Development of Site-Specific Water Quality Criteria
for the South Fork Coeur d'Alene River, Idaho

APPLICATION OF SITE-SPECIFIC WATER QUALITY CRITERIA DEVELOPED IN HEADWATER REACHES TO DOWNSTREAM WATERS

Frank S. Dillon
Christopher A. Mebane

Prepared in conjunction with and for:

Idaho Department of Environmental Quality
1410 N. Hilton
Boise, ID 83706

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Prepared by:

Windward environmental LLC
200 West Mercer Street, Suite 401 ♦ Seattle, Washington ♦ 98119

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Acronyms and Report Conventions

ACR	acute-to-chronic ratio
AET	apparent effects threshold
ALC	aquatic life criteria
AWQC	ambient water quality criteria
CC	Canyon Creek
CCC	criterion continuous concentration (“chronic criterion”)
CCU	cumulative criteria unit exceedance
CDA	Coeur d′ Alene
CI	confidence interval
CMC	criterion maximum concentration (“acute criterion”)
EF	hardness normalized SSC exceedance factor
EFPC	East Fork of Pine Creek
EPA	US Environmental Protection Agency
GMAV	genus mean acute value
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
IDHW	Idaho Department of Health and Welfare
LNF	Little North Fork of the South Fork Coeur d′Alene River
LSF	Lower South Fork of the Coeur d′Alene River
LOEC	lowest-observed-effects concentration
NAWQA	USGS National Water Quality Assessment Program
North Fork	North Fork Coeur d′Alene River
NOEC	no-observed-effects concentration
NROK	USGS NAWQA Northern Rockies Intermontane Basins study unit
NRT	refers to studies conducted by natural resource trustees as part of a natural resource damage assessment
RSP	resident species procedure (EPA 1985)
SF-8	sampling station upstream of the mouth of Canyon Creek
SF-9	sampling station just downstream of Mullan
SF-10	sampling station just downstream of Shