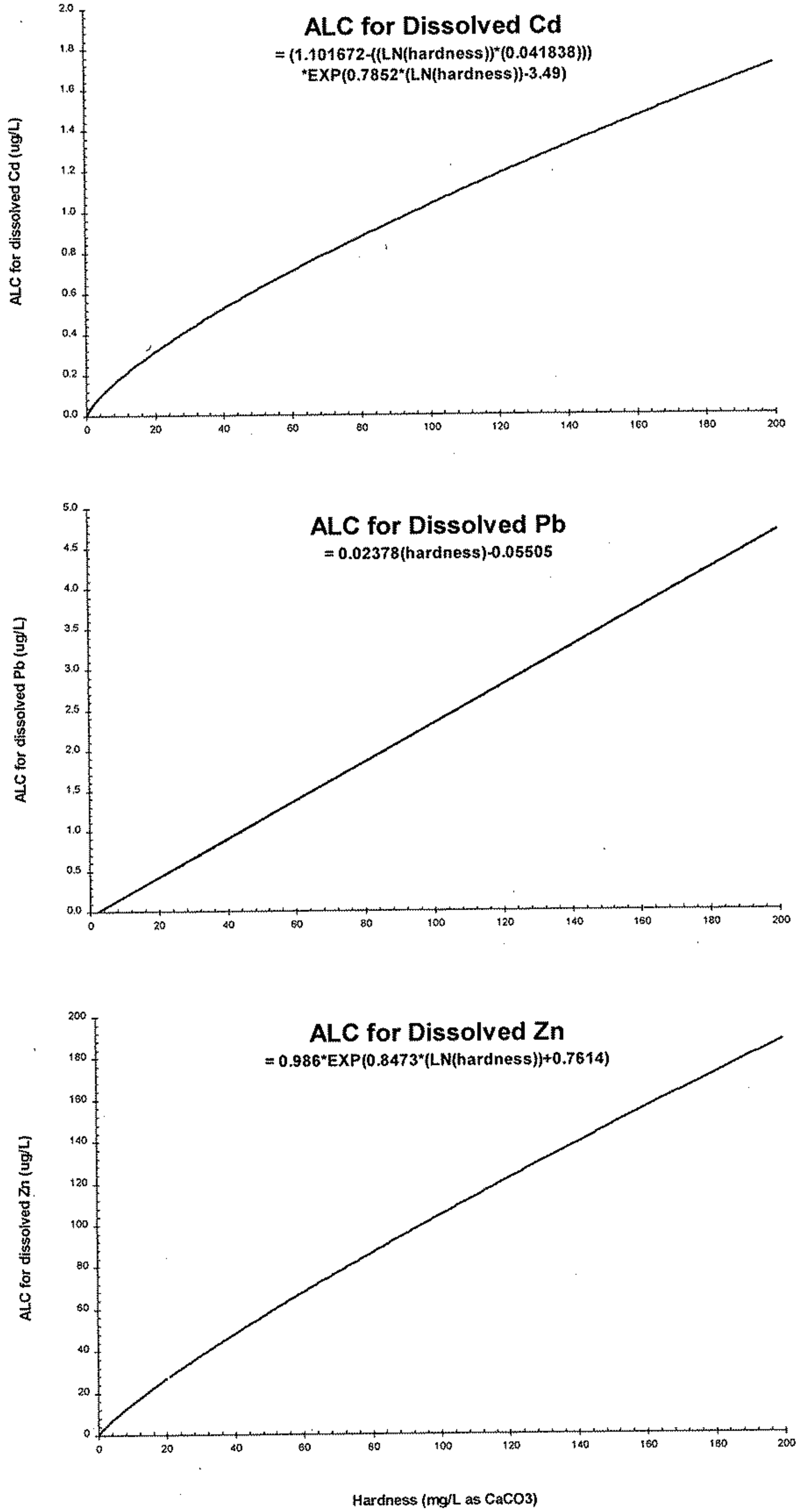


Figure 4. Recommended aquatic life criteria (ALC)
for effluent dissolved Cd, Pb, and Zn for calculation of permit limits.

Tables

Table 1. Current and projected future effluent design flows from NPDES dischargers to the Spokane River.

NPDES Discharger	Current mgd	Current cfs	20-Year Projection cfs	50-Year Projection cfs	20-Times Current (1) cfs
City of Coeur d'Alene AWTP	6	9.3	13	18	186
HARSB POTW	1.3	2.0	3.4	8.4	40
City of Post Falls (includes City of Rathdrum) POTW	3.1	4.8	6.3	21	96
Liberty Lake POTW	1	1.5	1.9	2.6	31
Kaiser Aluminum IWTP	23.3	36	45	54	72
Inland Empire Paper Company IWTP	4	6.2	7.7	9.3	12
City of Spokane AWTP	44	68	84	118	1362
Total:	83	128	161	231	1799

1) for "20-times current", the current flow rates from industrial dischargers were doubled instead of multiplying by 20 to provide and extreme worst-case for illustrative purposes.

Table 2. Estimated aquifer and tributary inflows and outflows at various scenarios of outflow from Lake Coeur d'Alene.

Spokane River Model Reach Number	Up-stream River Mile	Down-stream River Mile	Equation to Estimate Aquifer Inflow/Outflow from Lake Coeur d'Alene Outflow (cfs)	Inflow/ Outflow (cfs)	Inflow/ Outflow (cfs)	Inflow/ Outflow (cfs)
0	--	111.7	Lake Coeur d'Alene Outflow (Qcda):	300	2,000	20,000
1	111.7	106.6				
2	106.6	101.7				
3	101.7	96.0	*Aquifer Inflow/Outflow =37.46-(0.031367*Qcda)*	28	-25	-88
4	96.0	93.0	*Aquifer Inflow/Outflow =15.77-(0.013207*Qcda)*	12	-11	-37
5	93.0	90.4				
6	90.4	87.8				
7	87.8	85.3	*Aquifer Inflow =288.97+(0.048167*Qcda)*	303	385	482
8	85.3	82.6				
9	82.6	79.8	*Aquifer Inflow = -256.2*	-256	-256	-256
10	79.8	78.0	*Aquifer Inflow =338.54+(0.056428*Qcda)*	355	451	564
11	78.0	74.1	*Aquifer Outflow =-179.7*	-180	-180	-180
12	74.1	69.8	*Hangman Cr + Aquifer =3.3+(0.007237*Qcda)+135.53+(0.012548*Qcda)*	145	178	218
13	69.8	67.6	*Aquifer Inflow =42.75*	43	43	43
14	67.6	64.6	*Aquifer Inflow =58.3*	58	58	58
			Total net aquifer infow/outflow over all reaches:	**509**	**644**	**804**

Appendices

Appendix A

Derivation of the tangent equation for the chronic criteria for dissolved Lead

The tangent to the Lead criterion curve for any point can be found by taking the first derivative and evaluating it at that point. The numerical formula for the first derivative of the criterion curve at a hardness of 20 mg/L as CaCO3 is as follows using the symmetrical central difference approximation:

dy/dx = (f(x+h) - f(x-h)) / 2h

where:

y = chronic Lead criteria equation = f(x)
= (1.46203-((Ln(x))*(0.145712)))*EXP(1.273*(Ln(x))-4.705)
x = hardness (20 mg/L as CaCO3 for the critical river hardness)
h = small deviation in hardness (0.001 mg/L as CaCO3)
dy/dx = first derivative of the Lead criteria equation, which is the slope of the tangent equation

for x=20 and h=0.001, the first derivative is calculated from the following steps:

f(x+h) = (1.46203-((Ln(20.001))*(0.145712)))*EXP(1.273*(Ln(20.001))-4.705)
= 0.420554791
f(x-h) = (1.46203-((Ln(19.999))*(0.145712)))*EXP(1.273*(Ln(19.999))-4.705)
= 0.420507233
dy/dx = (f(x+h) - f(x-h)) / 2h
= (0.420554791 - 0.420507233) / (0.002)
= 0.023779
≅ 0.02378

Therefore, the slope of the tangent equation at a hardness of 20 mg/L is 0.02378. The intercept (b) for the equation for the tangent is calculated from the equation for a straight line:

y = x(dy/dx) + b

which can be rearranged to solved for the intercept b:

x = hardness (20 mg/L as CaCO3 for the critical river hardness)
y = (1.46203-((Ln(20))*(0.145712)))*EXP(1.273*(Ln(20))-4.705)
= 0.420531012
dy/dx = 0.023779
b = y - x(dy/dx)
= 0. 420531012 - 20(0.023779)
= -0.05505

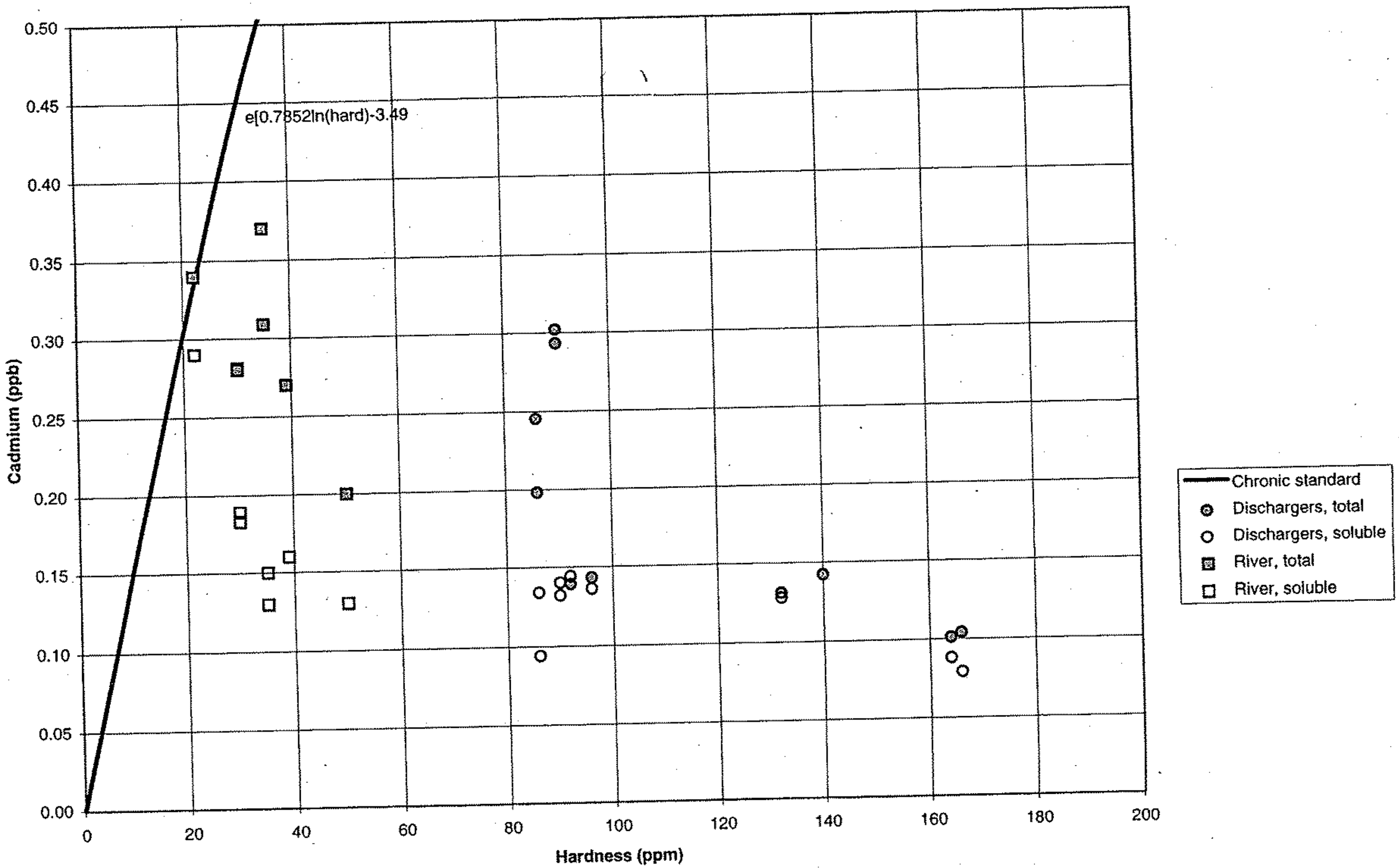
Appendix B

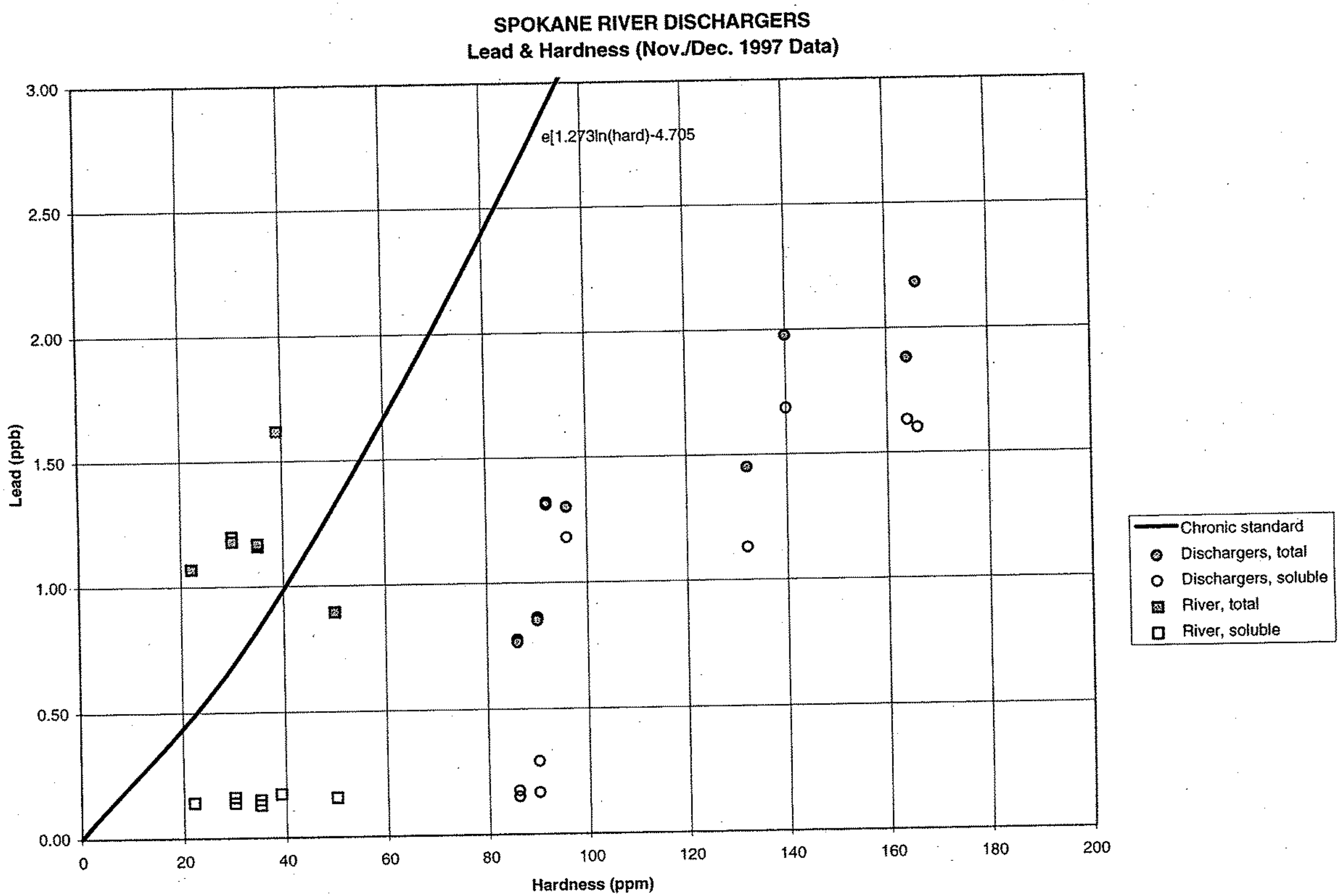
Spokane AWTP effluent dissolved and total recoverable metal data by Battelle (7/96 - 4/98)

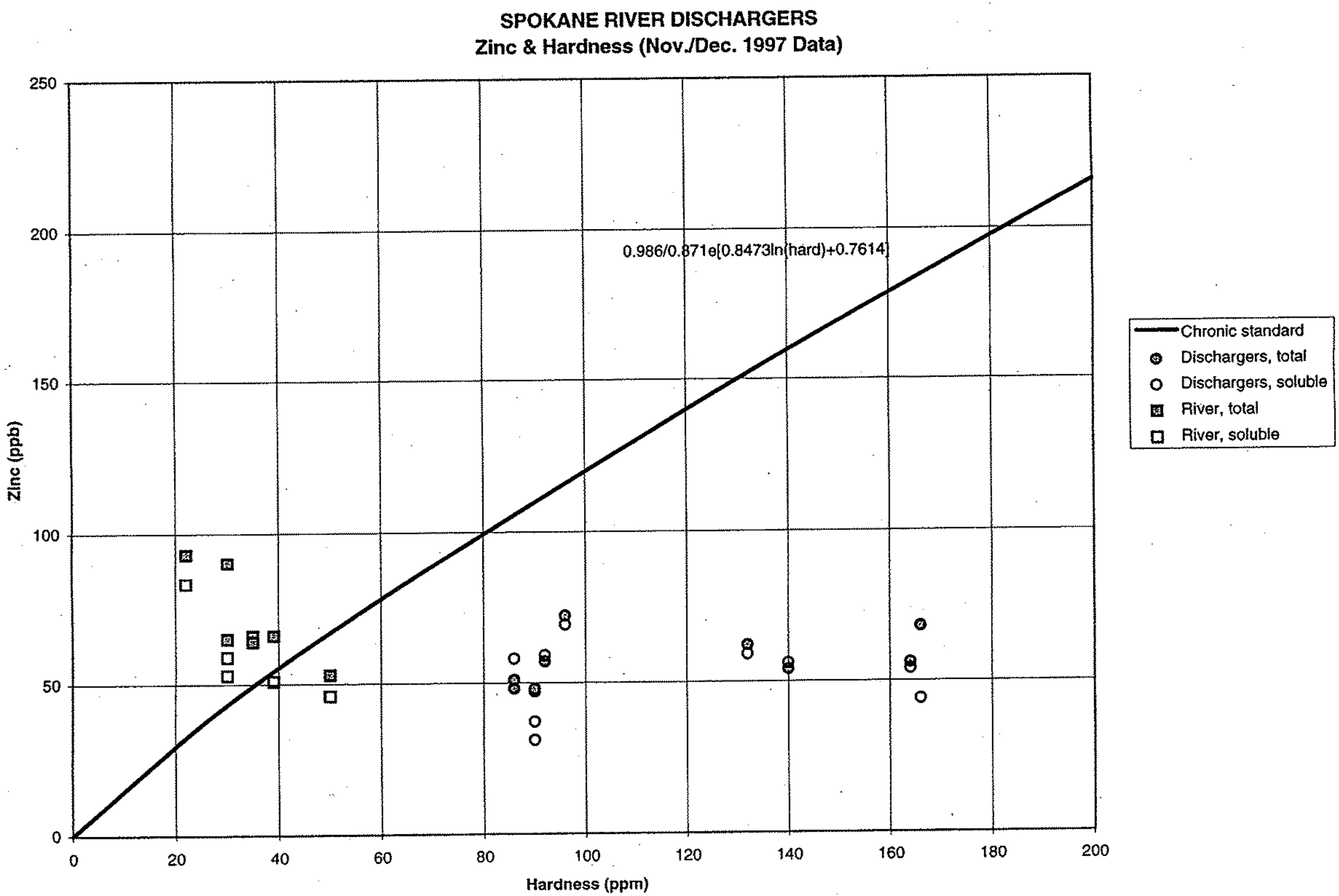
Date	Dissolved Metals						Total Recoverable Metals						Ratio of Diss/Total		
	Zn		Pb		Cd		Zn		Pb		Cd		Zn	Pb	Cd
	Concen-tration (ug/L)	Ln (Concen-tration)	Concen-tration (ug/L)	Ln (Concen-tration)	Concen-tration (ug/L)	Ln (Concen-tration)	Concen-tration (ug/L)	Ln (Concen-tration)	Concen-tration (ug/L)	Ln (Concen-tration)	Concen-tration (ug/L)	Ln (Concen-tration)			
7/12/96	42.2312	3.7431593	1.0994	0.0947646	0.0882	-2.4281483	41.9353	3.736128	1.2472	0.220901	0.0884	-2.4258833	1.000	0.881	0.998
7/19/96	35.1556	3.5597839	0.8897	-0.116871	0.0668	-2.7060522	38.8083	3.6586341	1.2254	0.2032673	0.0911	-2.3957975	0.906	0.726	0.733
7/26/96	35.7777	3.5773248	0.8637	-0.1465298	0.0804	-2.5207411	40.1882	3.6935734	1.12	0.1133287	0.0858	-2.4557363	0.890	0.771	0.937
8/12/96	27.6477	3.3195425	0.5602	-0.5794614	0.0614	-2.7903454	27.7292	3.322486	0.7302	-0.3144368	0.053	-2.9374634	0.997	0.767	1.000
8/19/96	23.1963	3.1439928	0.4731	-0.7484485	0.0372	-3.2914465	25.9452	3.2559866	0.6435	-0.4408333	0.053	U -3.6306105	0.894	0.735	
9/5/96	54.8	4.0036902	0.9654	-0.0352128	0.0542	-2.9150744	57.6135	4.0537569	1.3119	0.2714765	0.0623	-2.7757939	0.951	0.736	0.870
9/12/96	43.3733	3.769844	1.0302	0.029753	0.0845	-2.4710037	45.7439	3.8230584	1.4578	0.3769284	0.1016	-2.2867117	0.948	0.707	0.832
4/26/97	41.08	3.7155214	0.8132	-0.2067782	0.1155	-2.1584847	42.18	3.7419462	1.001	0.0009995	0.1268	-2.0651442	0.974	0.812	0.911
5/6/97	29.02	3.3679852	0.4684	-0.7584326	0.0543	-2.9132311	31.27	3.4426592	0.7466	-0.2922257	0.0638	-2.7520021	0.928	0.627	0.851
5/20/97	25.9883	3.2576464	0.3688	-0.9975008	0.0832	-2.4865079	29.7154	3.3916654	1.0898	0.0859942	0.0952	-2.3517753	0.875	0.338	0.874
6/3/97	31.015	3.434471	0.5942	-0.5205393	0.1168	-2.1472922	33.2076	3.5027788	0.8389	-0.1756638	0.121	-2.1119647	0.934	0.708	0.965
6/17/97	44.2646	3.7901853	0.8694	-0.139952	0.0713	-2.640859	49.1768	3.895422	1.0907	0.0868197	0.0826	-2.4937456	0.900	0.797	0.863
6/26/97	43.44	3.7713807	1.115	0.1088544	0.08209	-2.4999391	54.25	3.993603	1.393	0.3314597	0.09787	-2.3241152	0.801	0.800	0.839
7/8/97	52.94	3.9691592	0.9546	-0.0464629	0.09635	-2.3397679	54.28	3.9941558	1.073	0.0704585	0.09037	-2.4038429	0.975	0.890	1.000
7/22/97	35.37	3.565864	0.8901	-0.1164215	0.06532	-2.728457	36.88	3.6076694	1.127	0.1195592	0.0714	-2.6394574	0.959	0.790	0.915
8/7/97	37.6146	3.6273923	1.1348	0.1264564	0.0861	-2.4522459	35.5036	3.5696341	1.1473	0.1374114	0.0866	-2.4464555	1.000	0.989	0.994
8/19/97	31.3673	3.4457659	0.821	-0.1972322	0.0903	-2.4046178	44.0603	3.7855592	1.286	0.2515366	0.1401	-1.9653988	0.712	0.638	0.645
9/9/97	45.89	3.8262472	1.326	0.2821669	0.1281	-2.0549441	93.8	4.5411649	1.597	0.4681269	0.1225	-2.0996442	0.489	0.830	1.000
9/26/97	43.43	3.7711504	1.315	0.2738367	0.09242	-2.3814119	46.44	3.8381612	1.526	0.4226499	0.1072	-2.233059	0.935	0.862	0.862
10/10/97	49.03	3.8924324	1.531	0.4259211	0.1004	-2.2985931	50.36	3.9191972	1.889	0.6360476	0.1002	-2.3005871	0.974	0.810	1.000
10/24/97	46.94	3.8488702	1.258	0.2295232	0.1257	-2.0738572	49.77	3.9074124	1.47	0.3852624	0.1172	-2.1438734	0.943	0.856	1.000
11/21/97	54.14	3.9915733	1.627	0.4867378	0.08762	-2.434746	55.67	4.0194414	1.875	0.6286087	0.1008	-2.2946169	0.973	0.868	0.869
11/7/97	49.03	3.8924324	1.492	0.4001175	0.06841	-2.6822363	50.44	3.9207845	1.759	0.5647455	0.0909	-2.3979953	0.972	0.848	0.753
12/5/97	44.3	3.7909847	1.601	0.4706284	0.07472	-2.5940075	67.89	4.2178887	2.175	0.7770287	0.1037	-2.2662532	0.653	0.736	0.721
12/19/97	47.381	3.8582213	1.1157	0.109482	0.082	-2.501036	56.0879	4.0269201	1.3803	0.3223009	0.11	-2.2072749	0.845	0.808	0.745
1/9/98	55.1638	4.0103069	1.5945	0.4665602	0.1224	-2.1004609	60.266	4.0987681	1.9968	0.6915459	0.1473	-1.915284	0.915	0.799	0.831
1/30/98	41.8396	3.7338433	1.6225	0.4839682	0.2219	-1.5055284	49.209	3.8960765	2.5398	0.9320853	0.2338	-1.4532892	0.850	0.639	0.949
2/12/98	54.1045	3.9909174	1.8175	0.5974619	0.2359	-1.4443473	57.3717	4.0495512	2.478	0.9074518	0.2789	-1.276902	0.943	0.733	0.846
3/3/98	50.9	3.9298629	1.034	0.0334348	0.08676	-2.4446096	60.09	4.0958434	1.314	0.2730759	0.09799	-2.3228898	0.847	0.787	0.885
3/19/98	56.94	4.0419981	1.5	0.4054651	0.1368	-1.9892353	59.78	4.0906712	1.693	0.5265021	0.1752	-1.7418271	0.952	0.886	0.781
4/2/98	48.68	3.8852683	1.123	0.1160037	0.081	U -3.2064533	52.24	3.9558485	1.394	0.3321773	0.1202	-2.1185983	0.932	0.806	
Average	42.64679	3.726672	1.092529	0.017136	0.096067	-2.438893	48.31942	3.840208	1.406974	0.287567	0.11022	-2.297871	0.8989	0.7736	0.8782
Std Dev	9.374353	0.240658	0.385699	0.405220	0.042348	0.401821	13.65446	0.280317	0.471836	0.336450	0.047533	0.423974	0.1096	0.1137	0.0986
Variance	87.8785	0.057916	0.148764	0.164203	0.001793	0.161460	186.4444	0.078578	0.222629	0.113199	0.002259	0.179754	0.0120	0.0129	0.0097
CV	0.219814		0.353033		0.44082		0.282587		0.335355		0.431251		0.1219	0.1470	0.1123
n	31		31		31		31		31		31		31	31	29
rank 90%	54.14		1.601		0.1281		60.09		1.9968		0.1473		0.975	0.881	1.000
max	56.94		1.8175		0.2359		93.8		2.5398		0.2789		1.000	0.989	1.000
Log normal															
99.9%tile	87.39		3.56		0.30		110.66		3.77		0.37				
99%tile	72.71		2.61		0.22		89.33		2.92		0.27				
95%tile	61.72		1.98		0.17		73.80		2.32		0.20				
90%tile	56.55		1.71		0.15		66.65		2.05		0.17				
Arcsin sqrt															
99.9%tile													1.0000	0.9971	1.0000
99%tile													1.0000	0.9744	1.0000
95%tile													0.9999	0.9361	1.0000
90%tile													0.9951	0.9092	0.9964

revised Spokane awtp hardness.xls\AppB- SAWTP metals, 6/1/98

SPOKANE RIVER DISCHARGERS
Cadmium & Hardness (Nov./Dec. 1997 Data)




SPOKANE RIVER DISCHARGERS
Lead & Hardness (Nov./Dec. 1997 Data)
e[1.273ln(hard)-4.705
Lead (ppb)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
120
140
160
180
200
Hardness (ppm)
Chronic standard
Dischargers, total
Dischargers, soluble
River, total
River, soluble


SPOKANE RIVER DISCHARGERS
Zinc & Hardness (Nov./Dec. 1997 Data)
0.986/0.871e[0.8473ln(hard)+0.7614]
Zinc (ppb)
250
200
150
100
50
0
Hardness (ppm)
0
20
40
60
80
100
120
140
160
180
200
Chronic standard
Dischargers, total
Dischargers, soluble
River, total
River, soluble

SPOKANE RIVER DISCHARGERS
OUTFALL CADMIUM & HARDNESS CONCENTRATIONS

CHRONIC STANDARD

HARD (PPM)	CAD STND. (PPB)
0.001	0.00
30	0.44
60	0.76
90	1.04
120	1.31
150	1.56
180	1.80
200	1.95

DATE	OUTFALL	OUTFALL CONC.		RIVER CONC.		FILTERED?
		CADMIUM (PPB)	HARDNESS (PPM)	CADMIUM (PPB)	HARDNESS (PPM)	
11/21/97	SPK	0.101	164	0.20	50	NO
	SPK	0.088	164	0.13	50	YES
12/5/97	SPK	0.104	166	0.27	39	NO
	SPK	0.079	166	0.16	39	YES
12/9/97	CDA	0.142	140	0.34	22	NO
	CDA	0.142	140	0.29	22	YES
	KAI	0.198	86	0.281	30	NO
	KAI	0.245	86	0.28	30	NO
	KAI	0.134	86	0.189	30	YES
	KAI	0.094	86	0.183	30	YES
12/12/97	KAI	0.14	90	0.13	35	YES
	KAI	0.132	90	0.15	35	YES
	KAI	0.293	90	0.37	35	NO
	KAI	0.302	90	0.309	35	NO
12/18/97	CDA	0.131	132			NO
	CDA	0.128	132			YES
	HAY	0.139	92			NO
	HAY	0.144	92			YES
	POST	0.143	96			NO
	POST	0.136	96			YES

SPOKANE RIVER DISCHARGERS
OUTFALL LEAD & HARDNESS CONCENTRATIONS

CHRONIC STANDARD

HARD (PPM)	LEAD STND. (PPB)
0.001	0.00
30	0.69
60	1.66
90	2.78
120	4.01
150	5.33
180	6.72
200	7.69

DATE	OUTFALL	OUTFALL CONC. LEAD (PPB)	OUTFALL CONC. HARDNESS (PPM)	RIVER CONC. LEAD (PPB)	RIVER CONC. HARDNESS (PPM)	FILTERED?
11/21/97	SPK	1.88	164	0.894	50	NO
	SPK	1.63	164	0.156	50	YES
12/5/97	SPK	2.18	166	1.62	39	NO
	SPK	1.6	166	0.173	39	YES
12/9/97	CDA	1.975	140	1.07	22	NO
	CDA	1.684	140	0.141	22	YES
	KAI	0.775	86	1.2	30	NO
	KAI	0.764	86	1.18	30	NO
	KAI	0.173	86	0.161	30	YES
	KAI	0.149	86	0.139	30	YES
12/12/97	KAI	0.291	90	0.13	35	YES
	KAI	0.165	90	0.15	35	YES
	KAI	0.861	90	1.16	35	NO
	KAI	0.849	90	1.17	35	NO
12/18/97	CDA	1.45	132			NO
	CDA	1.13	132			YES
	HAY	1.32	92			NO
	HAY	1.31	92			YES
	POST	1.3	96			NO
	POST	1.18	96			YES

SPOKANE RIVER DISCHARGERS
OUTFALL ZINC & HARDNESS CONCENTRATIONS

CHRONIC STANDARD

HARD (PPM)	Zn STND. (PPB)
0.001	0
30	43
60	78
90	110
120	140
150	169
180	197
200	216

DATE	OUTFALL	OUTFALL CONC. ZINC (PPB)	OUTFALL CONC. HARDNESS (PPM)	RIVER CONC. ZINC (PPB)	RIVER CONC. HARDNESS (PPM)	FILTERED?
11/21/97	SPK	56	164	53	50	NO
	SPK	54	164	46	50	YES
12/5/97	SPK	68	166	66	39	NO
	SPK	44	166	51	39	YES
12/9/97	CDA	54	140	93	22	NO
	CDA	56	140	83	22	YES
	KAI	51	86	65	30	NO
	KAI	48	86	90	30	NO
	KAI	51	86	53	30	YES
	KAI	58	86	59	30	YES
12/12/97	KAI	37	90	64	35	YES
	KAI	31	90	64	35	YES
	KAI	47	90	66	35	NO
	KAI	48	90	64	35	NO
12/18/97	CDA	62	132			NO
	CDA	59	132			YES
	HAY	57	92			NO
	HAY	59	92			YES
	POST	72	96			NO
	POST	69	96			YES

Appendix C.1

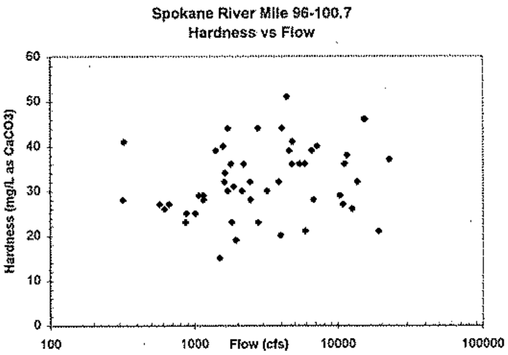
Hardness data and relationship with flow
(Pelletier, 1994)

Appendix C1. Hardness data from the Spokane River near Stateline and Post Falls (RM 96-100.7) (Pelletier, 1994).

```
Spokane River 96-100.7, Hardness (mg/L as CaCO3), 1983-94
 FILE = hard8394.txt   Column = 1

 RESULTS:

          Number of data .........          92
             .... Conf Limit (U) ..     31.4158
          Mean ... (95% CI) ......      29.4348
             .... Conf Limit (L) ..     27.4538
          Std Err Mean ...........       0.9973
          Std Deviation ..........       9.5656
          Coef of Variation ......       0.3250
          Coef of Skewness .......       2.3469
          n-Kurtosis .............      10.4564
          Geom Mean ..............      28.2261
          Maximum ................      84.0000
          0.950 perc .............      44.7000
          Median .................      27.0000
          0.050 perc .............      20.0000
          Minimum ................      15.0000
          IQR ....................      13.0000
             .... Conf Limit (U) ..     28.9108
          Trim. Mean (2x10%) .....      28.3243
             .... Conf Limit (L) ..     27.7379
          Trim Mean Std Err ......       0.8652
          Wins. Mean (2x10%) .....      28.7500
          Winsored Std Dev .......       8.2928
          Tukey Trimean ..........      28.2500
          MedAD*1.483 ............       6.6735
          MnAD*1.483 .............       9.5428
```



Station	River Mile	Date	Time	Hardness (mg/L as CaCO3)	Flow (cfs)
57A190	100.7	26-Oct-83	920	19	1960
57A190	100.7	30-Nov-83	910	39	4620
57A190	100.7	21-Dec-83	800	36	4820
57A190	100.7	18-Jan-84	730	36	5440
57A190	100.7	08-Feb-84	715	28	6820
57A190	100.7	07-Mar-84	750	36	5900
57A190	100.7	11-Apr-84	825	36	11200
57A190	100.7	09-May-84	840	84	11200
57A190	100.7	13-Jun-84	820	46	15300
57A190	100.7	11-Jul-84	815	32	2460
57A190	100.7	15-Aug-84	815	27	670
57A190	100.7	12-Sep-84	830	44	1730
57A190	100.7	10-Oct-84	855	36	1810
57A190	100.7	14-Nov-84	910	44	2780
57A190	100.7	12-Dec-84	840	44	4100
57A190	100.7	16-Jan-85	905	32	1630
57A190	100.7	06-Feb-85	850	40	1600
57A190	100.7	13-Mar-85	830	36	2220
57A190	100.7	03-Apr-85	655	40	7240
57A190	100.7	08-May-85	825	21	19300
57A190	100.7	12-Jun-85	835	999999	16300
57A190	100.7	14-Aug-85	810	23	873
57A190	100.7	18-Sep-85	805	999999	2240
57A190	100.7	23-Oct-85	810	23	1830
57A190	100.7	20-Nov-85	830	51	4440
57A190	100.7	11-Dec-85	815	999999	4110
57A190	100.7	15-Jan-86	805	34	1650
57A190	100.7	12-Feb-86	835	39	6620
57A190	100.7	12-Mar-86	810	37	22900
57A190	100.7	16-Apr-86	815	26	12600
57A190	100.7	14-May-86	810	999999	9070
57A190	100.7	11-Jun-86	830	20	4000
57A190	100.7	09-Jul-86	755	39	1420
57A190	100.7	13-Aug-86	715	41	325
57A190	100.7	10-Sep-86	730	28	320
57A190	100.7	22-Oct-86	830	999999	2310
57A190	100.7	05-Nov-86	735	999999	2960
57A190	100.7	10-Dec-86	730	32	3890
57A190	100.7	14-Jan-87	800	28	2470
57A190	100.7	11-Feb-87	730	23	2800
57A190	100.7	18-Mar-87	820	32	13700
57A190	100.7	15-Apr-87	705	38	11600
57A190	100.7	06-May-87	800	46	15500
57A190	100.7	03-Jun-87	650	30	3230
57A190	100.7	08-Jul-87	735	31	1900
57A190	100.7	05-Aug-87	740	27	576
57A190	100.7	09-Sep-87	800	29	1160
57A190	100.7	07-Oct-87	730	25	884
57A190	100.7	04-Nov-87	745	28	1160
57A190	100.7	09-Dec-87	740	30	2160
57A190	100.7	13-Jan-88	745	30	1720
57A190	100.7	03-Feb-88	735	15	1510
57A190	100.7	09-Mar-88	740	41	4860
57A190	100.7	06-Apr-88	610	27	10900
57A190	100.7	04-May-88	645	29	10400
57A190	100.7	08-Jun-88	710	21	5960
57A190	100.7	06-Jul-88	715	25	1020
57A190	100.7	03-Aug-88	720	26	621
57A190	100.7	14-Sep-88	705	29	1080
57A190	100.7	05-Oct-88	720	29	1080

Station	River Mile	Date	Time	Hardness (mg/L as CaCO3)	Flow (cfs)
57A190	100.7	08-Nov-88	720	28	2180
57A190	100.7	07-Dec-88	715	20	4060
57A190	100.7	04-Jan-89	705	30	2920
57A190	100.7	08-Feb-89	720	26	2610
57A190	100.7	08-Mar-89	735	37	2030
57A190	100.7	05-Apr-89	725	25	12700
57A190	100.7	03-May-89	715	25	21300
57A190	100.7	07-Jun-89	800	27	11900
57A190	100.7	06-Jul-89	715	31	11700
57A190	100.7	09-Aug-89	720	38	477
57A190	100.7	06-Sep-89	735	23	1120
57A190	100.7	04-Oct-89	715	24	1910
57A190	100.7	08-Nov-89	705	22	2140
57A190	100.7	06-Dec-89	720	30	11300
57A190	100.7	10-Jan-90	735	25	9800
57A190	100.7	07-Feb-90	735	24	5240
57A190	100.7	07-Mar-90	720	25	7500
57A190	100.7	04-Apr-90	750	24	14400
57A190	100.7	09-May-90	735	20	16400
57A190	100.7	06-Jun-90	730	17	24100
57A190	100.7	11-Jul-90	710	21	2480
57A190	100.7	08-Aug-90	745	24	695
57A190	100.7	05-Sep-90	655	23	395
57A190	100.7	10-Oct-90	725	23	1470
57A190	100.7	07-Nov-90	720	23	2980
57A150	96.0	05-Dec-90	720	24	15600
57A150	96.0	09-Jan-91	730	23	4500
57A150	96.0	06-Feb-91	710	23	5730
57A150	96.0	06-Mar-91	700	23	17100
57A150	96.0	03-Apr-91	710	23	6840
57A150	96.0	08-May-91	720	22	13000
57A150	96.0	05-Jun-91	645	23	13500
57A150	96.0	10-Jul-91	700	20	4550
57A150	96.0	07-Aug-91	645	20	1950
57A150	96.0	04-Sep-91	705	21	749
57A150	96.0	09-Oct-91	705	999999	1910
57A150	96.0	06-Nov-91	710	20	2150
57A150	96.0	04-Dec-91	710	21	2600
57A150	96.0	08-Jan-92	710	999999	3030
57A150	96.0	05-Feb-92	715	22	6810
57A150	96.0	04-Mar-92	645	999999	10400
57A150	96.0	08-Apr-92	645	999999	6890
57A150	96.0	06-May-92	630	999999	5050
57A150	96.0	03-Jun-92	635	999999	2530
57A150	96.0	08-Jul-92	640	999999	1150
57A150	96.0	05-Aug-92	610	999999	647
57A150	96.0	10-Sep-92	640	999999	237
57A150	96.0	07-Oct-92	700	999999	1440
57A150	96.0	04-Nov-92	643	999999	2030
57A150	96.0	03-Dec-92	730	999999	3260
57A150	96.0	06-Jan-93	750	999999	2070
57A150	96.0	03-Feb-93	700	999999	2280
57A150	96.0	03-Mar-93	620	999999	1820
57A150	96.0	07-Apr-93	645	999999	18000
57A150	96.0	05-May-93	730	999999	18600
57A150	96.0	09-Jun-93	805	999999	5700
57A150	96.0	07-Jul-93	700	999999	4050
57A150	96.0	04-Aug-93	710	999999	1230
57A150	96.0	08-Sep-93	710	999999	1160

Regression of hardness and flow for station 54A120 (HARDREGR.WK1, 07-Apr-94)

(RM66)

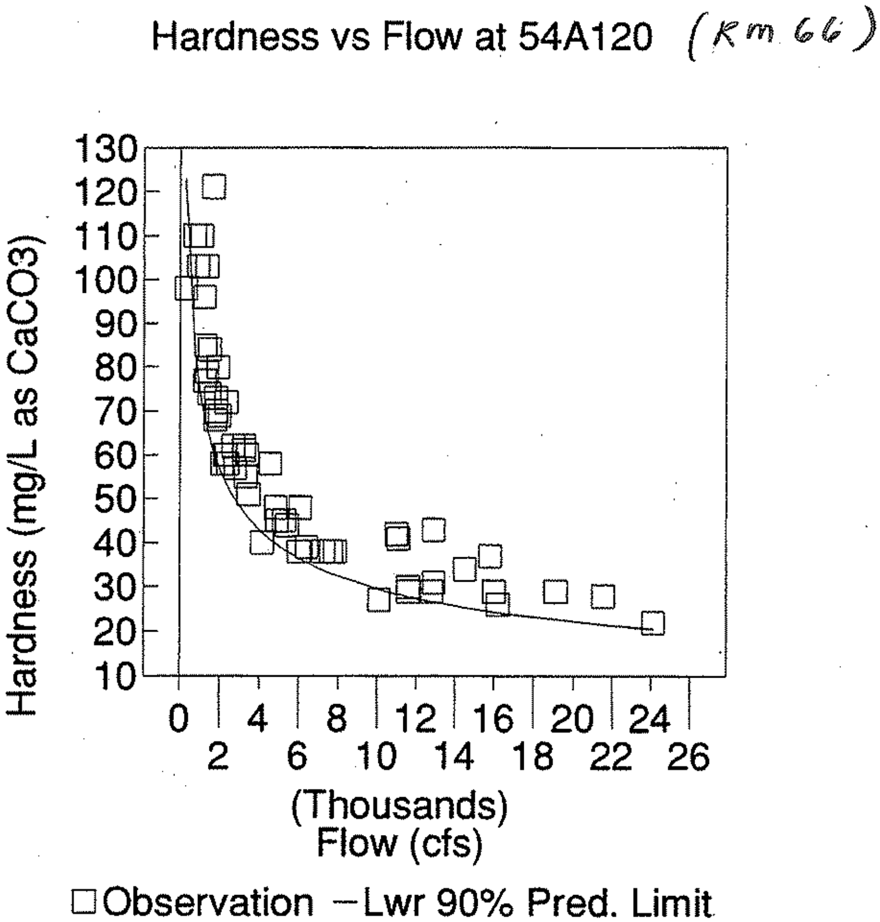
Data from Oct-83 to Sep-93 sorted by flow	Log base 10 [Flow (cfs)] Xi	Log base 10 [Hardness (mg/L as $CaCO_3$)] Yi	XiYi	Xi^2	Yi^2
	2.480006	1.991226	4.938254	6.150434	3.964981
	2.875061	2.041392	5.869129	8.265977	4.167284
	2.963315	2.012837	5.964671	8.781238	4.051513
	3.041392	2.041392	6.208676	9.250069	4.167284
	3.096910	1.982271	6.138915	9.590851	3.929399
	3.103803	1.886490	5.855296	9.633597	3.558847
	3.107209	1.929418	5.995109	9.654753	3.722657
	3.133538	2.012837	6.307303	9.819066	4.051513
	3.136720	1.897627	5.952325	9.839015	3.600988
	3.173186	1.869231	5.931420	10.06911	3.494027
	3.176091	1.924279	6.111686	10.08755	3.702850
	3.225309	2.082785	6.717626	10.40261	4.337994
	3.255272	1.832508	5.965315	10.59679	3.358088
	3.260071	1.863322	6.074565	10.62806	3.471972
	3.271841	1.845098	6.036868	10.70494	3.404386
	3.287801	1.903089	6.256982	10.80964	3.621751
	3.303196	1.838849	6.074079	10.91110	3.381365
	3.330413	1.763427	5.872944	11.09165	3.109678
	3.359835	1.778151	5.974295	11.28849	3.161821
	3.369215	1.778151	5.990975	11.35161	3.161821
	3.372912	1.857332	6.264619	11.37653	3.449684
	3.385606	1.763427	5.970272	11.46232	3.109678
	3.432969	1.792391	6.153225	11.78527	3.212667
	3.445604	1.755874	6.050049	11.87218	3.083096
	3.510545	1.785329	6.267480	12.32392	3.187402
	3.513217	1.792391	6.297062	12.34269	3.212667
	3.523746	1.740362	6.132596	12.41678	3.028862
	3.530199	1.778151	6.277229	12.46230	3.161821
	3.541579	1.707570	6.047495	12.54278	2.915795
	3.618048	1.602059	5.796330	13.09027	2.566596
	3.659916	1.763427	6.453998	13.39498	3.109678
	3.683947	1.681241	6.193603	13.57146	2.826572
	3.690196	1.653212	6.100678	13.61754	2.733111
	3.722633	1.653212	6.154304	13.85800	2.733111
	3.732393	1.643452	6.134012	13.93076	2.700936
	3.778151	1.579783	5.968661	14.27442	2.495716
	3.783903	1.681241	6.361654	14.31792	2.826572
	3.806858	1.591064	6.056957	14.49216	2.531486
	3.860338	1.579783	6.098498	14.90220	2.495716
	3.883661	1.579783	6.135344	15.08282	2.495716
	3.894869	1.579783	6.153051	15.17000	2.495716
	4.004321	1.431363	5.731640	16.03458	2.048802
	4.041392	1.623249	6.560187	16.33285	2.634938
	4.045322	1.612783	6.524231	16.36463	2.601071
	4.064457	1.477121	6.003697	16.51981	2.181887
	4.064457	1.462397	5.943855	16.51981	2.138607
	4.107209	1.462397	6.006375	16.86917	2.138607
	4.110589	1.633468	6.714518	16.89694	2.668219
	4.110589	1.491361	6.130376	16.89694	2.224159
	4.161368	1.531478	6.373047	17.31698	2.345427
	4.198657	1.568201	6.584341	17.62872	2.459256
	4.204119	1.462397	6.148096	17.67462	2.138607
	4.209515	1.414973	5.956351	17.72001	2.002149
	4.281033	1.462397	6.260574	18.32724	2.138607
	4.332438	1.447158	6.269723	18.77002	2.094266
	4.382017	1.342422	5.882519	19.20207	1.802098
SUM :	201.6389	96.25844	342.3931	736.2885	167.4095
N :	56				
MEAN :	3.600696	1.718900			

Regression of hardness and flow for station 54A120 (HARDREGR.WK1, 07-Apr-94)

SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE
TOTAL	1.950829	55	
LINEAR REGRESSION	1.724865	1	1.7248654
RESIDUAL	0.225963	54	0.0041845

Slope (B):	-0.41026
Y intercept:	3.196130
R squared:	0.884170
F Statistic:	412.2020
Std Err of B:	0.020207
Std Err of Y estimate:	0.064687

Plot of observed hardness and lower 90% confidence limit of predicted hardness (using 1-tailed t-statistic, probability=0.10) at Station 54A120



Comparison of hardness at Ecology
stations 54A120 and 57A145, WY 1973 (sorted by 54A120)
File HARDHARD.WK1
06-Apr-94

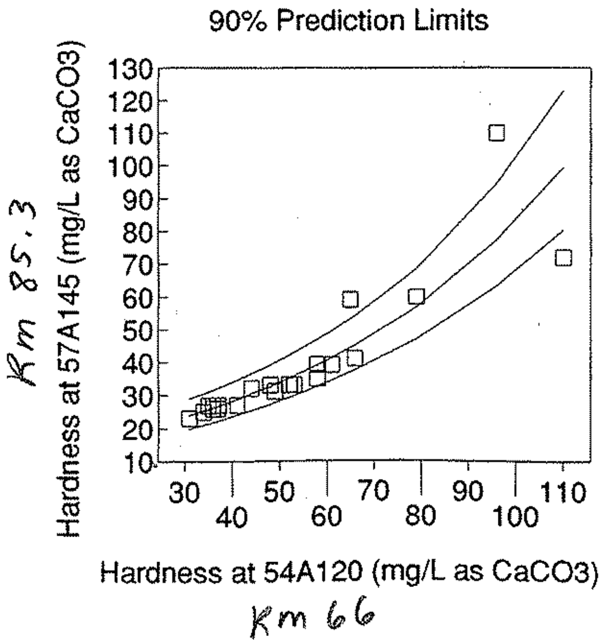
Date	Hardness (mg/L as CaCO3) at 54A120	Hardness (mg/L as CaCO3) at 57A145
	Rm 66	Rm 85.3
730424	31	23
721227	34	25
730327	35	27
730410	36	27
730313	36	26
721212	36	26
730320	37	26
730118	37	27
730612	41	27
730222	44	32
730925	48	33
730227	49	31
730626	52	33
730912	53	33
721010	58	35
721119	58	39
721031	61	39
730711	65	59
721129	66	41
730821	79	60
730724	96	110
730807	110	72

Regression of hardness at station 57A145 vs 54A120 (HARDREG2.WK1)

Data from Oct-72 to Sep-73 sorted by 54A120	Hardness (mg/L as CaCO3) @ 54A120 (RM 66.0) Xi	Log base 10 [Hardness (mg/L as CaCO3)] @ 57A145 (RM 85.3) Yi	XiYi	Xi^2	Yi^2
	31	1.361727	42.21356	961	1.854302
	34	1.397940	47.52996	1156	1.954236
	35	1.431363	50.09773	1225	2.048802
	36	1.431363	51.52909	1296	2.048802
	36	1.414973	50.93904	1296	2.002149
	36	1.414973	50.93904	1296	2.002149
	37	1.414973	52.35401	1369	2.002149
	37	1.431363	52.96045	1369	2.048802
	41	1.431363	58.68591	1681	2.048802
	44	1.505149	66.22659	1936	2.265476
	48	1.518513	72.88866	2304	2.305884
	49	1.491361	73.07672	2401	2.224159
	52	1.518513	78.96272	2704	2.305884
	53	1.518513	80.48123	2809	2.305884
	58	1.544068	89.55594	3364	2.384146
	58	1.591064	92.28174	3364	2.531486
	61	1.591064	97.05494	3721	2.531486
	65	1.770852	115.1053	4225	3.135916
	66	1.612783	106.4437	4356	2.601071
	79	1.778151	140.4739	6241	3.161821
	96	2.041392	195.9736	9216	4.167284
	110	1.857332	204.3065	12100	3.449684
SUM :	1162	34.06880	1870.080	70390	53.38038
N :	22				
MEAN :	52.81818	1.548582			

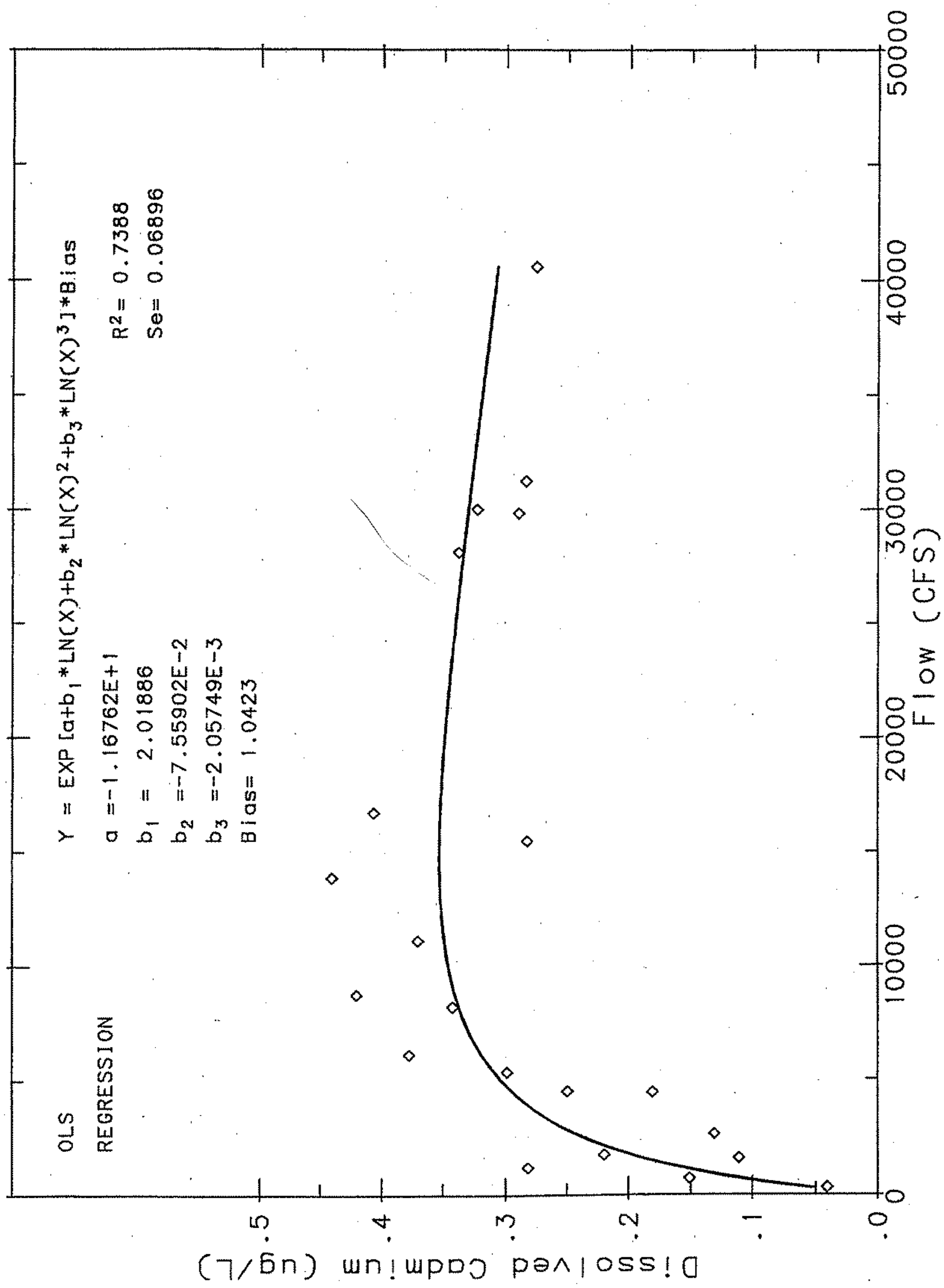
SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE
TOTAL	0.622041	21	
LINEAR REGRESSION	0.553323	1	0.553323
RESIDUAL	0.068717	20	0.003435

Slope (B):	0.007834
Y-Intercept:	1.134788
R squared:	0.889528
F Statistic:	161.0423
Std Err of B:	0.000617
Std Err of Y estimate:	0.058616

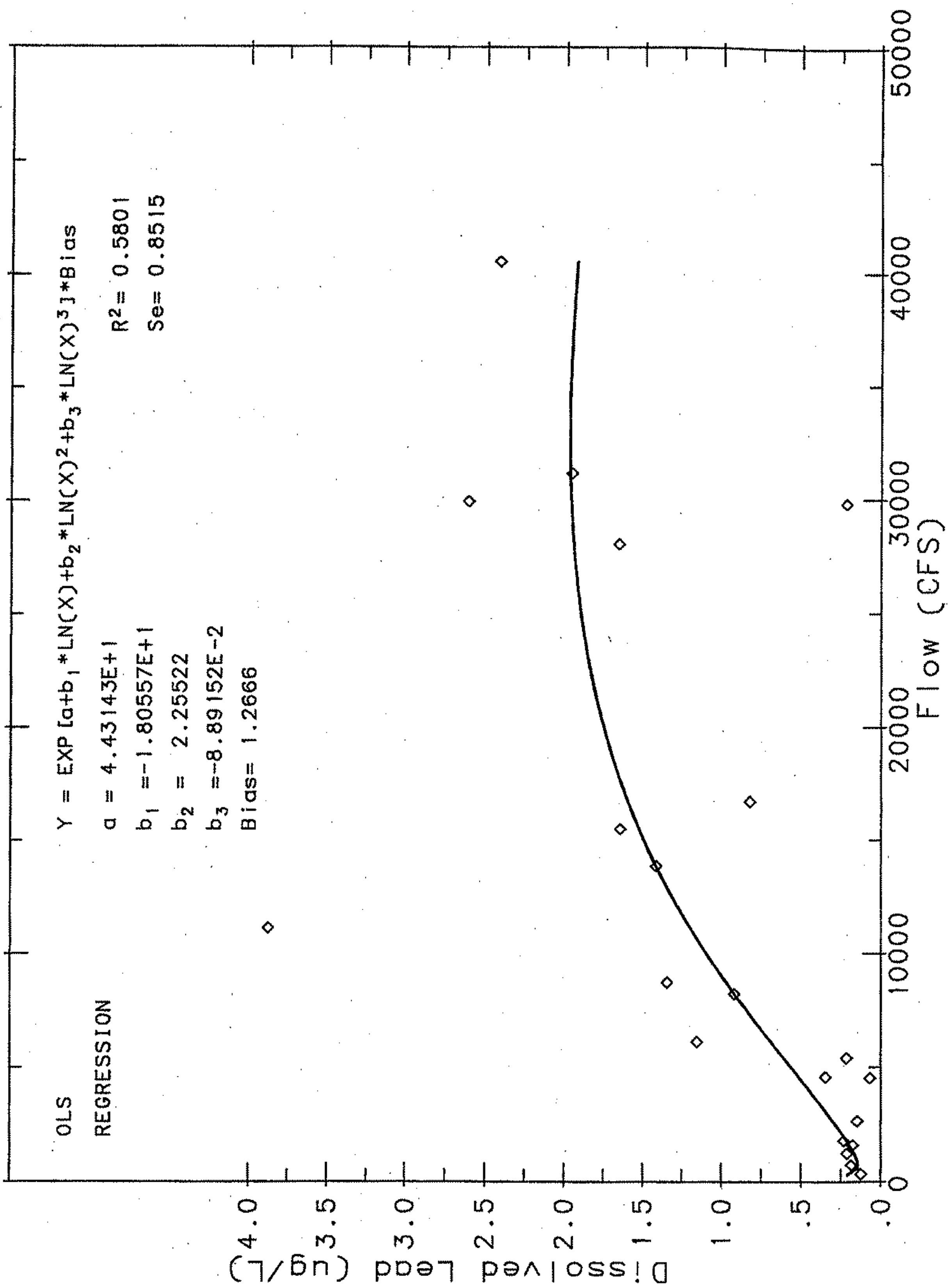


Appendix C.2

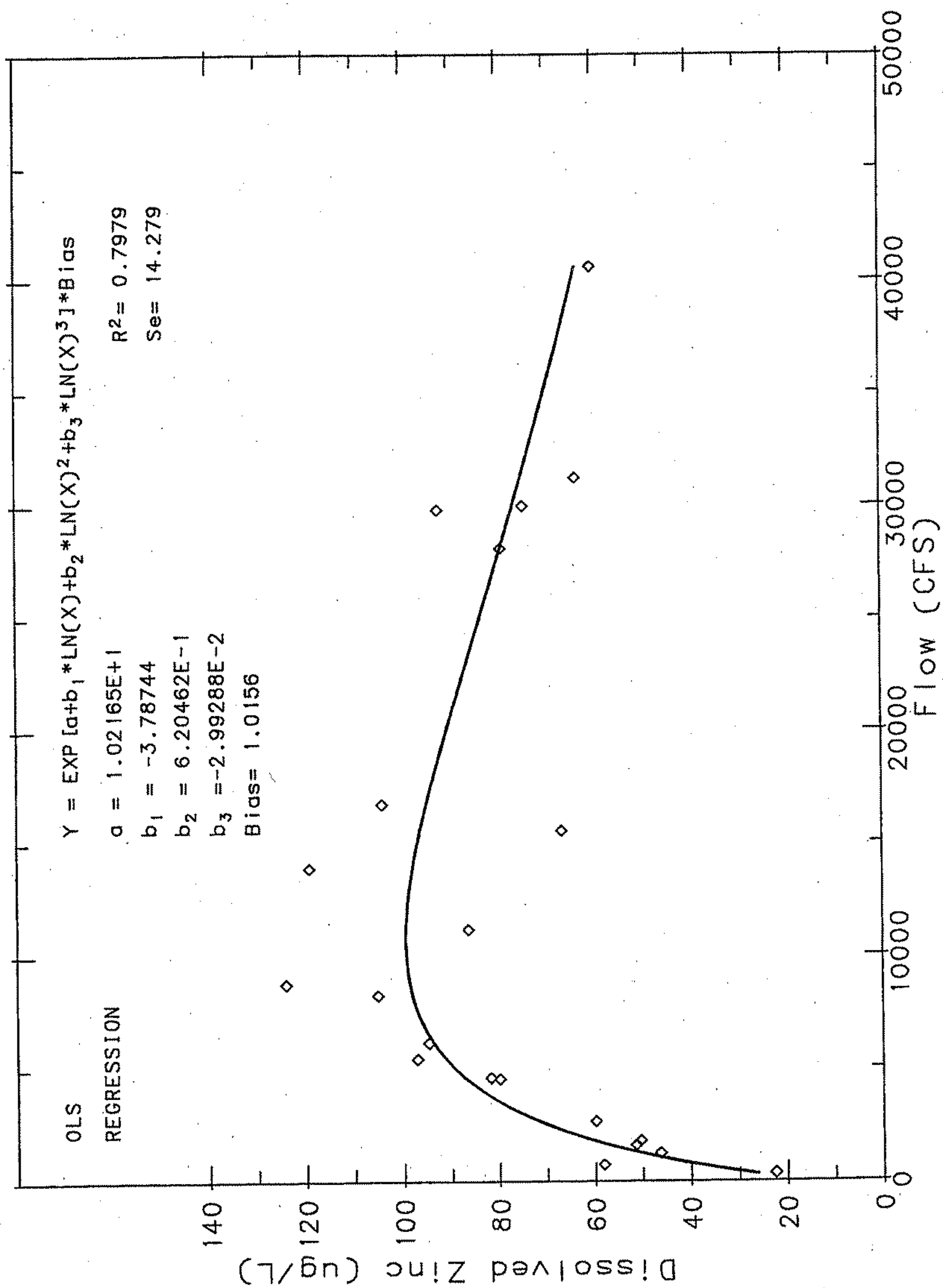
Metals data from the Spokane River at the Stateline Bridge at river mile 96 (compiled by Hopkins and Johnson, 1997)



Dissolved Cadmium vs. Flow, Spokane River @ Stateline Bridge, May 1994 - June 1997



Dissolved Lead vs. Flow, Spokane River @ Stateline Bridge, May 1994 - June 1997



Dissolved Zinc vs. Flow, Spokane River @ Stateline Bridge, May 1994 - June 1997

Ecology Spokane River Metals Data, April - June 1997

Date	Location	Sample Number	Hardness (mg/L)	Dissolved Metals (ug/L) Zinc	Lead	Cadmium	Copper	EPA 1995 Water Quality Criteria (ug/L) Zinc (acute)	Lead (chronic)	Cadmium (chronic)	Copper (chronic)
8-Apr	Stateline Bridge - center	156172	23.2	**119**	**1.41**	**0.440**	**0.860**	33	0.50	0.35	3.3
	filter blank	156175	- -	0.53	< 0.02	< 0.02	< 0.05				
6-May	Stateline Bridge - center	196172	20.3	**74.5**	**2.69**	**0.318**	**0.632**	29	0.42	0.31	2.9
	field split of above sample	196174	20.0	**74.1**	**2.50**	**0.326**	**0.617**	29	0.42	0.31	2.9
	Riverside State Park - right bank	196177	25.1	**73.9**	**2.47**	**0.307**	**0.659**	35	0.54	0.37	3.5
	filter blank	196176	- -	0.25	< 0.02	< 0.02	< 0.05				
	bottle blank	196175	- -	< 0.2	< 0.02	< 0.02	< 0.05				
12-May	2.5 mi. above stateline - right bank	208085	19.0	**61.8**	**2.01**	**0.283**	**0.549**	28	0.40	0.30	2.8
	2.5 mi. above stateline - left bank	208084	18.3	**63.7**	**2.01**	**0.278**	**0.599**	27	0.37	0.29	2.6
	Stateline - right bank, above bridge	208083	18.8	**62.7**	**1.97**	**0.283**	**0.610**	28	0.40	0.30	2.8
	Stateline Bridge - right	208080	18.8	**64.8**	**1.89**	**0.282**	**0.580**	28	0.40	0.30	2.8
	Stateline Bridge - center	208081	19.3	**61.0**	**1.93**	**0.275**	**0.576**	28	0.40	0.30	2.8
	lab split of above sample	208090	18.4	**62.7**	**1.93**	**0.289**	**0.740**	27	0.37	0.29	2.6
	Stateline Bridge - left	208082	18.9	**63.9**	**1.99**	**0.284**	**0.658**	28	0.40	0.30	2.8
	T.J. Meenach Bridge - center	208086	22.4	**61.3**	**1.93**	**0.282**	**0.636**	32	0.47	0.34	3.1
	Riverside State Park - right bank	208087	23.4	**61.3**	**1.84**	**0.281**	**0.628**	33	0.50	0.35	3.3
	lab split of above sample	208093	18.4	**59.9**	**1.87**	**0.289**	**0.570**	27	0.37	0.29	2.6
	Bridge bw. Long Lk. Dam - center	208089	27.8	**42.0**	**1.38**	**0.120**	**0.653**	39	0.61	0.40	3.8
	filter blank	208091	- -	0.78	< 0.02	< 0.02	< 0.05				
	transfer blank	208094	- -	< 0.2	< 0.02	< 0.02	< 0.05				
	bottle blank	208092	- -	8.79	0.021	< 0.02	0.370				
20-May	2.5 mi. above stateline - right bank	218005	18.3	**58.0**	**2.47**	**0.277**	**0.582**	27	0.37	0.29	2.6
	Stateline - right bank, above bridge	218006	18.2	**59.9**	**2.41**	**0.275**	**0.591**	27	0.37	0.29	2.6
	Riverside State Park- right bank	218008	21.6	**54.2**	**2.17**	**0.250**	**0.728**	32	0.47	0.34	3.1
3-Jun	Stateline Bridge - center	236172	16.3	**78.9**	**1.65**	**0.337**	**0.640**	24	0.33	0.27	2.4
	T.J. Meenach Bridge - center	236177	38.0	**67.2**	**1.41**	**0.288**	**0.771**	50	0.87	0.50	5.0
	Riverside State Park - right bank	236176	24.0	**72.1**	**1.51**	**0.310**	**0.608**	33	0.50	0.35	3.3

Station No.: 57A150 SPOKANE R @ STATELINE BR Water Class: A Latitude: 47 41 55.0

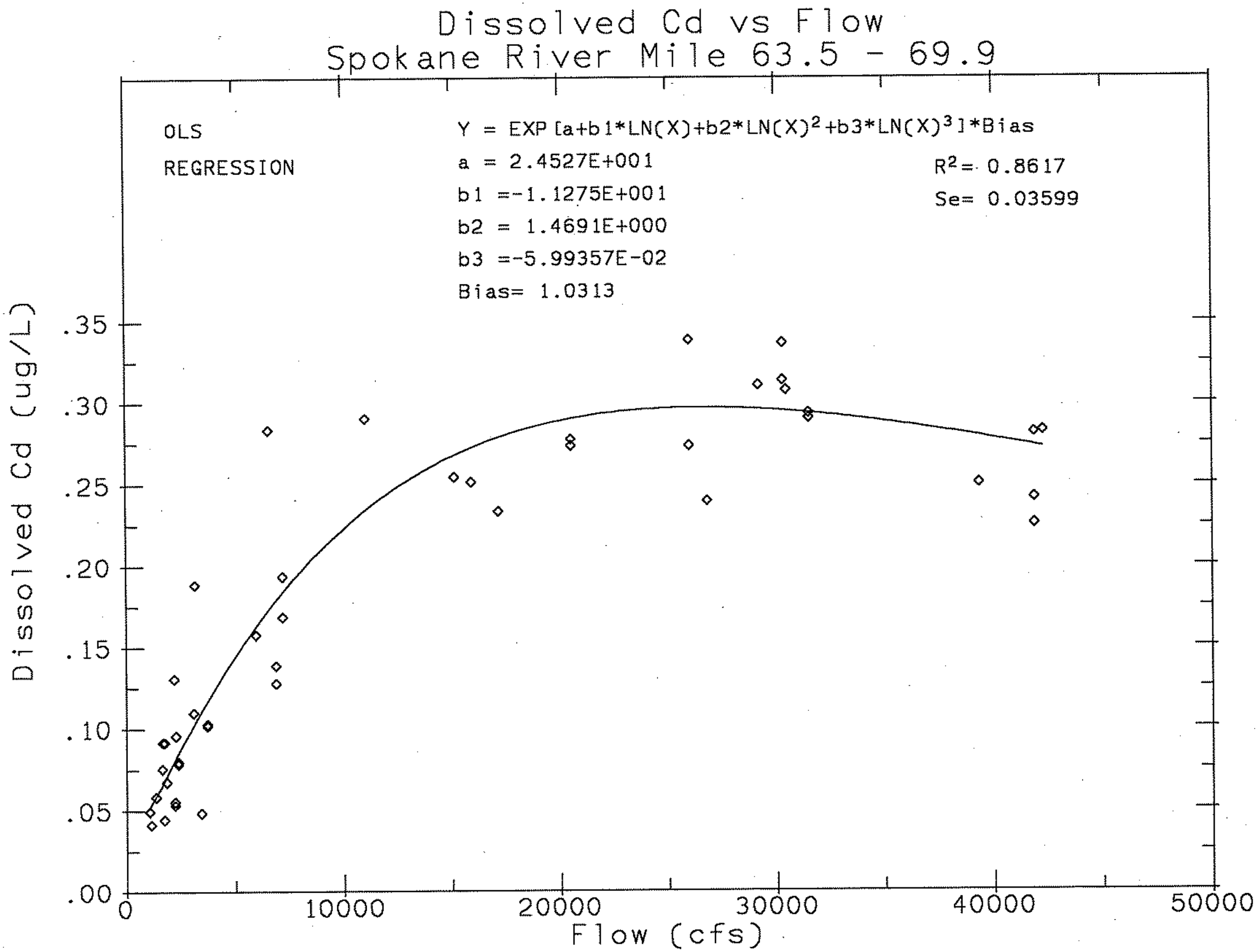
Water Body No.: WA-57-1010 River Mile: 96.00 Longitude: 117 02 37.0

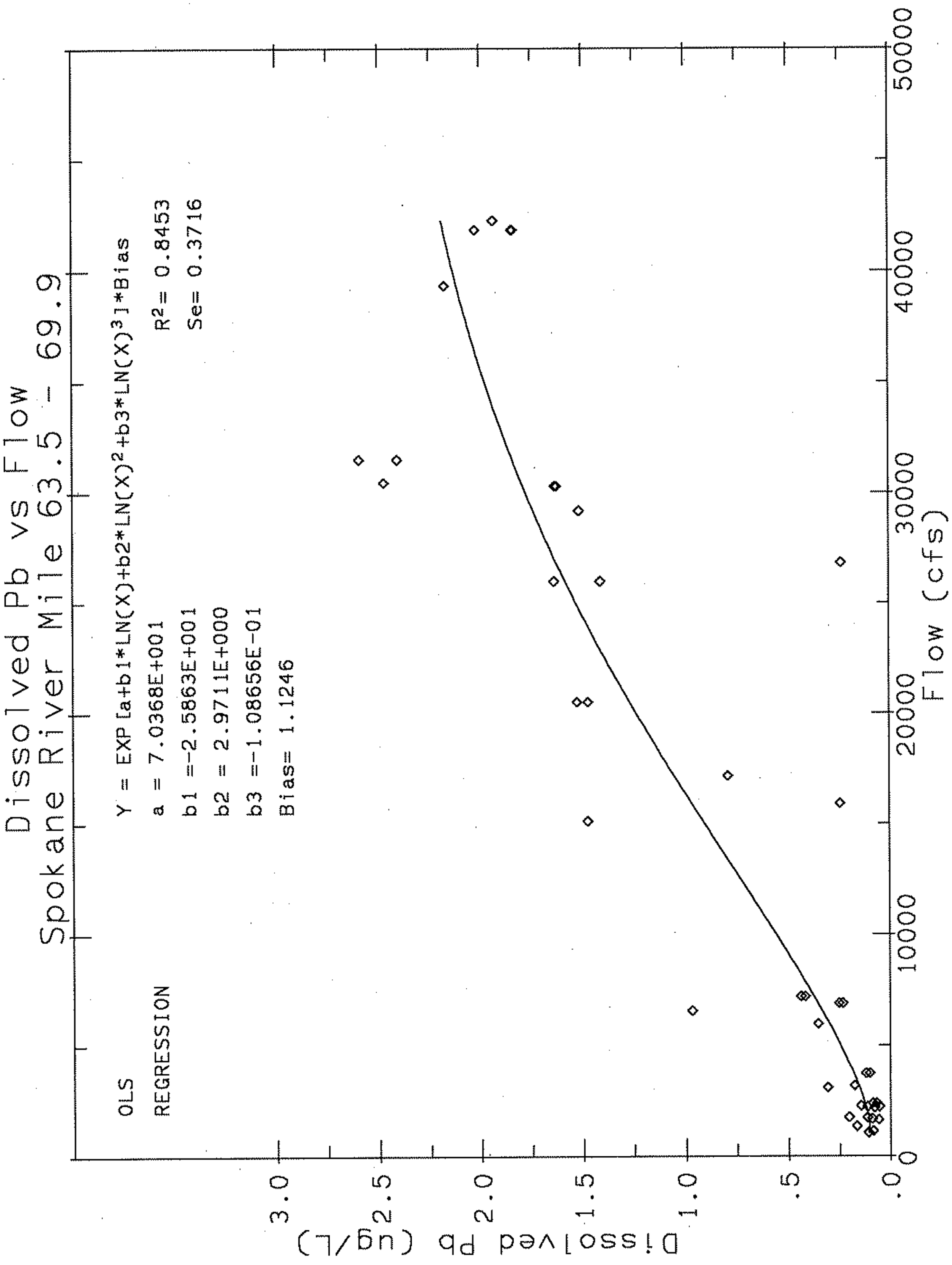
Date	Time	Flow (CFS)	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Cadmium (ug/L)	Cadmium Dissol. (ug/L)	Copper Dissol. (ug/L)	Lead Dissol (ug/L)	Zinc Dissol. (ug/L)
94/04/05	1010	7090.0								
94/05/03	0950	5380.0					0.298 P	1.420	0.209	96.900
94/06/07	1010	3900.0								
94/07/06	0955	697.0					0.150 P	0.496 P	0.180 P	58.000
94/08/02	1020	366.0								
94/09/06	1000	303.0					0.040 U	0.400 P	0.120 P	22.300
94/10/10	1105	1450.0								
94/11/07	1040	2630.0					0.130 P	0.495 P	0.143 P	59.700
94/12/05	1135	1460.0								
95/01/09	1015	4490.0	14.0 P	20.0 U	79.5	3.00 U	0.180 P	0.440 P	0.064 P	79.700
95/02/06	1100	14400.0								
95/03/06	1115	16700.0					0.406	0.706	0.818	104.000
95/04/03	1125	12700.0								
95/05/02	1120	9020.0								
95/06/05	0930	5800.0								
95/07/10	0820	3080.0								
95/08/07	1050	746.0								
95/09/05	0820	424.0								
95/10/02	1010	1570.0	0.4	1.4	48.4 N	0.16	0.110	0.410	0.172	51.200
95/11/06	0940	3680.0								
95/12/04	0945	29800.0	0.6	3.7	102.0 B	0.47	0.289	0.345	0.212	92.100
96/01/08	1010	8370.0								
96/02/05	0920	6100.0	0.9	5.4	89.6	0.46	0.377	0.841	1.150	94.500
96/03/04	1010	16000.0								
96/04/09	0945	11100.0	1.1	14.8	82.3	0.40	0.370	0.931	3.870	86.100
96/05/06	0955	19800.0								
96/06/03	1100	15500.0	0.9	5.6	67.1 J	0.34	0.282	0.547	1.640	66.500
96/07/08	1205	3070.0								
96/08/05	1010	1200.0	1.1	1.4	45.7	0.45	0.281	0.450	0.206	46.100
96/09/03	1105	615.0								
96/10/08	0945	1750.0	0.8 J	1.2	46.9 J	0.18	0.219	0.500	0.227	50.200 J
96/11/05	0940	2780.0								
96/12/03	0930	4550.0	0.6	1.5	78.6	0.30	0.249	0.450	0.340	81.600
97/01/14	0945	13300.0								
97/02/04	0945	8210.0	0.7	3.1	110.0 J	0.34	0.342	0.593	0.914	105.000

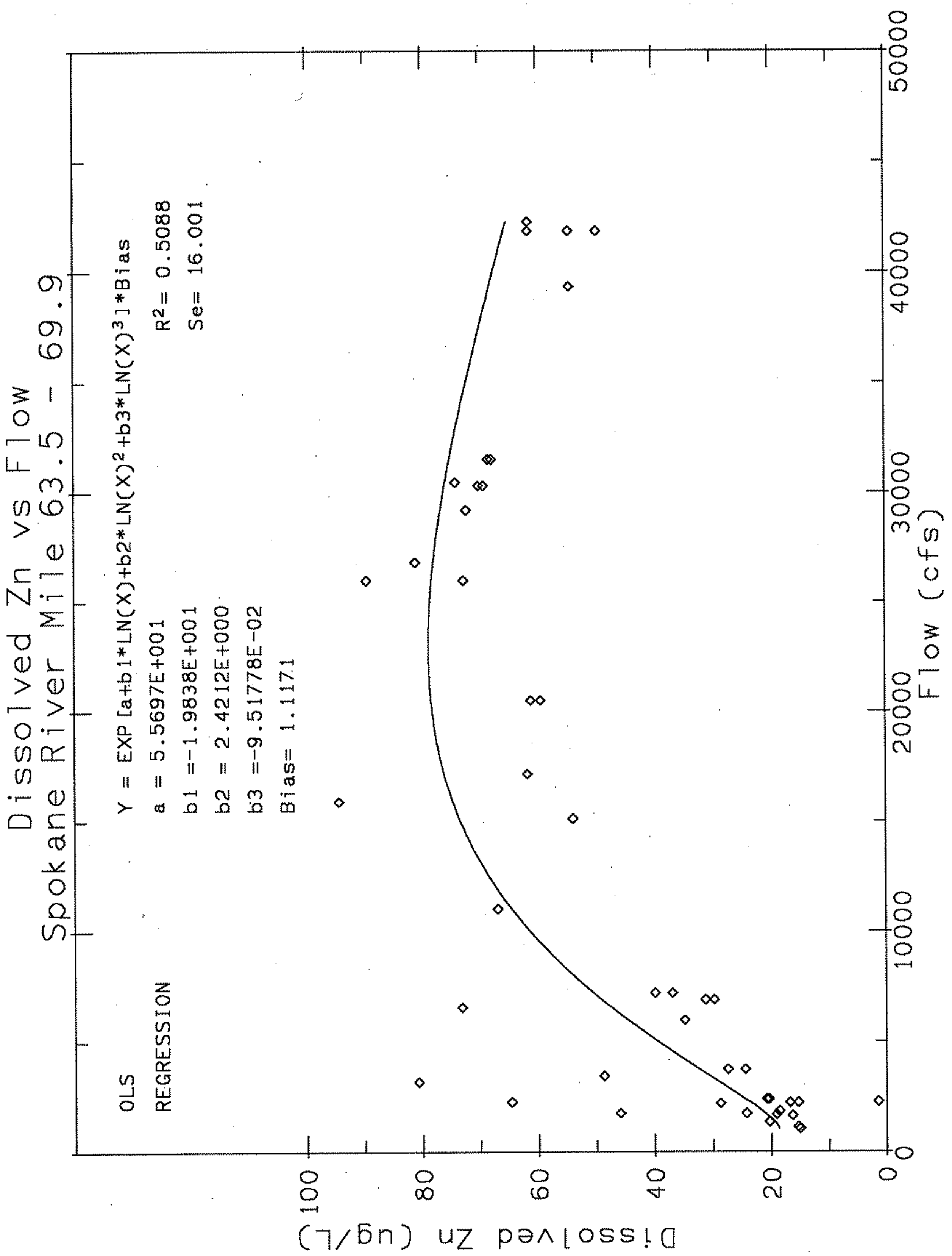
Remarks: U,K - Below reporting limit; B - analyte in blank; X - background organisms; J - Estimate; S - Spreader colonies, P - below quantitation limit.

Appendix C.3

Metals data from Spokane River between river miles 63.5–69.9 (compiled by CH2M Hill, 1997)


Dissolved Cd vs Flow
Spokane River Mile 63.5 - 69.9
OLS
REGRESSION
Y = EXP [a+b1*LN(X)+b2*LN(X)²+b3*LN(X)³]*Bias
a = 2.4527E+001
b1 =-1.1275E+001
b2 = 1.4691E+000
b3 =-5.99357E-02
Bias= 1.0313
R²= 0.8617
Se= 0.03599
Dissolved Cd (ug/L)
.35
.30
.25
.20
.15
.10
.05
.00
0
10000
20000
30000
40000
50000
Flow (cfs)


Dissolved Pb vs Flow
Spokane River Mile 63.5 - 69.9
OLS
REGRESSION
Y = EXP[a+b1*LN(X)+b2*LN(X)²+b3*LN(X)³]*Bias
a = 7.0368E+001
b1 =-2.5863E+001
b2 = 2.9711E+000
b3 =-1.08656E-01
Bias= 1.1246
R²= 0.8453
Se= 0.3716
Dissolved Pb (ug/L)
.0
.5
1.0
1.5
2.0
2.5
3.0
Flow (cfs)
0
10000
20000
30000
40000
50000



Dissolved Zn vs Flow
Spokane River Mile 63.5 - 69.9
OLS
REGRESSION
Y = EXP [a+b1*LN(X)+b2*LN(X)²+b3*LN(X)³]*Bias
a = 5.5697E+001
b1 =-1.9838E+001
b2 = 2.4212E+000
b3 =-9.51778E-02
Bias= 1.1171
R² = 0.5088
Se= 16.001
Dissolved Zn (ug/L)
0
20
40
60
80
100
Flow (cfs)
0
10000
20000
30000
40000
50000

DATA FOR GRAPHING - Undetected Values not Included. All Concentrations in ug/L.

SOURCE	STA	Name	River Mile	Date	Flow (cfs)	TR Ag	Dis Ag	TR Cd	Dis Cd	TR Cu	Dis Cu	TR Hg	TR Pb	Dis Pb	TR Zn	Dis Zn
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	6/27/96	5944			0.2325	0.1575	0.399	0.1915	0.000382	1.99	0.351	45.7	34.7
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	7/12/96	3072			0.225	0.109	0.25	0.15	0.00144	1.32	0.306	45.2	
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	7/19/96	2174		0.001285	0.163	0.13	0.258	0.151	0.000663	0.92	0.0752	35.4	28.6
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	7/26/96	1827	0.12		0.129	0.0667	0.414	0.0866	0.0001995	1.01		127	18.5
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	8/12/96	1624	0.0181		0.1	0.07535	0.462	0.324	0.000359	0.894	0.05535	23	16.25
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	8/19/96	1036			0.0688	0.0488	0.535	0.306	0.000281	0.751	0.105	20.7	14.9
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	9/5/96	1115	0.0506	0.0199	0.0747	0.04115	0.505	0.438	0.000557	1.83	0.0824	18.6	15.2
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	9/12/96	2250			0.0956		0.576	0.035	0.000363	1.76		23.2	1.34
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	4/25/97	25970	0.0246	0.0673	0.559	0.338	1.23	0.752	0.00232	7.70	1.63	113	89.4
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	5/7/97	30552	0.0369	0.0134	0.401	0.290	0.978	0.5858	0.00305	11.6	2.40	88.2	67.7
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	5/19/97	41095	0.0475	0.0110	0.466	0.225	1.4347	0.5775	0.01463	18.4	1.83	84.5	49.5
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	6/2/97	30039	0.0119	0.0196	0.446	0.313	0.9725	0.5801	0.00093	9.9	1.63	89.2	69.1
SAWTP	FW	Fort Wright (Meenach Bridge)	69.9	6/16/97	21351	0.0164	0.0147	0.436	0.277	0.7026	0.5084	0.00138	7.4	1.52	78.9	61.0
DOE	B&P	54A120	66	10/2/95	1720				0.044		0.488	0.0010		0.110		24.1
DOE	B&P	54A120	66	8/5/96	1660				0.091		0.450	0.0010		0.087		19.0
DOE	B&P	54A120	66	12/4/95	26800				0.239		0.416	0.0010		0.232		80.9
DOE	B&P	54A120	66	6/3/96	15100				0.254		0.510	0.0010		1.470		53.8
DOE	B&P	54A120	66	2/5/96	6540				0.283		0.698	0.0010		0.966		73.0
DOE	B&P	54A120	66	4/9/96	11000				0.290		0.931	0.0010		4.270		66.8
DOE		Rifle Club	63.5-64.5	7/28/92	1326			0.098	0.058	1.0900	0.184	0.00086	0.896	0.163	40.9	20.2
DOE		Rifle Club	63.5-64.6	9/24/92	1836.3			0.137		1.2500			1.5		51.6	
DOE		Rifle Club	63.5-64.7	11/25/92	3153			0.203	0.188	1.0500	0.974	0.00122	1.0	0.17	105.0	80.6
DOE		Rifle Club	63.5-64.8	1/27/93	3415			0.133	0.048	3.3300		0.00414	2.3		91.1	48.6
DOE		Rifle Club	63.5-64.9	3/31/93	15882			0.501	0.251	1.2300	0.86	0.00365	3.2	0.24	179.0	94.3
DOE		Rifle Club	63.5-64.10	5/25/93	17134			0.344	0.233	0.0670	0.48	0.00166	5.4	0.79	73.9	61.6
DOE		Rifle Club	63.5-64.11	8/11/93	2246			0.127	0.095	1.2800	1.18	0.00091	0.6	0.14	77.0	64.5
DOE		Rifle Club	63.5-64.12	9/8/93	1735			0.164	0.091	0.7400	0.61	0.00150	0.9	0.20	55.8	45.8
DOE		Riverside State Park - right bank	66.0	5/8/97					0.307		0.659			2.47		73.9
DOE		T.J. Meenach bridge - center	66.0	5/19/97					0.282		0.636			1.93		61.3
DOE		Riverside State Park - right bank	66.0	5/20/97					0.281		0.628			1.84		61.3
DOE		Riverside State Park- right bank	66.0	5/22/97					0.250		0.728			2.17		54.2
DOE		Riverside State Park - right bank	66.0	6/5/97					0.310		0.608			1.51		72.1

Appendix C.4

Model calibration for hardness, cadmium, lead, zinc (calibration location are shown in the shaded cells)

Appendix C4a. Model calibration results for Cd (shaded cells show calibration checks for the mass balance).

Spokane River Model Reaches			Effluent Characteristics					Aquifer/Tributary Inflow/Outflow				Reach Mass Balance Calculations								
Spokane River Model Reach Number	Up-stream River Mile	Down-stream River Mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total Recoverable Cd (ug/L)		Inflow/ Outflow (cfs)	Inflow Hardness (mg/L as CaCO3) (2)	Inflow Dissolved Cd (ug/L) (1) (3)	Flow at Upstream End of Reach (cfs)	Flow at Downstream End of Reach (cfs)	Mass Balance Hardness at Up-stream End of Reach (mg/L as CaCO3)	Mass Balance Hardness at Down-stream End of Reach (mg/L as CaCO3)	Check of Mass Balance with Regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of Dissolved/ Total Recoverable Cd	Mass Balance Dissolved Cd at Upstream End of Reach (ug/L)	Mass Balance Dissolved Cd at Down-stream End of Reach after complete mix (ug/L)	Check of Mass Balance with Regression Estimate of 90% prediction limit for dissolved Cd at RM 96-100.7 (Hopkins and Johnson) and RM 66 (CH2M-Hill data compilation) and log-log cubic regression (ug/L) (3)
0	--	111.7	*Lake CDA Outlet*					*Lk CDA Outlet (1)*	1,000	20.0	0.23	--	1,000	--	20		0.976	--	0.23	
1	111.7	106.6	*CDA STP*	6	9.28	145	0.30					1,000	1,009	20	21		0.974	0.23	0.23	
2	106.6	101.7	*Hayden STP*	1.3	2.01	145	0.30					1,009	1,011	21	21		0.974	0.23	0.23	
3	101.7	96.0	*Post Falls STP*	3.1	4.80	145	0.30	*Aquifer Inflow/Outflow*	6.09	85.0	0.008	1,011	1,022	21	22	20	0.972	0.23	0.23	0.23
4	96.0	93.0						*Aquifer Inflow/Outflow*	2.56	85.0	0.008	1,022	1,025	22	23		0.971	0.23	0.23	
5	93.0	90.4	*Liberty Lake STP*	1	1.55	145	0.30					1,025	1,026	23	23		0.971	0.23	0.23	
6	90.4	87.8										1,026	1,026	23	23		0.971	0.23	0.23	
7	87.8	85.3	*Kaiser*	23.3	36.05	120	0.30	*Aquifer Inflow*	337.14	85.0	0.008	990	1,363	23	41		0.947	0.23	0.17	
8	85.3	82.6										1,363	1,363	41	41	42	0.947	0.17	0.17	
9	82.6	79.8	*IEPCo*	4	6.19	145	0.30	*Aquifer Inflow*	-256.20	na	na	1,363	1,113	41	41		0.946	0.17	0.17	
10	79.8	78.0						*Aquifer Inflow*	394.97	85.0	0.008	1,113	1,508	41	53		0.936	0.17	0.13	
11	78.0	74.1						*Aquifer Outflow*	-179.70	na	na	1,508	1,329	53	53		0.936	0.13	0.13	
12	74.1	69.8						*Hangman Cr + Aquifer*	158.62	85.0	0.008	1,329	1,487	53	56		0.933	0.13	0.12	
13	69.8	67.6						*Aquifer Inflow*	42.75	85.0	0.008	1,487	1,530	56	57		0.933	0.12	0.11	
14	67.6	64.6	*Spokane AWTP*	44	68.08	145	0.30	*Aquifer Inflow*	58.30	85.0	0.008	1,530	1,656	57	62	62	0.929	0.11	0.11	0.11

(1) dissolved Cd was estimated as the 90% prediciton limit of the regression equation for Spokane River at the state line presented by Hopkins and Johnson (1997)
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10% prediction limit for RM 66 with spreadsheet mass balance. Lake CDA outlet hardness asssumed to be 5%tile (and seasonal 10%tile) of 20 mg/L as CaCO3 from Pelletier (1994)
(3) aquifer diss Cd assumed to be a 90%tile of 0.008 ug/L based on comparison of regression estimate for diss Cd at RM 66 (CH2M-Hill data compilation) with mass balance estimate for downstream end reach log-log cubic regresssion.

Appendix C4b. Model calibration results for Pb (shaded cells show calibration checks for the mass balance).

Spokane River Model Reaches			Effluent Characteristics					Aquifer/Tributary Inflow/Outflow				Reach Mass Balance Calculations								
Spokane River Model Reach Number	Up-stream River Mile	Down-stream River Mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total Recoverable Pb (ug/L)		Inflow/Outflow (cfs)	Inflow Hardness (mg/L as CaCO3) (2)	Inflow Dissolved Pb (ug/L) (1) (3)	Flow at Upstream End of Reach (cfs)	Flow at Downstream End of Reach (cfs)	Mass Balance Hardness at Up-stream End of Reach (mg/L as CaCO3)	Mass Balance Hardness at Down-stream End of Reach (mg/L as CaCO3)	Check of Mass Balance with Regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of Dissolved/ Total Recoverable Pb	Mass Balance Dissolved Pb at Upstream End of Reach (ug/L)	Mass Balance Dissolved Pb at Down-stream End of Reach after complete mix (ug/L)	Check of Mass Balance with Regression Estimate of 90% prediction limit for dissolved Pb at RM 96-100.7 (Hopkins and Johnson) and RM 66 (CH2M-Hill data compilation) and log-log cubic regression (ug/L) (3)
0	--	111.7	Lake CDA Outlet					Lk CDA Outlet (1)	1,000	20.0	1.2	--	1,000	--	20		1.00	--	1.2	
1	111.7	106.6	CDA STP	6	9.28	145	2.5					1,000	1,009	20	21		1.00	1.2	1.3	
2	106.6	101.7	Hayden STP	1.3	2.01	145	2.5					1,009	1,011	21	21		1.00	1.3	1.3	
3	101.7	96.0	Post Falls STP	3.1	4.80	145	2.5	Aquifer Inflow/Outflow	6.09	85.0	0.09	1,011	1,022	21	22	20	1.00	1.3	1.3	1.2
4	96.0	93.0						Aquifer Inflow/Outflow	2.56	85.0	0.09	1,022	1,025	22	23		1.00	1.3	1.3	
5	93.0	90.4	Liberty Lake STP	1	1.55	145	2.5					1,025	1,026	23	23		1.00	1.3	1.3	
6	90.4	87.8										1,026	1,026	23	23		1.00	1.3	1.3	
7	87.8	85.3	Kaiser	23.3	36.05	120	2.5	Aquifer Inflow	337.14	85.0	0.09	990	1,363	23	41		0.92	1.3	0.9	
8	85.3	82.6										1,363	1,363	41	41	42	0.92	0.9	0.9	
9	82.6	79.8	IEPCo	4	6.19	145	2.5	Aquifer Inflow	-256.20	na	na	1,363	1,113	41	41		0.92	0.9	0.9	
10	79.8	78.0						Aquifer Inflow	394.97	85.0	0.09	1,113	1,508	41	53		0.88	0.9	0.7	
11	78.0	74.1						Aquifer Outflow	-179.70	na	na	1,508	1,329	53	53		0.88	0.7	0.7	
12	74.1	69.8						Hangman Cr + Aquifer	158.62	85.0	0.09	1,329	1,487	53	56		0.88	0.7	0.6	
13	69.8	67.6						Aquifer Inflow	42.75	85.0	0.09	1,487	1,530	56	57		0.87	0.6	0.6	
14	67.6	64.6	Spokane AWTP	44	68.08	145	2.5	Aquifer Inflow	58.30	85.0	0.09	1,530	1,656	57	62	62	0.86	0.6	0.6	0.6

(1) dissolved Pb was estimated as the 90% prediciton limit of the regression equation for Spokane River at the state line presented by Hopkins and Johnson (1997)
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10% prediction limit for RM 66 with spreadsheet mass balance. Lake CDA outlet hardness assumed to be 5%tile (and seasonal 10%tile) of 20 mg/L as CaCO3 from Pelletier (1994)
(3) aquifer diss Pb assumed to be: 0.09 ug/L based on comparison of regression estimate for diss Pb at RM 66 (Jerry Bills data compilation) with mass balance estimate for downstream end reach log-log cubic regresssion.

Appendix C4c. Model calibration results for Zn (shaded cells show calibration checks for the mass balance).

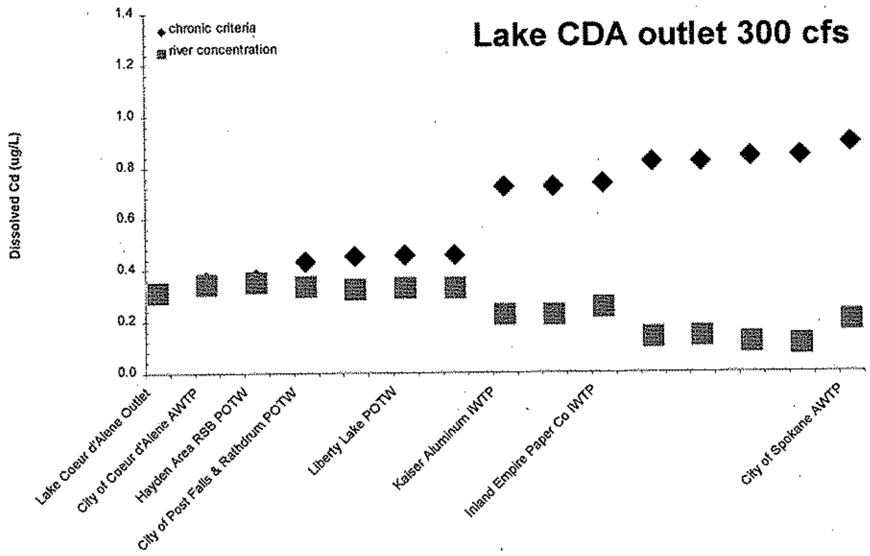
Spokane River Model Reaches			*Effluent Characteristics*					*Aquifer/Tributary Inflow/Outflow*				*Reach Mass Balance Calculations*								
Spokane River Model Reach Number	Up-stream River Mile	Down-stream River Mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total Recoverable Zn (ug/L)		Inflow/Outflow (cfs)	Inflow Hardness (mg/L as CaCO3) (2)	Inflow Dissolved Zn (ug/L) (1) (3)	Flow at Upstream End of Reach (cfs)	Flow at Downstream End of Reach (cfs)	Mass Balance Hardness at Up-stream End of Reach (mg/L as CaCO3)	Mass Balance Hardness at Down-stream End of Reach (mg/L as CaCO3)	Check of Mass Balance with Regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of Dissolved/ Total Recoverable Zn	Mass Balance Dissolved Zinc at Upstream End of Reach (ug/L)	Mass Balance Dissolved Zn at Down-stream End of Reach after complete mix (ug/L)	Check of Mass Balance with Regression Estimate of 90% prediction limit for dissolved Zn at RM 96-100.7 (Hopkins and Johnson) and RM 66 (CH2M-Hill data compilation) and log-log cubic regression (ug/L) (3)
0	--	111.7	*Lake CDA Outlet*					*Lk CDA Outlet (1)*	1,000	20.0	63.5	--	1,000	--	20		0.986	--	63.5	
1	111.7	106.6	*CDA STP*	6	9.28	145	100					1,000	1,009	20	21		0.986	63.5	63.8	
2	106.6	101.7	*Hayden STP*	1.3	2.01	145	100					1,009	1,011	21	21		0.986	63.8	63.9	
3	101.7	96.0	*Post Falls STP*	3.1	4.80	145	100	*Aquifer Inflow/Outflow*	6.09	85.0	18	1,011	1,022	21	22	20	0.986	63.9	63.8	63.5
4	96.0	93.0						*Aquifer Inflow/Outflow*	2.56	85.0	18	1,022	1,025	22	23		0.986	63.8	63.7	
5	93.0	90.4	*Liberty Lake STP*	1	1.55	145	100					1,025	1,026	23	23		0.986	63.7	63.7	
6	90.4	87.8										1,026	1,026	23	23		0.986	63.7	63.7	
7	87.8	85.3	*Kaiser*	23.3	36.05	120	100	*Aquifer Inflow*	337.14	85.0	18	990	1,363	23	41		0.986	63.7	53.3	
8	85.3	82.6										1,363	1,363	41	41	42	0.986	53.3	53.3	
9	82.6	79.8	*IEPCo*	4	6.19	145	85	*Aquifer Inflow*	-256.20	na	na	1,363	1,113	41	41		0.986	53.3	53.6	
10	79.8	78.0						*Aquifer Inflow*	394.97	85.0	18	1,113	1,508	41	53		0.986	53.6	44.2	
11	78.0	74.1						*Aquifer Outflow*	-179.70	na	na	1,508	1,329	53	53		0.986	44.2	44.3	
12	74.1	69.8						*Hangman Cr + Aquifer*	158.62	85.0	18	1,329	1,487	53	56		0.986	44.3	41.5	
13	69.8	67.6						*Aquifer Inflow*	42.75	85.0	18	1,487	1,530	56	57		0.986	41.5	40.8	
14	67.6	64.6	*Spokane AWTP*	44	68.08	145	100	*Aquifer Inflow*	58.30	85.0	18	1,530	1,656	57	62	62	0.986	40.8	42.4	42.1

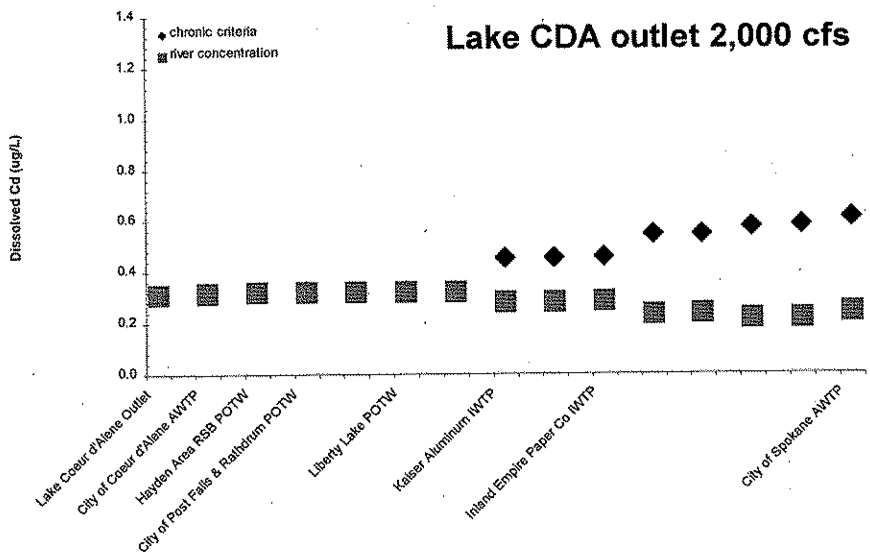
(1) dissolved Zn was estimated as the 90% prediciton limit of the regression equation for Spokane River at the state line presented by Hopkins and Johnson (1997)
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10% prediction limit for RM 66 with spreadsheet mass balance. Lake CDA outlet hardness asssumed to be 5%tile (and seasonal 10%tile) of 20 mg/L as CaCO3 from Pelletier (1994)
(3) aquifer diss Zn assumed to be a 90%tile of 18 ug/L based on comparison of regression estimate for diss Zn at RM 66 (Jerry Bills data compilation) with mass balance estimate for downstream end reach log-log cubic regresssion is docmuemted in wqhydro.regfile.di.zn.rm.66.doc

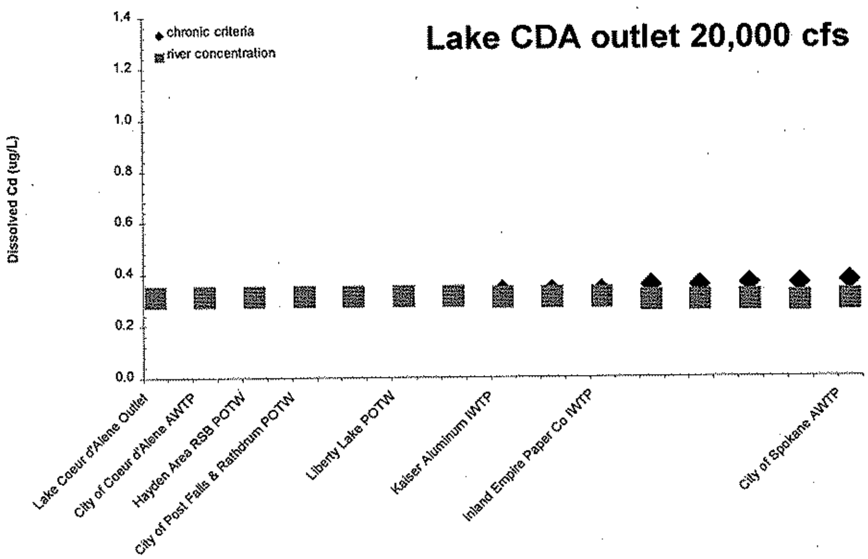
Appendix D.1

Results for Cadmium

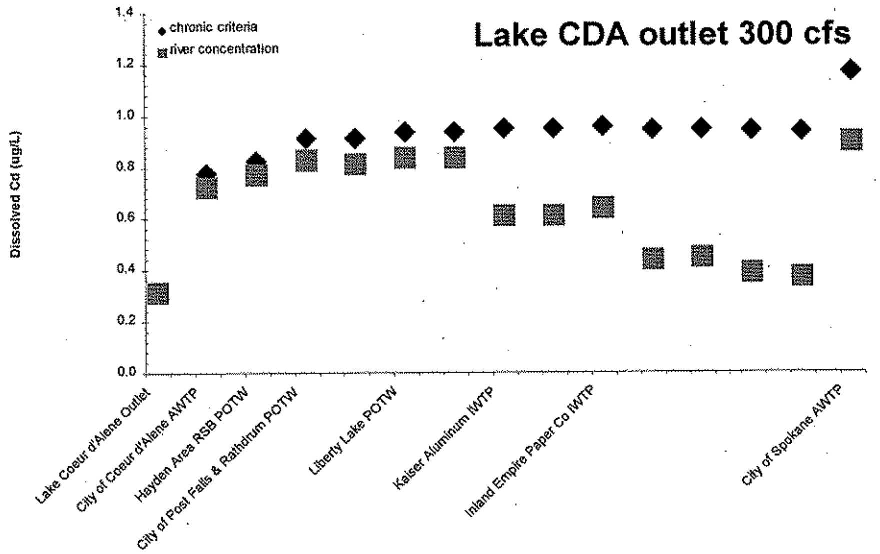
Dissolved Cd after complete mix at current effluent design flows.

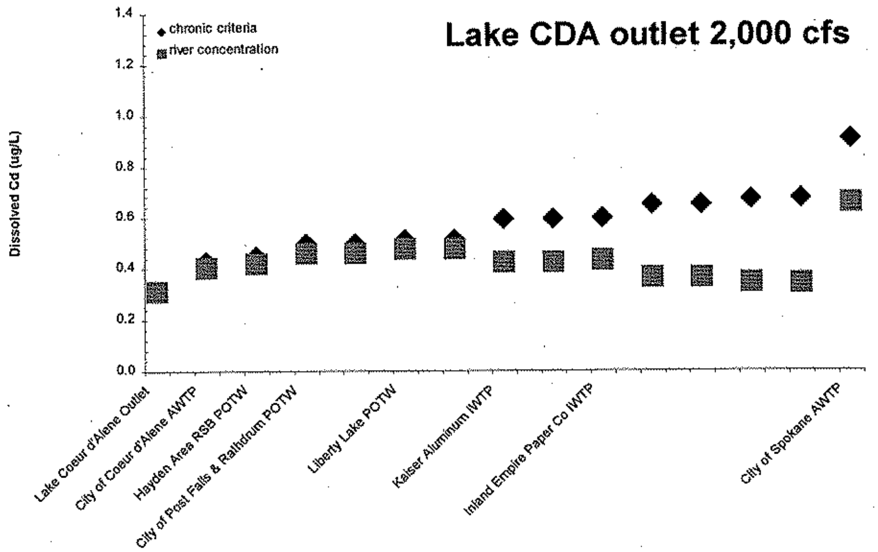


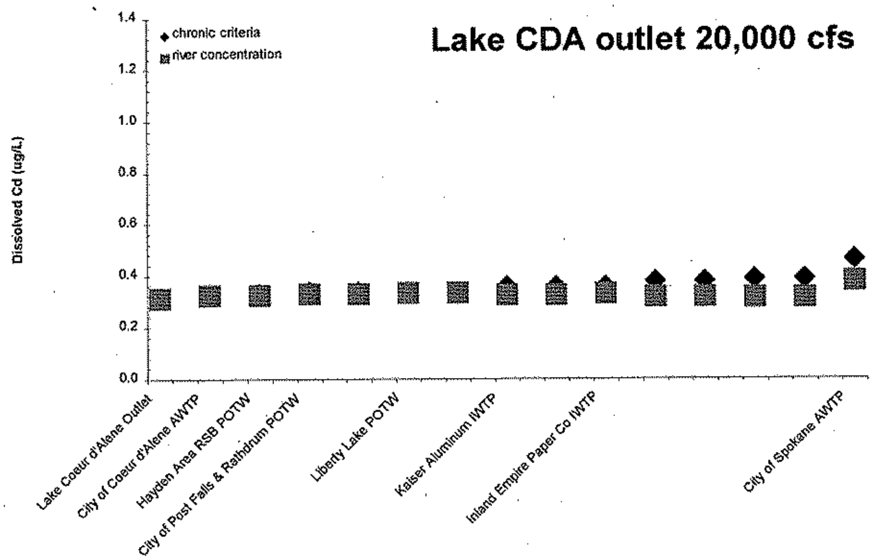




Dissolved Cd after complete mix at 20X current effluent design flows.







Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 300 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*Effluent Characteristics*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Cd (ug/L)	Effluent ratio of dissolved/total rec. Cd	Dissolved Cd (ug/L)	Acute dissolved Cd criteria (ug/L)	Chronic dissolved Cd criteria (ug/L)	Effluent meets end of-pipe criteria?
0	--	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	1.52	0.893	1.36	5.54	1.36	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	1.52	0.893	1.36	5.54	1.36	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	1.52	0.893	1.36	5.54	1.36	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	1.52	0.893	1.36	5.54	1.36	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	1.31	0.901	1.18	4.51.	1.18	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	1.52	0.893	1.36	5.54	1.36	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	1.52	0.893	1.36	5.54	1.36	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*Aquifer/Tributary Inflow/Outflow*				*Reach Mass Balance Calculations*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Cd (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Cd at down-stream end of reach	Mass balance dissolved Cd at upstream end of reach (ug/L)	Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L)	Check of mass balance with regression estimate of 90%tile diss. Cd at RM 66 based on CH2M-Hill's data compilation and log-log cubic regression (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	300	20	0.31	--	300	--	20.0	na	0.976	--	0.31	
1	111.7	106.6					300	309	20.0	23.8	na	0.969	0.31	0.35	
2	106.6	101.7					309	311	23.8	24.5	na	0.968	0.35	0.35	
3	101.7	96.0	*Aquifer Inflow/Outflow*	28.05	85.0	0.008	311	344	24.5	31.1	na	0.958	0.35	0.34	
4	96.0	93.0	*Aquifer Inflow/Outflow*	11.81	85.0	0.008	344	356	31.1	32.9	na	0.955	0.34	0.32	
5	93.0	90.4					356	357	32.9	33.4	na	0.955	0.32	0.33	
6	90.4	87.8					357	357	33.4	33.4	na	0.955	0.33	0.33	
7	87.8	85.3	*Aquifer Inflow*	303.42	85.0	0.008	321	661	33.4	61.8	na	0.929	0.33	0.23	
8	85.3	82.6					661	661	61.8	61.8	na	0.929	0.23	0.23	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	661	411	61.8	63.1	na	0.928	0.23	0.25	
10	79.8	78.0	*Aquifer Inflow*	355.47	85.0	0.008	411	766	63.1	73.2	na	0.922	0.25	0.14	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	766	587	73.2	73.2	na	0.922	0.14	0.14	
12	74.1	69.8	*Hangman Cr + Aquifer*	144.77	85.0	0.008	587	731	73.2	75.6	na	0.921	0.14	0.11	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	0.008	731	774	75.6	76.1	na	0.920	0.11	0.11	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	0.008	774	901	76.1	81.9	na	0.917	0.11	0.20	na

(1) dissolved Cd was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Cd assumed to be: 0.008 ug/L based on comparison of regression estimate for diss Cd at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 300 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			NPDES Dischargers	Acute Mixing Zone Boundary						Chronic Mixing Zone Boundary						Complete Mix				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Cd criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Cd conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Cd criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Cd conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Cd criteria (ug/L)	Chronic dissolved Cd criteria (ug/L)	Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	0.65	0.31	0.31	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	1.81	89.1	3.27	0.949	0.93	Yes	9.08	33.8	0.46	0.954	0.43	Yes	23.8	0.78	0.36	0.35	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	4.84	48.8	1.70	0.974	0.58	Yes	39.44	26.8	0.39	0.964	0.37	Yes	24.5	0.81	0.36	0.35	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	2.62	70.5	2.53	0.959	0.77	Yes	17.23	31.5	0.44	0.957	0.41	Yes	31.1	1.04	0.43	0.34	Yes
4	96.0	93.0														32.9	1.11	0.45	0.32	Yes
5	93.0	90.4	*Liberty Lake POTW*	6.75	49.5	1.73	0.973	0.50	Yes	58.51	34.8	0.47	0.953	0.34	Yes	33.4	1.13	0.46	0.33	Yes
6	90.4	87.8														33.4	1.13	0.46	0.33	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	1.22	104.2	3.87	0.942	1.07	Yes	3.23	60.2	0.71	0.930	0.60	Yes	61.8	2.20	0.72	0.23	Yes
8	85.3	82.6														61.8	2.20	0.72	0.23	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	3.67	84.5	3.08	0.951	0.56	Yes	27.70	64.8	0.75	0.927	0.27	Yes	63.1	2.25	0.73	0.25	Yes
10	79.8	78.0														73.2	2.64	0.82	0.14	Yes
11	78.0	74.1														73.2	2.64	0.82	0.14	Yes
12	74.1	69.8														75.6	2.73	0.84	0.11	Yes
13	69.8	67.6														76.1	2.75	0.84	0.11	Yes
14	67.6	64.6	*City of Spokane AWTP*	1.28	129.7	4.91	0.933	1.13	Yes	3.84	94.0	0.99	0.912	0.44	Yes	81.9	2.98	0.89	0.20	Yes

Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*Effluent Characteristics*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Cd (ug/L)	Effluent ratio of dissolved/total rec. Cd	Dissolved Cd (ug/L)	Acute dissolved Cd criteria (ug/L)	Chronic dissolved Cd criteria (ug/L)	Effluent meets end of-pipe criteria?
0	--	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	1.52	0.893	1.36	5.54	1.36	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	1.52	0.893	1.36	5.54	1.36	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	1.52	0.893	1.36	5.54	1.36	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	1.52	0.893	1.36	5.54	1.36	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	1.31	0.901	1.18	4.51	1.18	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	1.52	0.893	1.36	5.54	1.36	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	1.52	0.893	1.36	5.54	1.36	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			Aquifer/Tributary Inflow/Outflow				Reach Mass Balance Calculations									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Cd (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Cd at down-stream end of reach	Mass balance dissolved Cd at upstream end of reach (ug/L)	Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L)	Check of mass balance with regression estimate of 90%tile diss. Cd at RM 66 based on CH2M-Hill's data compilation and log-log cubic regression (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	2,000	20	0.31	--	2,000	--	20.0	na	0.976	--	0.31	
1	111.7	106.6					2,000	2,009	20.0	20.6	na	0.975	0.31	0.32	
2	106.6	101.7					2,009	2,011	20.6	20.7	na	0.975	0.32	0.32	
3	101.7	96.0	*Aquifer Inflow/Outflow*	-25.27	na	na	2,011	1,991	20.7	21.0	na	0.974	0.32	0.32	
4	96.0	93.0	*Aquifer Inflow/Outflow*	-10.64	na	na	1,991	1,980	21.0	21.0	na	0.974	0.32	0.32	
5	93.0	90.4					1,980	1,982	21.0	21.1	na	0.974	0.32	0.32	
6	90.4	87.8					1,982	1,982	21.1	21.1	na	0.974	0.32	0.32	
7	87.8	85.3	*Aquifer Inflow*	385.30	85.0	0.008	1,946	2,367	21.1	33.0	na	0.955	0.32	0.28	
8	85.3	82.6					2,367	2,367	33.0	33.0	na	0.955	0.28	0.28	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	2,367	2,117	33.0	33.3	na	0.955	0.28	0.29	
10	79.8	78.0	*Aquifer Inflow*	451.40	85.0	0.008	2,117	2,568	33.3	42.4	na	0.945	0.29	0.23	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	2,568	2,389	42.4	42.4	na	0.945	0.23	0.23	
12	74.1	69.8	*Hangman Cr + Aquifer*	178.40	85.0	0.008	2,389	2,567	42.4	45.4	na	0.942	0.23	0.22	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	0.008	2,567	2,610	45.4	46.0	na	0.941	0.22	0.21	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	0.008	2,610	2,736	46.0	49.3	na	0.939	0.21	0.24	na

(1) dissolved Cd was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Cd assumed to be: 0.008 ug/L based on comparison of regression estimate for diss Cd at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			NPDES Dischargers	Acute Mixing Zone Boundary						Chronic Mixing Zone Boundary						Complete Mix				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Cd criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Cd conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Cd criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Cd conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Cd criteria (ug/L)	Chronic dissolved Cd criteria (ug/L)	Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	0.65	0.31	0.31	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6.39	39.6	1.35	0.983	0.50	Yes	54.86	22.3	0.34	0.972	0.33	Yes	20.6	0.67	0.32	0.32	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	25.97	25.4	0.84	1.001	0.37	Yes	250.74	21.1	0.33	0.974	0.32	Yes	20.7	0.67	0.32	0.32	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	11.48	31.5	1.06	0.992	0.43	Yes	105.84	21.9	0.33	0.973	0.33	Yes	21.0	0.68	0.32	0.32	Yes
4	96.0	93.0														21.0	0.68	0.32	0.32	Yes
5	93.0	90.4	*Liberty Lake POTW*	33.00	24.8	0.81	1.002	0.37	Yes	320.96	21.4	0.33	0.974	0.33	Yes	21.1	0.68	0.33	0.32	Yes
6	90.4	87.8														21.1	0.68	0.33	0.32	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	2.35	63.2	2.25	0.963	0.72	Yes	14.49	27.9	0.40	0.962	0.38	Yes	33.0	1.11	0.45	0.28	Yes
8	85.3	82.6														33.0	1.11	0.45	0.28	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	10.56	43.6	1.51	0.979	0.40	Yes	96.62	34.2	0.47	0.954	0.29	Yes	33.3	1.12	0.46	0.29	Yes
10	79.8	78.0														42.4	1.46	0.55	0.23	Yes
11	78.0	74.1														42.4	1.46	0.55	0.23	Yes
12	74.1	69.8														45.4	1.57	0.57	0.22	Yes
13	69.8	67.6														46.0	1.60	0.58	0.21	Yes
14	67.6	64.6	*City of Spokane AWTP*	1.96	96.6	3.56	0.945	0.84	Yes	10.58	55.4	0.67	0.934	0.33	Yes	49.3	1.72	0.61	0.24	Yes

Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			Effluent Characteristics										
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Cd (ug/L)	Effluent ratio of dissolved/total rec. Cd	Dissolved Cd (ug/L)	Acute dissolved Cd criteria (ug/L)	Chronic dissolved Cd criteria (ug/L)	Effluent meets end of-pipe criteria?
0	--	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	1.52	0.893	1.36	5.54	1.36	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	1.52	0.893	1.36	5.54	1.36	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	1.52	0.893	1.36	5.54	1.36	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	1.52	0.893	1.36	5.54	1.36	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	1.31	0.901	1.18	4.51	1.18	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	1.52	0.893	1.36	5.54	1.36	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	1.52	0.893	1.36	5.54	1.36	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			Aquifer/Tributary Inflow/Outflow				Reach Mass Balance Calculations								
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Cd (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Cd at down-stream end of reach	Mass balance dissolved Cd at upstream end of reach (ug/L)	Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L)	Check of mass balance with regression estimate of 90%tile diss. Cd at RM 66 based on CH2M-Hill's data compilation and log-log cubic regression (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	**20,000**	20	0.31	--	20,000	--	20.0	na	0.976	--	0.31	
1	111.7	106.6					20,000	20,009	20.0	20.1	na	0.976	0.31	0.31	
2	106.6	101.7					20,009	20,011	20.1	20.1	na	0.976	0.31	0.31	
3	101.7	96.0	*Aquifer Inflow/Outflow*	-88.01	na	na	20,011	19,928	20.1	20.1	na	0.976	0.31	0.31	
4	96.0	93.0	*Aquifer Inflow/Outflow*	-37.06	na	na	19,928	19,891	20.1	20.1	na	0.976	0.31	0.31	
5	93.0	90.4					19,891	19,893	20.1	20.1	na	0.976	0.31	0.31	
6	90.4	87.8					19,893	19,893	20.1	20.1	na	0.976	0.31	0.31	
7	87.8	85.3	*Aquifer Inflow*	481.64	85.0	0.008	19,857	20,374	20.1	21.8	na	0.973	0.31	0.31	
8	85.3	82.6					20,374	20,374	21.8	21.8	na	0.973	0.31	0.31	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	20,374	20,124	21.8	21.9	na	0.973	0.31	0.31	
10	79.8	78.0	*Aquifer Inflow*	564.25	85.0	0.008	20,124	20,688	21.9	23.6	na	0.969	0.31	0.30	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	20,688	20,509	23.6	23.6	na	0.969	0.30	0.30	
12	74.1	69.8	*Hangman Cr + Aquifer*	217.97	85.0	0.008	20,509	20,727	23.6	24.2	na	0.968	0.30	0.30	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	0.008	20,727	20,769	24.2	24.4	na	0.968	0.30	0.29	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	0.008	20,769	20,896	24.4	24.9	na	0.967	0.29	0.30	na

(1) dissolved Cd was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Cd assumed to be: 0.008 ug/L based on comparison of regression estimate for diss Cd at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Cadmium

Lake Coeur d'Alene Outlet at 20,000 cfs

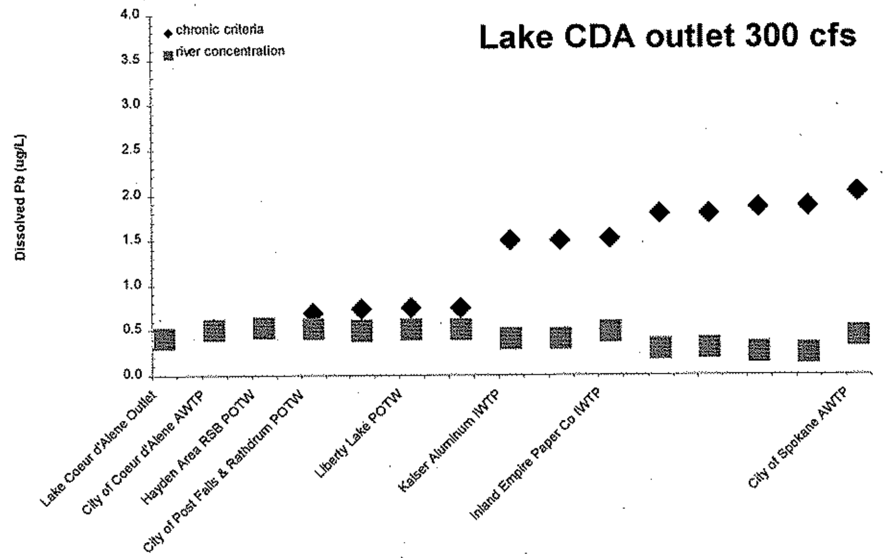
NPDES Dischargers at Current Design Flows

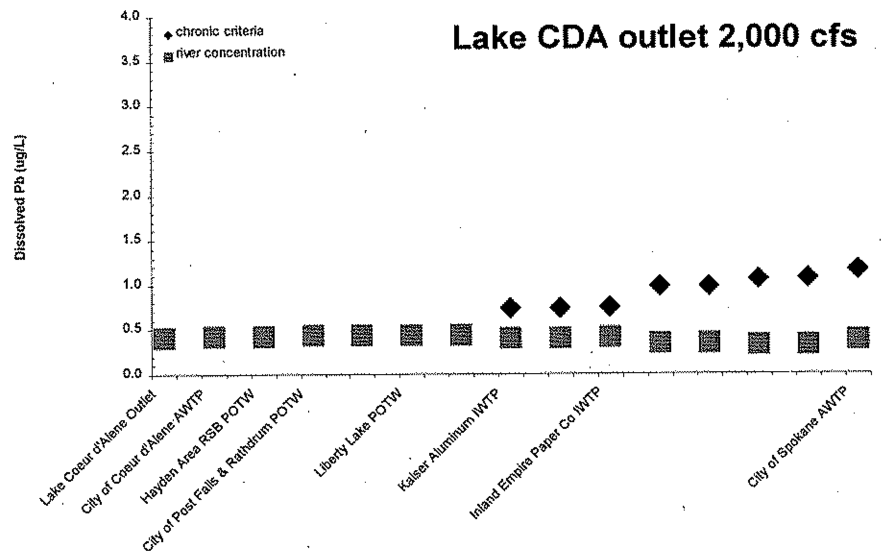
Spokane River Model Reaches			NPDES Dischargers	Acute Mixing Zone Boundary						Chronic Mixing Zone Boundary						Complete Mix				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Cd criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Cd conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Cd criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Cd conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Cd criteria (ug/L)	Chronic dissolved Cd criteria (ug/L)	Mass balance dissolved Cd at down-stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	0.65	0.31	0.31	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	54.86	22.3	0.73	1.007	0.34	Yes	539.61	20.2	0.32	0.976	0.31	Yes	20.1	0.65	0.31	0.31	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	249.70	20.6	0.67	1.010	0.33	Yes	2488.03	20.1	0.31	0.976	0.31	Yes	20.1	0.65	0.31	0.31	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	105.31	21.3	0.69	1.009	0.34	Yes	1044.05	20.2	0.32	0.976	0.31	Yes	20.1	0.65	0.31	0.31	Yes
4	96.0	93.0														20.1	0.65	0.31	0.31	Yes
5	93.0	90.4	*Liberty Lake POTW*	322.40	20.5	0.66	1.010	0.33	Yes	3215.04	20.1	0.31	0.976	0.31	Yes	20.1	0.65	0.31	0.31	Yes
6	90.4	87.8														20.1	0.65	0.31	0.31	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	14.77	26.9	0.89	0.999	0.39	Yes	138.70	20.8	0.32	0.975	0.32	Yes	21.8	0.71	0.33	0.31	Yes
8	85.3	82.6														21.8	0.71	0.33	0.31	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	83.30	23.3	0.76	1.005	0.33	Yes	824.03	22.0	0.34	0.972	0.31	Yes	21.9	0.71	0.33	0.31	Yes
10	79.8	78.0														23.6	0.77	0.35	0.30	Yes
11	78.0	74.1														23.6	0.77	0.35	0.30	Yes
12	74.1	69.8														24.2	0.80	0.36	0.30	Yes
13	69.8	67.6														24.4	0.80	0.36	0.29	Yes
14	67.6	64.6	*City of Spokane AWTP*	8.63	38.3	1.31	0.984	0.44	Yes	77.27	25.9	0.38	0.965	0.31	Yes	24.9	0.82	0.37	0.30	Yes

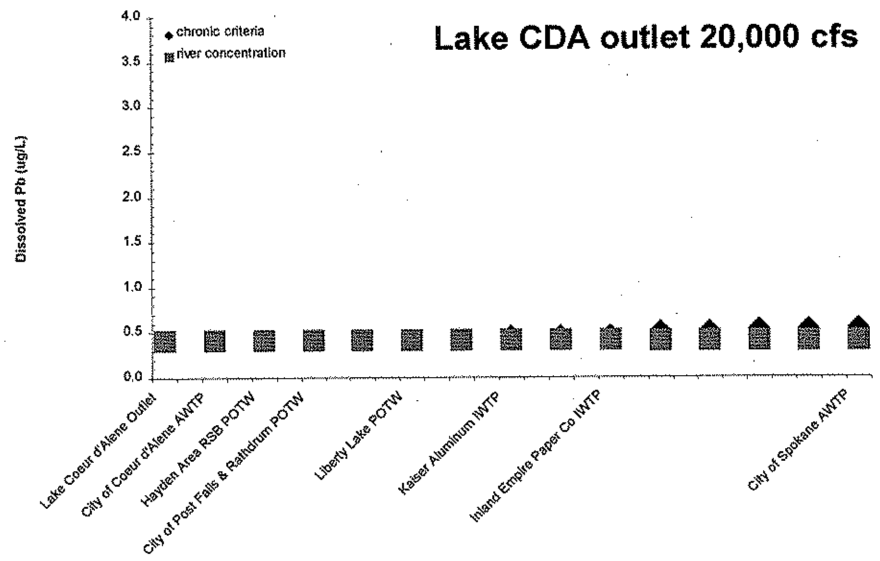
Appendix D.2

Results for Lead

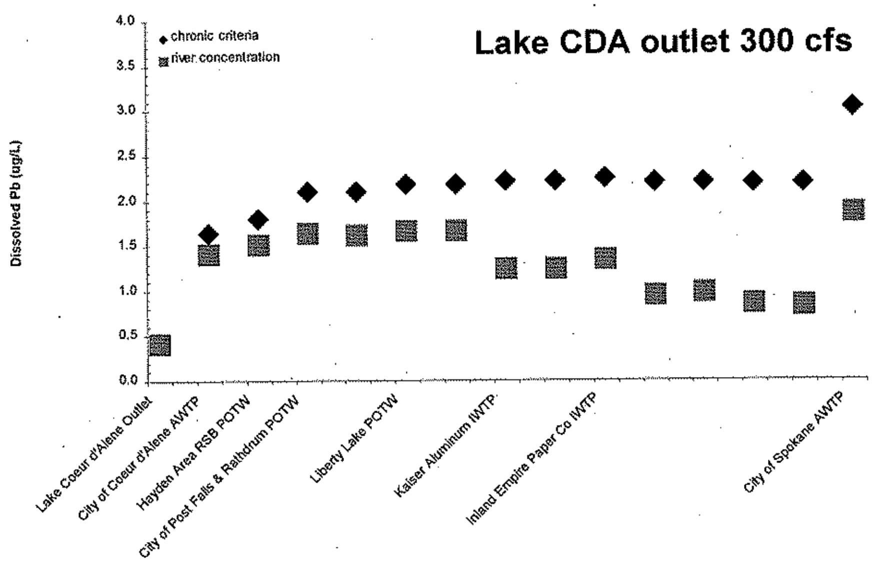
Dissolved Pb after complete mix at current effluent design flows.

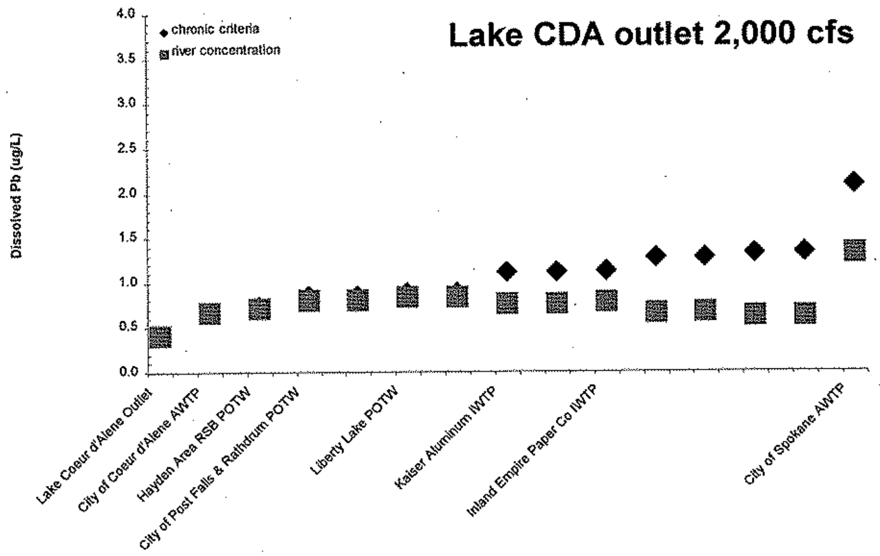


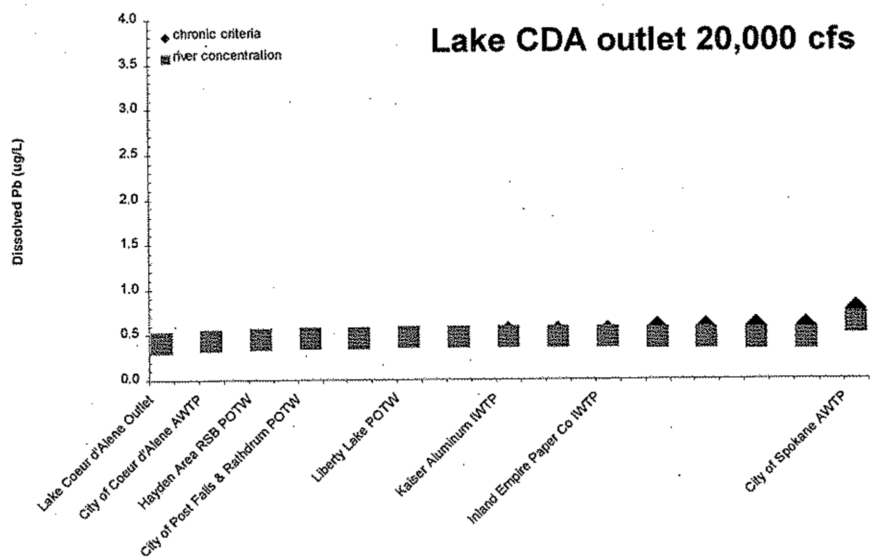




Dissolved Pb after complete mix at 20X current design flows.







Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 300 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches				*Effluent Characteristics*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Pb from total rec. tangent equation (ug/L)	Effluent ratio of dis-solved/ total rec. Pb	Dissolved Pb (ug/L)	Acute dissolved Pb criteria (ug/L)	Chronic dissolved Pb criteria (ug/L)	Effluent meets end-of-pipe criteria?
0	--	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	3.7	0.737	2.7	96.5	3.8	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	3.7	0.737	2.7	96.5	3.8	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	3.7	0.737	2.7	96.5	3.8	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	3.7	0.737	2.7	96.5	3.8	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	3.0	0.764	2.3	78.7	3.1	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	3.7	0.737	2.7	96.5	3.8	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	3.7	0.737	2.7	96.5	3.8	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*Aquifer/Tributary Inflow/Outflow*				*Reach Mass Balance Calculations*										
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Pb (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regres sion 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Pb at down stream end of reach	Mass balance dissolved Pb at upstream end of reach (ug/L)	Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L)	Check of mass balance with regres sion estimate of 90%tile diss. Pb at RM 66 based on CH2M-Hill's data comp-ilation and log-log cubic regres-sion (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	300	20	0.41	--	300	--	20.0	na	1.000	--	0.41	
1	111.7	106.6					300	309	20.0	23.8	na	1.000	0.41	0.51	
2	106.6	101.7					309	311	23.8	24.5	na	0.996	0.51	0.53	
3	101.7	96.0	*Aquifer Inflow/Outflow*	28.05	85.0	0.09	311	344	24.5	31.1	na	0.961	0.53	0.52	
4	96.0	93.0	*Aquifer Inflow/Outflow*	11.81	85.0	0.09	344	356	31.1	32.9	na	0.953	0.52	0.50	
5	93.0	90.4					356	357	32.9	33.4	na	0.951	0.50	0.51	
6	90.4	87.8					357	357	33.4	33.4	na	0.951	0.51	0.51	
7	87.8	85.3	*Aquifer Inflow*	303.42	85.0	0.09	321	661	33.4	61.8	na	0.861	0.51	0.40	
8	85.3	82.6					661	661	61.8	61.8	na	0.861	0.40	0.40	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	661	411	61.8	63.1	na	0.858	0.40	0.48	
10	79.8	78.0	*Aquifer Inflow*	355.47	85.0	0.09	411	766	63.1	73.2	na	0.836	0.48	0.28	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	766	587	73.2	73.2	na	0.836	0.28	0.30	
12	74.1	69.8	*Hangman Cr + Aquifer*	144.77	85.0	0.09	587	731	73.2	75.6	na	0.832	0.30	0.25	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	0.09	731	774	75.6	76.1	na	0.831	0.25	0.24	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	0.09	774	901	76.1	81.9	na	0.820	0.24	0.44	na

(1) dissolved Pb was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Pb assumed to be: 0.09 ug/L based on comparison of regression estimate for diss Pb at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 300 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			NPDES Dischargers	Acute Mixing Zone Boundary						Chronic Mixing Zone Boundary						Complete Mix				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Pb criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Pb conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Pb criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Pb conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Pb criteria (ug/L)	Chronic dissolved Pb criteria (ug/L)	Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	10.5	0.41	0.41	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	1.81	89.1	57.0	0.808	1.8	Yes	9.08	33.8	0.76	0.949	0.73	Yes	23.8	13.1	0.51	0.51	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	4.84	48.8	29.3	0.896	1.0	Yes	39.44	26.8	0.59	0.983	0.58	Yes	24.5	13.6	0.53	0.53	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	2.62	70.5	44.0	0.842	1.5	Yes	17.23	31.5	0.70	0.959	0.68	Yes	31.1	17.8	0.69	0.52	Yes
4	96.0	93.0														32.9	18.9	0.74	0.50	Yes
5	93.0	90.4	*Liberty Lake POTW*	6.75	49.5	29.8	0.893	0.9	Yes	58.51	34.8	0.79	0.945	0.54	Yes	33.4	19.2	0.75	0.51	Yes
6	90.4	87.8														33.4	19.2	0.75	0.51	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	1.22	104.2	67.5	0.785	2.0	Yes	3.23	60.2	1.44	0.865	1.13	Yes	61.8	38.1	1.49	0.40	Yes
8	85.3	82.6														61.8	38.1	1.49	0.40	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	3.67	84.5	53.7	0.816	1.1	Yes	27.70	64.8	1.57	0.854	0.50	Yes	63.1	39.0	1.52	0.48	Yes
10	79.8	78.0														73.2	45.9	1.79	0.28	Yes
11	78.0	74.1														73.2	45.9	1.79	0.30	Yes
12	74.1	69.8														75.6	47.5	1.85	0.25	Yes
13	69.8	67.6														76.1	47.9	1.87	0.24	Yes
14	67.6	64.6	*City of Spokane AWTP*	1.28	129.7	85.6	0.753	2.2	Yes	3.84	94.0	2.35	0.800	0.94	Yes	81.9	51.9	2.02	0.44	Yes

Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches				*Effluent Characteristics*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Pb from total rec. tangent equation (ug/L)	Effluent ratio of dis-solved/ total rec. Pb	Dissolved Pb (ug/L)	Acute dissolved Pb criteria (ug/L)	Chronic dissolved Pb criteria (ug/L)	Effluent meets end-of-pipe criteria?
0	–	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	3.7	0.737	2.7	96.5	3.8	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	3.7	0.737	2.7	96.5	3.8	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	3.7	0.737	2.7	96.5	3.8	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	3.7	0.737	2.7	96.5	3.8	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	3.0	0.764	2.3	78.7	3.1	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	3.7	0.737	2.7	96.5	3.8	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	3.7	0.737	2.7	96.5	3.8	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*Aquifer/Tributary Inflow/Outflow*				*Reach Mass Balance Calculations*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Pb (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regres sion 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Pb at down stream end of reach	Mass balance dissolved Pb at upstream end of reach (ug/L)	Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L)	Check of mass balance with regres sion estimate of 90%tile diss. Pb at RM 66 based on CH2M-Hill's data comp-ilation and log-log cubic regres-sion (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	2,000	20	0.41	--	2,000	--	20.0	na	1.000	--	0.41	
1	111.7	106.6					2,000	2,009	20.0	20.6	na	1.000	0.41	0.43	
2	106.6	101.7					2,009	2,011	20.6	20.7	na	1.000	0.43	0.43	
3	101.7	96.0	*Aquifer Inflow/Outflow*	-25.27	na	na	2,011	1,991	20.7	21.0	na	1.000	0.43	0.44	
4	96.0	93.0	*Aquifer Inflow/Outflow*	-10.64	na	na	1,991	1,980	21.0	21.0	na	1.000	0.44	0.44	
5	93.0	90.4					1,980	1,982	21.0	21.1	na	1.000	0.44	0.44	
6	90.4	87.8					1,982	1,982	21.1	21.1	na	1.000	0.44	0.44	
7	87.8	85.3	*Aquifer Inflow*	385.30	85.0	0.09	1,946	2,367	21.1	33.0	na	0.953	0.44	0.40	
8	85.3	82.6					2,367	2,367	33.0	33.0	na	0.953	0.40	0.40	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	2,367	2,117	33.0	33.3	na	0.951	0.40	0.41	
10	79.8	78.0	*Aquifer Inflow*	451.40	85.0	0.09	2,117	2,568	33.3	42.4	na	0.916	0.41	0.34	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	2,568	2,389	42.4	42.4	na	0.916	0.34	0.34	
12	74.1	69.8	*Hangman Cr + Aquifer*	178.40	85.0	0.09	2,389	2,567	42.4	45.4	na	0.906	0.34	0.32	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	0.09	2,567	2,610	45.4	46.0	na	0.904	0.32	0.32	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	0.09	2,610	2,736	46.0	49.3	na	0.894	0.32	0.38	na

(1) dissolved Pb was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Pb assumed to be: 0.09 ug/L based on comparison of regression estimate for diss Pb at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*NPDES Dischargers*	*Acute Mixing Zone Boundary*						*Chronic Mixing Zone Boundary*						*Complete Mix*				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Pb criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Pb conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Pb criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Pb conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Pb criteria (ug/L)	Chronic dissolved Pb criteria (ug/L)	Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	10.5	0.41	0.41	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6.39	39.6	23.2	0.926	0.9	Yes	54.86	22.3	0.47	1.000	0.47	Yes	20.6	10.9	0.43	0.43	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	25.97	25.4	14.1	0.991	0.5	Yes	250.74	21.1	0.44	1.000	0.44	Yes	20.7	11.0	0.43	0.43	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	11.48	31.5	18.0	0.959	0.7	Yes	105.84	21.9	0.46	1.000	0.46	Yes	21.0	11.2	0.44	0.44	Yes
4	96.0	93.0														21.0	11.2	0.44	0.44	Yes
5	93.0	90.4	*Liberty Lake POTW*	33.00	24.8	13.7	0.994	0.5	Yes	320.96	21.4	0.45	1.000	0.45	Yes	21.1	11.3	0.44	0.44	Yes
6	90.4	87.8														21.1	11.3	0.44	0.44	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	2.35	63.2	39.1	0.858	1.3	Yes	14.49	27.9	0.61	0.977	0.60	Yes	33.0	19.0	0.74	0.40	Yes
8	85.3	82.6														33.0	19.0	0.74	0.40	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	10.56	43.6	25.9	0.912	0.7	Yes	96.62	34.2	0.77	0.947	0.43	Yes	33.3	19.2	0.75	0.41	Yes
10	79.8	78.0														42.4	25.1	0.98	0.34	Yes
11	78.0	74.1														42.4	25.1	0.98	0.34	Yes
12	74.1	69.8														45.4	27.1	1.05	0.32	Yes
13	69.8	67.6														46.0	27.5	1.07	0.32	Yes
14	67.6	64.6	*City of Spokane AWTP*	1.96	96.6	62.2	0.796	1.6	Yes	10.58	55.4	1.32	0.877	0.58	Yes	49.3	29.7	1.16	0.38	Yes

Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 20,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches				Effluent Characteristics									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Pb from total rec. tangent equation (ug/L)	Effluent ratio of dis-solved/ total rec. Pb	Dissolved Pb (ug/L)	Acute dissolved Pb criteria (ug/L)	Chronic dissolved Pb criteria (ug/L)	Effluent meets end-of-pipe criteria?
0	--	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	3.7	0.737	2.7	96.5	3.8	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	3.7	0.737	2.7	96.5	3.8	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	3.7	0.737	2.7	96.5	3.8	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	3.7	0.737	2.7	96.5	3.8	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	3.0	0.764	2.3	78.7	3.1	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	3.7	0.737	2.7	96.5	3.8	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	3.7	0.737	2.7	96.5	3.8	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Lead

Lake Coeur d'Alene Outlet at 20,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			Aquifer/Tributary Inflow/Outflow				Reach Mass Balance Calculations								
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Pb (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Pb at down stream end of reach	Mass balance dissolved Pb at upstream end of reach (ug/L)	Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L)	Check of mass balance with regression estimate of 90%tile diss. Pb at RM 66 based on CH2M-Hill's data compilation and log-log cubic regres-sion (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	20,000	20	0.41	--	20,000	--	20.0	na	1.000	--	0.41	
1	111.7	106.6					20,000	20,009	20.0	20.1	na	1.000	0.41	0.41	
2	106.6	101.7					20,009	20,011	20.1	20.1	na	1.000	0.41	0.41	
3	101.7	96.0	*Aquifer Inflow/Outflow*	-88.01	na	na	20,011	19,928	20.1	20.1	na	1.000	0.41	0.41	
4	96.0	93.0	*Aquifer Inflow/Outflow*	-37.06	na	na	19,928	19,891	20.1	20.1	na	1.000	0.41	0.41	
5	93.0	90.4					19,891	19,893	20.1	20.1	na	1.000	0.41	0.41	
6	90.4	87.8					19,893	19,893	20.1	20.1	na	1.000	0.41	0.41	
7	87.8	85.3	*Aquifer Inflow*	481.64	85.0	0.09	19,857	20,374	20.1	21.8	na	1.000	0.41	0.41	
8	85.3	82.6					20,374	20,374	21.8	21.8	na	1.000	0.41	0.41	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	20,374	20,124	21.8	21.9	na	1.000	0.41	0.41	
10	79.8	78.0	*Aquifer Inflow*	564.25	85.0	0.09	20,124	20,688	21.9	23.6	na	1.000	0.41	0.40	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	20,688	20,509	23.6	23.6	na	1.000	0.40	0.40	
12	74.1	69.8	*Hangman Cr + Aquifer*	217.97	85.0	0.09	20,509	20,727	23.6	24.2	na	0.998	0.40	0.40	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	0.09	20,727	20,769	24.2	24.4	na	0.997	0.40	0.40	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	0.09	20,769	20,896	24.4	24.9	na	0.994	0.40	0.41	na

(1) dissolved Pb was estimated to meet the chronic criteria at the Lake CDA outlet

(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.

(3) aquifer diss Pb assumed to be: 0.09 ug/L based on comparison of regression estimate for diss Pb at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Lead

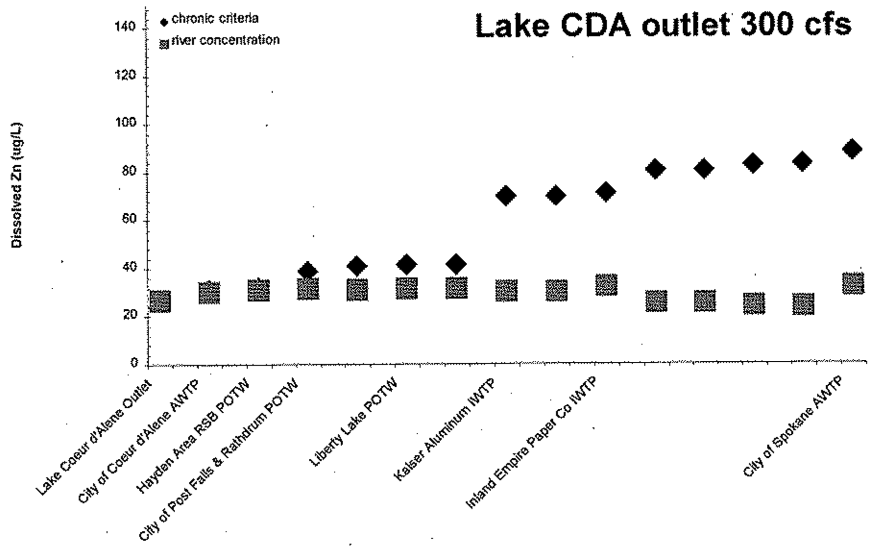
Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

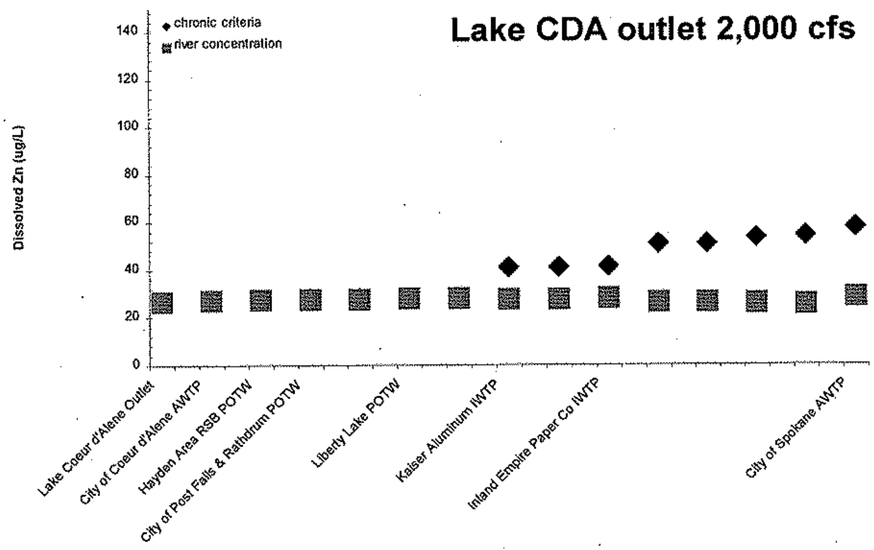
Spokane River Model Reaches			NPDES Dischargers	Acute Mixing Zone Boundary						Chronic Mixing Zone Boundary						Complete Mix				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Pb criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Pb conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Pb criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Pb conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Pb criteria (ug/L)	Chronic dissolved Pb criteria (ug/L)	Mass balance dissolved Pb at down stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	10.5	0.41	0.41	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	54.86	22.3	12.2	1.000	0.5	Yes	539.61	20.2	0.42	1.000	0.42	Yes	20.1	10.6	0.41	0.41	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	249.70	20.6	11.1	1.000	0.4	Yes	2488.03	20.1	0.41	1.000	0.41	Yes	20.1	10.6	0.41	0.41	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	105.31	21.3	11.6	1.000	0.4	Yes	1044.05	20.2	0.42	1.000	0.42	Yes	20.1	10.6	0.41	0.41	Yes
4	96.0	93.0														20.1	10.6	0.41	0.41	Yes
5	93.0	90.4	*Liberty Lake POTW*	322.40	20.5	11.1	1.000	0.4	Yes	3215.04	20.1	0.41	1.000	0.41	Yes	20.1	10.6	0.41	0.41	Yes
6	90.4	87.8														20.1	10.6	0.41	0.41	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	14.77	26.9	15.1	0.982	0.6	Yes	138.70	20.8	0.43	1.000	0.43	Yes	21.8	11.8	0.46	0.41	Yes
8	85.3	82.6														21.8	11.8	0.46	0.41	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	83.30	23.3	12.8	1.000	0.4	Yes	824.03	22.0	0.46	1.000	0.41	Yes	21.9	11.8	0.46	0.41	Yes
10	79.8	78.0														23.6	13.0	0.51	0.40	Yes
11	78.0	74.1														23.6	13.0	0.51	0.40	Yes
12	74.1	69.8														24.2	13.4	0.52	0.40	Yes
13	69.8	67.6														24.4	13.5	0.53	0.40	Yes
14	67.6	64.6	*City of Spokane AWTP*	8.63	38.3	22.4	0.931	0.7	Yes	77.27	25.9	0.56	0.988	0.44	Yes	24.9	13.8	0.54	0.41	Yes

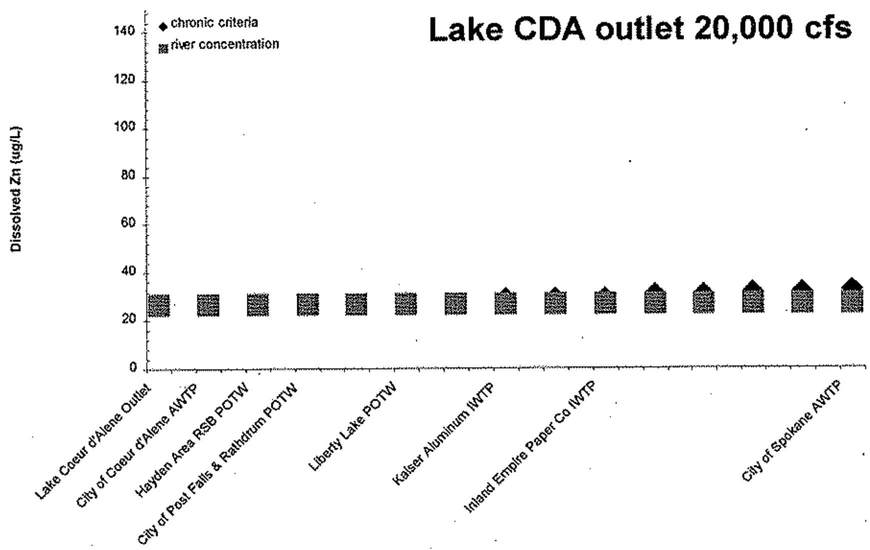
Appendix D.3

Results for Zinc

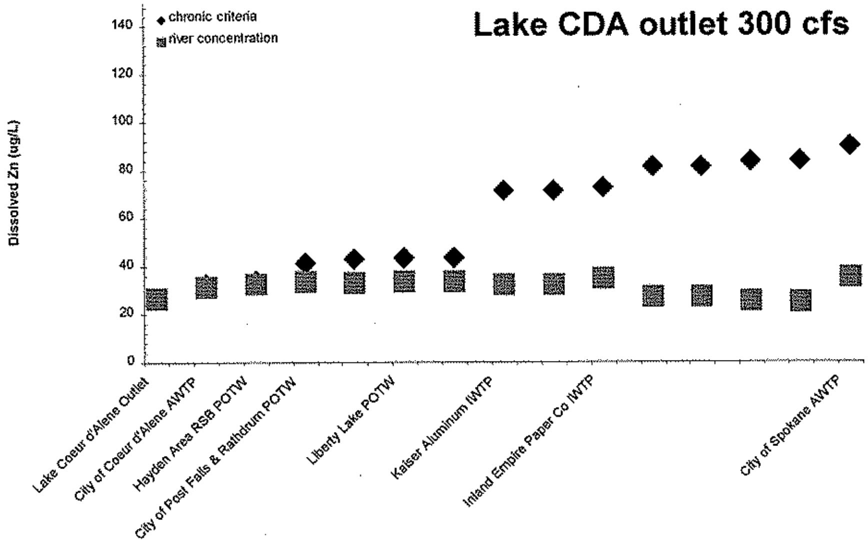
Dissolved Zn after complete mix at current effluent design flows.

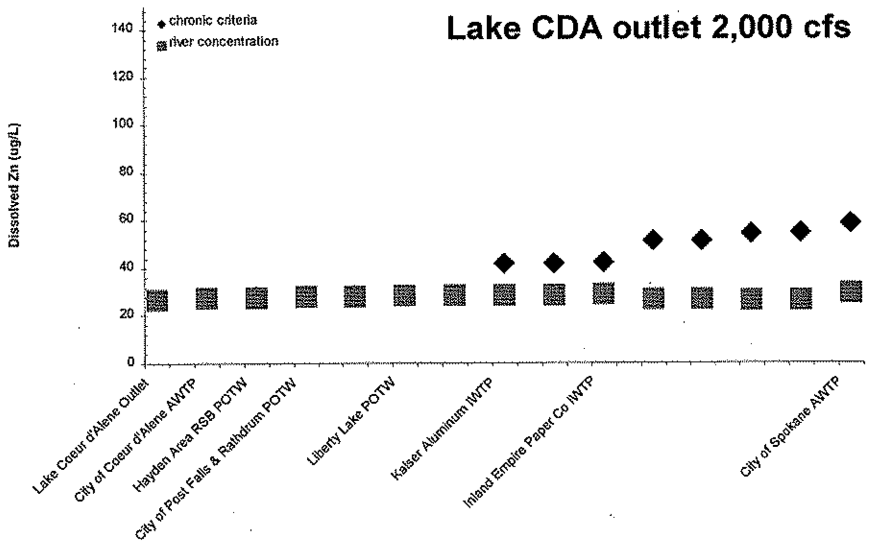


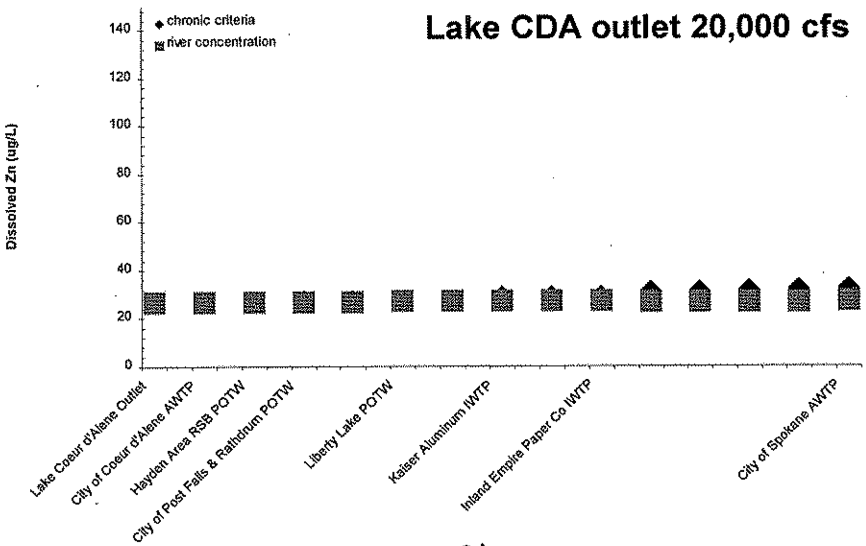




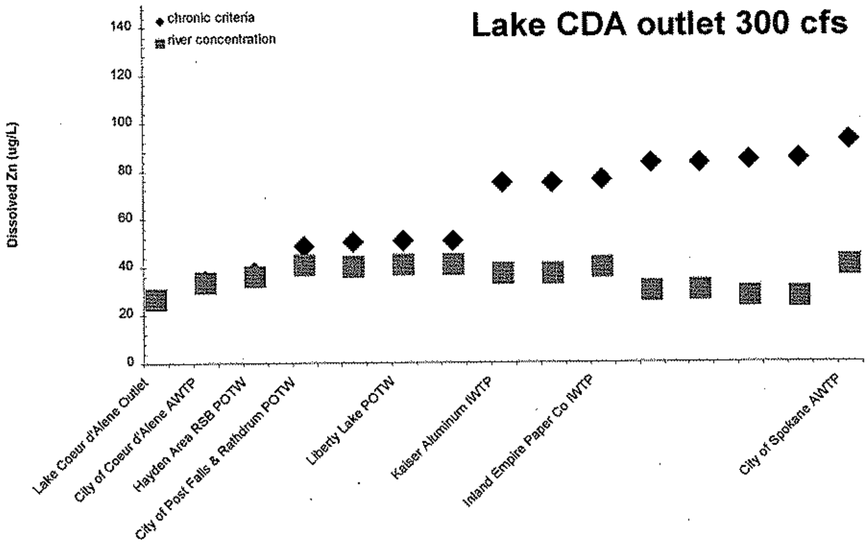
Dissolved Zn after complete mix at 20-year projected design flows.

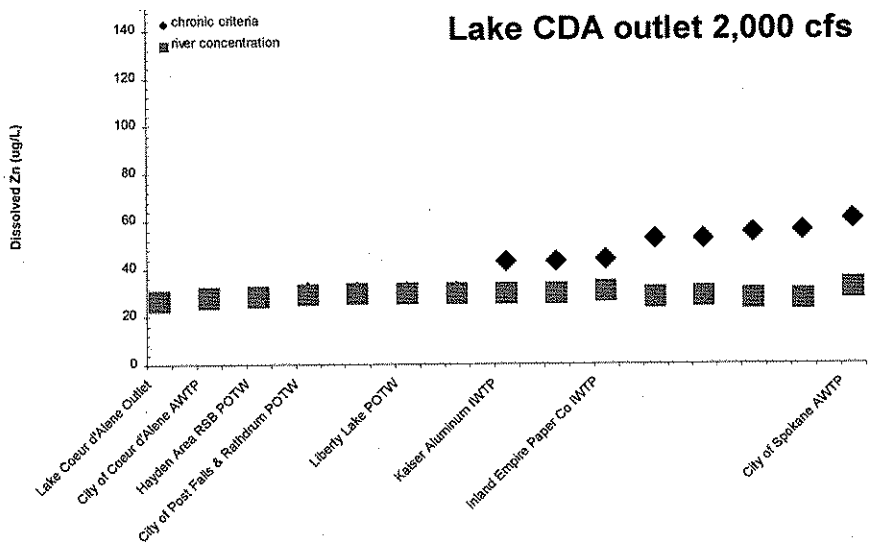


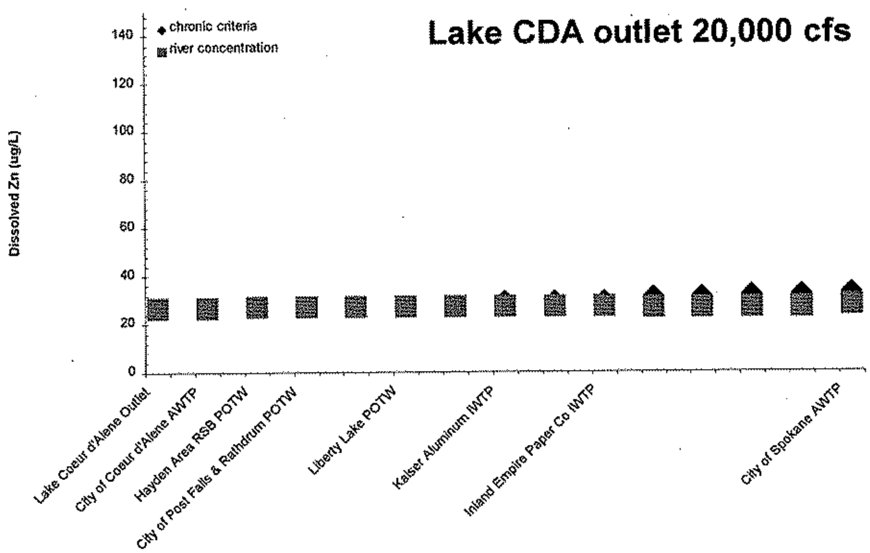




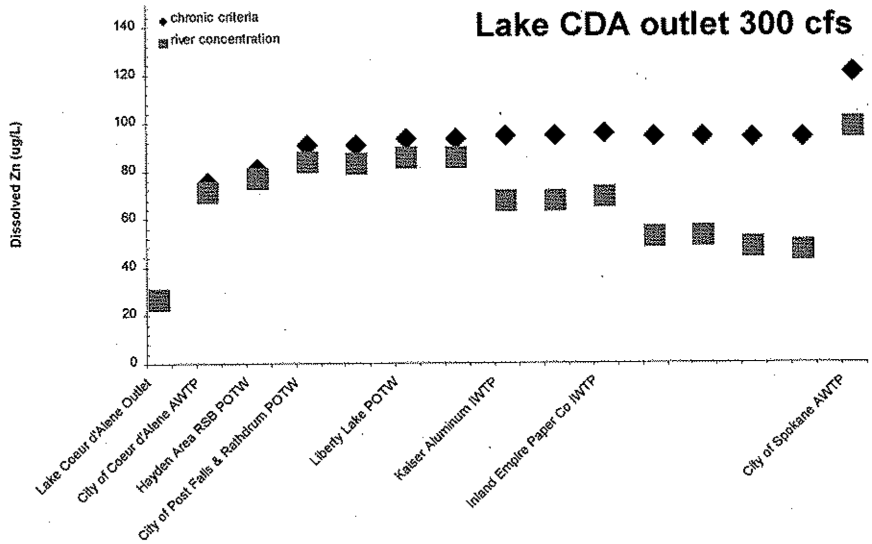
Dissolved Zn after complete mix at 50-year projected design flows.

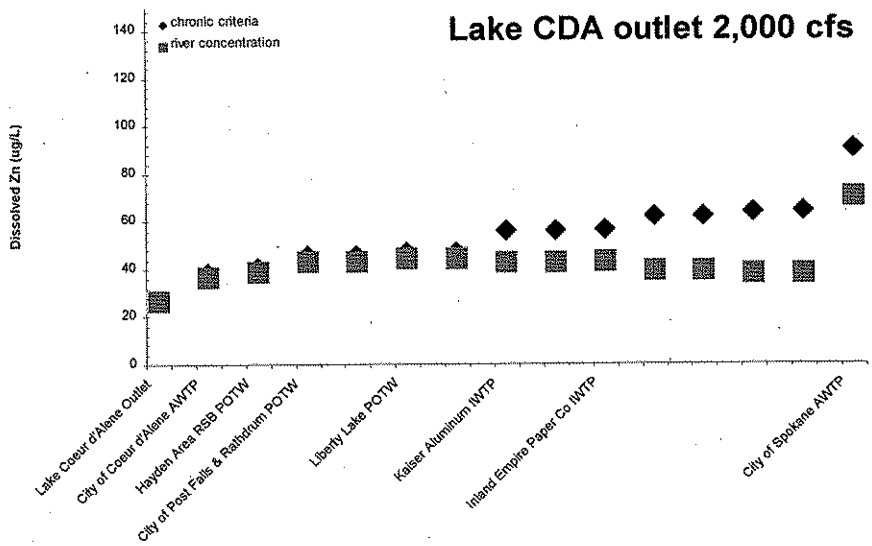


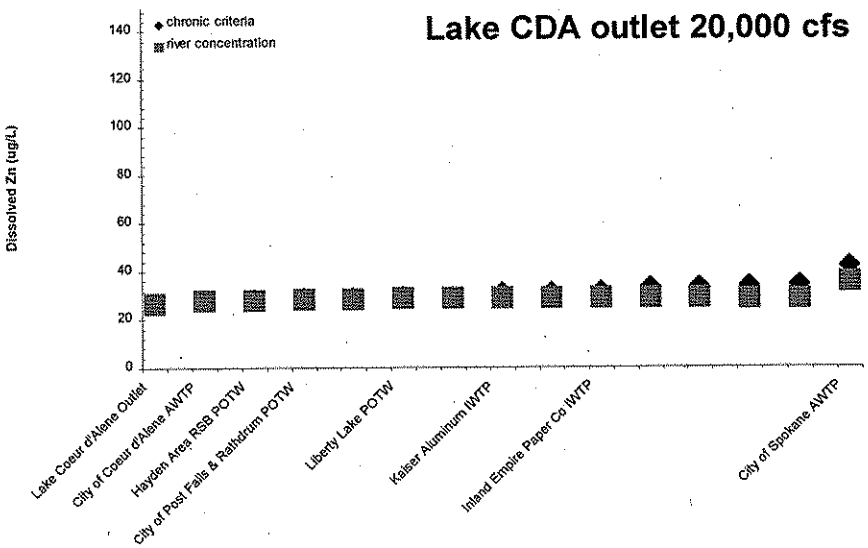




Dissolved Zn after complete mix at 20X current effluent design flows.







Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 300 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*Effluent Characteristics*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Zn (ug/L)	Effluent ratio of dissolved/total rec. Zn	Dissolved Zn (ug/L)	Acute dissolved Zn criteria (ug/L)	Chronic dissolved Zn criteria (ug/L)	Effluent meets end of-pipe criteria?
0	--	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	145.2	0.986	143.2	156.8	143.2	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	145.2	0.986	143.2	156.8	143.2	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	145.2	0.986	143.2	156.8	143.2	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	145.2	0.986	143.2	156.8	143.2	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	123.7	0.986	122.0	133.6	122.0	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	145.2	0.986	143.2	156.8	143.2	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	145.2	0.986	143.2	156.8	143.2	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 300 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			Aquifer/Tributary Inflow/Outflow				Reach Mass Balance Calculations									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Zn (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Zn	Mass balance dissolved Zn at upstream end of reach (ug/L)	Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L)	Check of mass balance with regression estimate of 90%tile diss. Zn at RM 66 based on CH2M-Hill's data compilation and log-log cubic regression (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	300	20	26.7	--	300	--	20.0	na	0.986	--	26.7	
1	111.7	106.6					300	309	20.0	23.8	na	0.986	26.7	30.2	
2	106.6	101.7					309	311	23.8	24.5	na	0.986	30.2	30.9	
3	101.7	96.0	*Aquifer Inflow/Outflow*	28.05	85.0	18	311	344	24.5	31.1	na	0.986	30.9	31.4	
4	96.0	93.0	*Aquifer Inflow/Outflow*	11.81	85.0	18	344	356	31.1	32.9	na	0.986	31.4	31.0	
5	93.0	90.4					356	357	32.9	33.4	na	0.986	31.0	31.5	
6	90.4	87.8					357	357	33.4	33.4	na	0.986	31.5	31.5	
7	87.8	85.3	*Aquifer Inflow*	303.42	85.0	18	321	661	33.4	61.8	na	0.986	31.5	30.1	
8	85.3	82.6					661	661	61.8	61.8	na	0.986	30.1	30.1	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	661	411	61.8	63.1	na	0.986	30.1	32.1	
10	79.8	78.0	*Aquifer Inflow*	355.47	85.0	18	411	766	63.1	73.2	na	0.986	32.1	25.4	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	766	587	73.2	73.2	na	0.986	25.4	25.5	
12	74.1	69.8	*Hangman Cr + Aquifer*	144.77	85.0	18	587	731	73.2	75.6	na	0.986	25.5	24.0	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	18	731	774	75.6	76.1	na	0.986	24.0	23.7	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	18	774	901	76.1	81.9	na	0.986	23.7	32.3	na

(1) dissolved zinc was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Zn assumed to be: 18 ug/L based on comparison of regression estimate for diss Zn at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 300 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			NPDES Dischargers	Acute Mixing Zone Boundary						Chronic Mixing Zone Boundary						Complete Mix				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Zn criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Zn conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Zn criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Zn conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Zn criteria (ug/L)	Chronic dissolved Zn criteria (ug/L)	Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	29.3	26.7	26.7	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	1.81	89.1	103.8	0.978	90.4	Yes	9.08	33.8	41.7	0.986	39.6	Yes	23.8	33.9	30.9	30.2	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	4.84	48.8	62.3	0.978	53.1	Yes	39.44	26.8	34.3	0.986	33.1	Yes	24.5	34.8	31.8	30.9	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	2.62	70.5	85.1	0.978	73.1	Yes	17.23	31.5	39.3	0.986	37.5	Yes	31.1	42.6	38.9	31.4	Yes
4	96.0	93.0														32.9	44.7	40.8	31.0	Yes
5	93.0	90.4	*Liberty Lake POTW*	6.75	49.5	63.1	0.978	47.2	Yes	58.51	34.8	42.8	0.986	32.9	Yes	33.4	45.2	41.3	31.5	Yes
6	90.4	87.8														33.4	45.2	41.3	31.5	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	1.22	104.2	118.5	0.978	104.6	Yes	3.23	60.2	68.0	0.986	59.5	Yes	61.8	76.1	69.5	30.1	Yes
8	85.3	82.6														61.8	76.1	69.5	30.1	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	3.67	84.5	99.2	0.978	60.4	Yes	27.70	64.8	72.4	0.986	34.2	Yes	63.1	77.4	70.7	32.1	Yes
10	79.8	78.0														73.2	87.9	80.3	25.4	Yes
11	78.0	74.1														73.2	87.9	80.3	25.5	Yes
12	74.1	69.8														75.6	90.3	82.4	24.0	Yes
13	69.8	67.6														76.1	90.8	82.9	23.7	Yes
14	67.6	64.6	*City of Spokane AWTP*	1.28	129.7	142.7	0.978	115.8	Yes	3.84	94.0	99.2	0.986	54.8	Yes	81.9	96.6	88.2	32.3	Yes

Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches				*Effluent Characteristics*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Zn (ug/L)	Effluent ratio of dissolved/total rec. Zn	Dissolved Zn (ug/L)	Acute dissolved Zn criteria (ug/L)	Chronic dissolved Zn criteria (ug/L)	Effluent meets end of-pipe criteria?
0	--	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	145.2	0.986	143.2	156.8	143.2	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	145.2	0.986	143.2	156.8	143.2	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	145.2	0.986	143.2	156.8	143.2	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	145.2	0.986	143.2	156.8	143.2	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	123.7	0.986	122.0	133.6	122.0	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	145.2	0.986	143.2	156.8	143.2	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	145.2	0.986	143.2	156.8	143.2	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 2,000 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*Aquifer/Tributary Inflow/Outflow*				*Reach Mass Balance Calculations*									
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Zn (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Zn	Mass balance dissolved Zn at upstream end of reach (ug/L)	Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L)	Check of mass balance with regression estimate of 90%tile diss. Zn at RM 66 based on CH2M-Hill's data compilation and log-log cubic regression (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	2,000	20	26.7	--	2,000	--	20.0	na	0.986	--	26.7	
1	111.7	106.6					2,000	2,009	20.0	20.6	na	0.986	26.7	27.3	
2	106.6	101.7					2,009	2,011	20.6	20.7	na	0.986	27.3	27.4	
3	101.7	96.0	*Aquifer Inflow/Outflow*	-25.27	na	na	2,011	1,991	20.7	21.0	na	0.986	27.4	27.7	
4	96.0	93.0	*Aquifer Inflow/Outflow*	-10.64	na	na	1,991	1,980	21.0	21.0	na	0.986	27.7	27.7	
5	93.0	90.4					1,980	1,982	21.0	21.1	na	0.986	27.7	27.8	
6	90.4	87.8					1,982	1,982	21.1	21.1	na	0.986	27.8	27.8	
7	87.8	85.3	*Aquifer Inflow*	385.30	85.0	18	1,946	2,367	21.1	33.0	na	0.986	27.8	27.6	
8	85.3	82.6					2,367	2,367	33.0	33.0	na	0.986	27.6	27.6	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	2,367	2,117	33.0	33.3	na	0.986	27.6	27.9	
10	79.8	78.0	*Aquifer Inflow*	451.40	85.0	18	2,117	2,568	33.3	42.4	na	0.986	27.9	26.2	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	2,568	2,389	42.4	42.4	na	0.986	26.2	26.2	
12	74.1	69.8	*Hangman Cr + Aquifer*	178.40	85.0	18	2,389	2,567	42.4	45.4	na	0.986	26.2	25.6	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	18	2,567	2,610	45.4	46.0	na	0.986	25.6	25.5	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	18	2,610	2,736	46.0	49.3	na	0.986	25.5	28.2	na

(1) dissolved zinc was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Zn assumed to be: 18 ug/L based on comparison of regression estimate for diss Zn at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 2,000 cfs

NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*NPDES Dischargers*	*Acute Mixing Zone Boundary*						*Chronic Mixing Zone Boundary*						*Complete Mix*				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Zn criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Zn conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Zn criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Zn conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Zn criteria (ug/L)	Chronic dissolved Zn criteria (ug/L)	Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	29.3	26.7	26.7	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6.39	39.6	52.2	0.978	44.6	Yes	54.86	22.3	29.3	0.986	28.8	Yes	20.6	30.0	27.4	27.3	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	25.97	25.4	35.8	0.978	31.5	Yes	250.74	21.1	27.9	0.986	27.7	Yes	20.7	30.1	27.5	27.4	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	11.48	31.5	43.0	0.978	37.2	Yes	105.84	21.9	28.8	0.986	28.5	Yes	21.0	30.5	27.9	27.7	Yes
4	96.0	93.0														21.0	30.5	27.9	27.7	Yes
5	93.0	90.4	*Liberty Lake POTW*	33.00	24.8	35.1	0.978	30.9	Yes	320.96	21.4	28.3	0.986	28.0	Yes	21.1	30.6	28.0	27.8	Yes
6	90.4	87.8														21.1	30.6	28.0	27.8	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	2.35	63.2	77.6	0.978	67.3	Yes	14.49	27.9	35.5	0.986	34.3	Yes	33.0	44.7	40.9	27.6	Yes
8	85.3	82.6														33.0	44.7	40.9	27.6	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	10.56	43.6	56.7	0.978	38.2	Yes	96.62	34.2	42.1	0.986	28.8	Yes	33.3	45.1	41.2	27.9	Yes
10	79.8	78.0														42.4	55.3	50.5	26.2	Yes
11	78.0	74.1														42.4	55.3	50.5	26.2	Yes
12	74.1	69.8														45.4	58.6	53.5	25.6	Yes
13	69.8	67.6														46.0	59.3	54.1	25.5	Yes
14	67.6	64.6	*City of Spokane AWTP*	1.96	96.6	111.1	0.978	84.9	Yes	10.58	55.4	63.3	0.986	36.6	Yes	49.3	62.9	57.4	28.2	Yes

Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			*Effluent Characteristics*										
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Flow (mgd)	Flow (cfs)	Hardness (mg/L as CaCO3)	Total rec. Zn (ug/L)	Effluent ratio of dissolved/total rec. Zn	Dissolved Zn (ug/L)	Acute dissolved Zn criteria (ug/L)	Chronic dissolved Zn criteria (ug/L)	Effluent meets end of-pipe criteria?
0	--	111.7	*Lake Coeur d'Alene Outlet*									
1	111.7	106.6	*City of Coeur d'Alene AWTP*	6	9.28	145	145.2	0.986	143.2	156.8	143.2	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	1.3	2.01	145	145.2	0.986	143.2	156.8	143.2	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	3.1	4.80	145	145.2	0.986	143.2	156.8	143.2	Yes
4	96.0	93.0										
5	93.0	90.4	*Liberty Lake POTW*	1	1.55	145	145.2	0.986	143.2	156.8	143.2	Yes
6	90.4	87.8										
7	87.8	85.3	*Kaiser Aluminum IWTP*	23.3	36.05	120	123.7	0.986	122.0	133.6	122.0	Yes
8	85.3	82.6										
9	82.6	79.8	*Inland Empire Paper Co IWTP*	4	6.19	145	145.2	0.986	143.2	156.8	143.2	Yes
10	79.8	78.0										
11	78.0	74.1										
12	74.1	69.8										
13	69.8	67.6										
14	67.6	64.6	*City of Spokane AWTP*	44	68.08	145	145.2	0.986	143.2	156.8	143.2	Yes

multiplier for municipal effluent flow = 1
multiplier for industrial effluent flow = 1

Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			Aquifer/Tributary Inflow/Outflow				*Reach Mass Balance Calculations*								
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Inflow or outflow (cfs)	Inflow hardness (mg/L as CaCO3) (2)	Inflow dissolved Zn (ug/L) (3)	Flow at upstream end of reach (cfs)	Flow at down-stream end of reach (cfs)	Mass balance hardness at up-stream end of reach (mg/L as CaCO3)	Mass balance hardness at down-stream end of reach (mg/L as CaCO3)	Check of mass balance with regression 10th %tile hardness from Pelletier 1994 (mg/L as CaCO3)	Ratio of dissolved/ total rec. Zn	Mass balance dissolved Zn at upstream end of reach (ug/L)	Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L)	Check of mass balance with regression estimate of 90%tile diss. Zn at RM 66 based on CH2M-Hill's data compilation and log-log cubic regression (ug/L) (3)
0	--	111.7	*Lk CDA Outlet (1)*	20,000	20	26.7	--	20,000	--	20.0	na	0.986	--	26.7	
1	111.7	106.6					20,000	20,009	20.0	20.1	na	0.986	26.7	26.8	
2	106.6	101.7					20,009	20,011	20.1	20.1	na	0.986	26.8	26.8	
3	101.7	96.0	*Aquifer Inflow/Outflow*	-88.01	na	na	20,011	19,928	20.1	20.1	na	0.986	26.8	26.8	
4	96.0	93.0	*Aquifer Inflow/Outflow*	-37.06	na	na	19,928	19,891	20.1	20.1	na	0.986	26.8	26.8	
5	93.0	90.4					19,891	19,893	20.1	20.1	na	0.986	26.8	26.8	
6	90.4	87.8					19,893	19,893	20.1	20.1	na	0.986	26.8	26.8	
7	87.8	85.3	*Aquifer Inflow*	481.64	85.0	18	19,857	20,374	20.1	21.8	na	0.986	26.8	26.8	
8	85.3	82.6					20,374	20,374	21.8	21.8	na	0.986	26.8	26.8	
9	82.6	79.8	*Aquifer Outflow*	-256.20	na	na	20,374	20,124	21.8	21.9	na	0.986	26.8	26.8	
10	79.8	78.0	*Aquifer Inflow*	564.25	85.0	18	20,124	20,688	21.9	23.6	na	0.986	26.8	26.6	
11	78.0	74.1	*Aquifer Outflow*	-179.70	na	na	20,688	20,509	23.6	23.6	na	0.986	26.6	26.6	
12	74.1	69.8	*Hangman Cr + Aquifer*	217.97	85.0	18	20,509	20,727	23.6	24.2	na	0.986	26.6	26.5	
13	69.8	67.6	*Aquifer Inflow*	42.75	85.0	18	20,727	20,769	24.2	24.4	na	0.986	26.5	26.5	
14	67.6	64.6	*Aquifer Inflow*	58.30	85.0	18	20,769	20,896	24.4	24.9	na	0.986	26.5	26.8	na

(1) dissolved zinc was estimated to meet the chronic criteria at the Lake CDA outlet
(2) aquifer hardness assumed to be: 85 mg/L as CaCO3 based on comparison of Pelletier (1994) regression estimate of 10%tile for station 54A120 with mass balance estimate. Lake CDA outlet hardness asssumed to be 5%tile 20 mg/L as CaCO3.
(3) aquifer diss Zn assumed to be: 18 ug/L based on comparison of regression estimate for diss Zn at RM 66 (CH2M-Hill, 1997) with mass balance estimate for downstream end reach.

Spokane River Metals Model: Zinc

Lake Coeur d'Alene Outlet at 20,000 cfs
NPDES Dischargers at Current Design Flows

Spokane River Model Reaches			NPDES Dischargers	Acute Mixing Zone Boundary						Chronic Mixing Zone Boundary						Complete Mix				
Spokane River model reach number	Up-stream river mile	Down-stream river mile		Acute dilution factor (allowing 2.5% of river flow)	Hardness at acute boundary (mg/L as CaCO3)	Acute dissolved Zn criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Zn conc. at acute boundary	Meets acute criteria at acute mixing zone boundary?	Chronic dilution factor (allowing 25% of river flow)	Hardness at chronic boundary (mg/L as CaCO3)	Chronic dissolved Zn criteria (ug/L)	Ratio of dissolved/ total rec. Pb at mixing zone boundary	Dissolved Zn conc. at chronic boundary (ug/L)	Meets chronic criteria at chronic mixing zone boundary?	Hardness at down-stream end of reach after complete mix (mg/L as CaCO3)	Acute dissolved Zn criteria (ug/L)	Chronic dissolved Zn criteria (ug/L)	Mass balance dissolved Zn at down stream end of reach after complete mix (ug/L)	Meets chronic criteria after complete mix at down-stream end of reach?
0	--	111.7														20.0	29.3	26.7	26.7	Yes
1	111.7	106.6	*City of Coeur d'Alene AWTP*	54.86	22.3	32.1	0.978	28.6	Yes	539.61	20.2	27.0	0.986	26.9	Yes	20.1	29.3	26.8	26.8	Yes
2	106.6	101.7	*Hayden Area RSB POTW*	249.70	20.6	30.0	0.978	27.0	Yes	2488.03	20.1	26.8	0.986	26.8	Yes	20.1	29.4	26.8	26.8	Yes
3	101.7	96.0	*City of Post Falls & Rathdrum POTW*	105.31	21.3	30.8	0.978	27.7	Yes	1044.05	20.2	26.9	0.986	26.9	Yes	20.1	29.4	26.8	26.8	Yes
4	96.0	93.0														20.1	29.4	26.8	26.8	Yes
5	93.0	90.4	*Liberty Lake POTW*	322.40	20.5	29.9	0.978	27.0	Yes	3215.04	20.1	26.9	0.986	26.9	Yes	20.1	29.4	26.8	26.8	Yes
6	90.4	87.8														20.1	29.4	26.8	26.8	Yes
7	87.8	85.3	*Kaiser Aluminum IWTP*	14.77	26.9	37.6	0.978	33.0	Yes	138.70	20.8	27.7	0.986	27.5	Yes	21.8	31.5	28.8	26.8	Yes
8	85.3	82.6														21.8	31.5	28.8	26.8	Yes
9	82.6	79.8	*Inland Empire Paper Co IWTP*	83.30	23.3	33.3	0.978	28.0	Yes	824.03	22.0	28.9	0.986	26.9	Yes	21.9	31.6	28.8	26.8	Yes
10	79.8	78.0														23.6	33.6	30.7	26.6	Yes
11	78.0	74.1														23.6	33.6	30.7	26.6	Yes
12	74.1	69.8														24.2	34.4	31.4	26.5	Yes
13	69.8	67.6														24.4	34.6	31.6	26.5	Yes
14	67.6	64.6	*City of Spokane AWTP*	8.63	38.3	50.8	0.978	39.7	Yes	77.27	25.9	33.3	0.986	28.0	Yes	24.9	35.3	32.2	26.8	Yes

Appendix E

Appendix E. Comparison of alternative formulas for calculating WLAs for total recoverable Pb.

WLA for total recoverable Pb = dissolved tangent / conversion factor

	Hardness (mg/L as CaCO3)	WLAs for total recoverable Pb: dissolved tangent / conversion factor WLA = (0.02378(hardness)-0.05505)/ (1.46203-((LN(hardness))*(0.145712))) (ug/L)	conversion factor =(1.46203- -((LN(hardness)) *(0.145712)))	dissolved Pb criteria equation (ug/L)	total rec Pb = WLA (ug/L)	dissolved Pb = WLA * conversion factor (ug/L)	dissolved Pb exceeds chronic criterion?
Effluent:	150	4.798	0.732	3.902	4.80	3.51	No
River:	20		1.000	0.410	0.41	0.41	No
Hypothetical mixed concentration of river and effluent dilution= 2		**<--- violates if DF>2**					
	85		0.815	2.108	2.60	2.12	**Yes**

WLA for total recoverable Pb = total recoverable tangent

	Hardness (mg/L as CaCO3)	WLAs for total recoverable Pb: total recoverable tangent WLA = (0.0261*(Hardness)-0.1119) (ug/L)	conversion factor =(1.46203- -((LN(hardness)) *(0.145712)))	dissolved Pb criteria equation (ug/L)	total rec Pb = WLA (ug/L)	dissolved Pb = WLA * conversion factor (ug/L)	dissolved Pb exceeds chronic criterion?
Effluent:	150	3.803	0.732	3.902	3.80	2.78	No
River:	20		1.000	0.410	0.41	0.41	No
Hypothetical mixed concentration of river and effluent dilution= 2		**<--- meets criteria at all dilution factors**					
	85		0.815	2.108	2.11	1.72	**No**

WLA for total recoverable Pb = dissolved tangent (effluent conversion factor = 1)

	Hardness (mg/L as CaCO3)	WLAs for total recoverable Pb: dissolved tangent WLA = (0.02378(hardness)-0.05505) (ug/L)	conversion factor = 1	dissolved Pb criteria equation (ug/L)	total rec Pb = WLA (ug/L)	dissolved Pb = WLA * conversion factor (ug/L)	dissolved Pb exceeds chronic criterion?
Effluent:	150	3.512	**1.000**	3.902	3.51	3.51	No
River:	20		1.000	0.410	0.41	0.41	No
Hypothetical mixed concentration of river and effluent dilution= 2		**<--- meets criteria at all dilution factors**					
	85		0.815	2.108	1.96	1.60	**No**

Metals Criteria.xls\hypothetical Pb, 4/29/98

Appendix F

Appendix F. Spreadsheet for calculation of WLAs and permit limits for total recoverable Cd, Pb, and Zn for NPDES dischargers to the Spokane River. The input values are for the example described in the text for the Spokane AWTP.

	Cd	***Pb***	***Zn***
Potential limits based on meeting the aquatic life criteria at effluent hardness			
1. Effluent hardness 5th percentile (mg/L as CaCO3):	138	138	138
2. Chronic aquatic life criteria for dissolved metals (ug/L)	1.31	3.23	137
3. Ratio of total recoverable / dissolved metals	1.12	---	1.01
4. Chronic aquatic life criteria for total recoverable metals (ug/L)	1.46	3.49	139
5. Number of samples (n2) required per month for compliance monitoring:	2	2	2
6. Coefficient of variation for effluent total recoverable metals:	0.431	0.335	0.283
7. Calculated limits using the equations in Box 5-2 of the 1991 TSD			
Z statistic for water quality-based LTA derivation (99%tile):	2.3263	2.3263	2.3263
Z-statistic for water quality-based daily maximum permit limit (99%tile):	2.3263	2.3263	2.3263
Z statistic for water quality-based monthly average permit limit (95%tile):	1.6449	1.6449	1.6449
number of days (n1) for averageing of chronic aquatic life criteria:	4	4	4
σ^2:	0.170385	0.106363	0.077043
σ^2-n1:	0.045394	0.027670	0.019824
LTA for chronic (n1-day) aquatic life criteria:	0.91	2.4	101
σ^2-n2:	0.088817	0.054595	0.039264
Maximum Daily Limit (ug/L):	2.2	4.9	186
Average Monthly Limit (ug/L):	1.4	3.4	138

Appendix G

Appendix G. Formulas for the Microsoft Excel spreadsheet for calculation of WLAs and permit limits for total recoverable Cd, Pb, and Zn for NPDES dischargers to the Spokane River. The input values are for the example described in the text for the Spokane AWTP.

	A	B	C	D
1				
2				
3		*Cd*	*Pb*	*Zn*
4				
5	**I. Potential limits based on meeting the aquatic life criteria at effluent hardness**			
6				
7	1. Effluent hardness 5th percentile (mg/L as CaCO3):	138	138	138
8				
9	2. Chronic aquatic life criteria for dissolved metals (ug/L)	=(1.101672-((LN(B7))*(0.041838)))*EXP(0.7852*(LN(B7))-3.49)	=0.02378*C7-0.05505	=0.986*EXP(0.8473*(LN(D7))+0.7614)
10				
11	3. Ratio of total recoverable / dissolved metals	=1/(1.101672-((LN(B7))*(0.041838)))	–	=1/0.986
12				
13	4. Chronic aquatic life criteria for total recoverable metals (ug/L)	=B9*B11	=0.0261*C7-0.1119	=D9*D11
14				
15	5. Number of samples (n2) required per month for compliance monitoring:	2	2	2
16				
17	6. Coefficient of variation for effluent metals (use 0.6 if data are not available):	0.431	0.335	0.283
18				
19	7. Calculated limits using the equations in Box 5-2 of the 1991 TSD			
20	Z statistic for water quality-based LTA derivation (99%tile):	2.3263	2.3263	2.3263
21	Z-statistic for water quality-based daily maximum permit limit (99%tile):	2.3263	2.3263	2.3263
22	Z statistic for water quality-based monthly average permit limit (95%tile):	1.6449	1.6449	1.6449
23	number of days (n1) for averageing of chronic aquatic life criteria:	4	4	4
24	σ^2:	=LN(B17^2+1)	=LN(C17^2+1)	=LN(D17^2+1)
25	σ^2-n1:	=LN((B17^2/B23)+1)	=LN((C17^2/C23)+1)	=LN((D17^2/D23)+1)
26	LTA for chronic (n1-day) aquatic life criteria:	=B13*EXP(0.5*B25-B20*SQRT(B25))	=C13*EXP(0.5*C25-C20*SQRT(C25))	=D13*EXP(0.5*D25-D20*SQRT(D25))
27	σ^2-n2:	=LN((B17^2/B15)+1)	=LN((C17^2/C15)+1)	=LN((D17^2/D15)+1)
28	Maximum Daily Limit (ug/L):	=B26*EXP(B21*SQRT(B24)-0.5*B24)	=C26*EXP(C21*SQRT(C24)-0.5*C24)	=D26*EXP(D21*SQRT(D24)-0.5*D24)
29	Average Monthly Limit (ug/L):	=B26*EXP(B22*SQRT(B27)-0.5*B27)	=C26*EXP(C22*SQRT(C27)-0.5*C27)	=D26*EXP(D22*SQRT(D27)-0.5*D27)
30				
31				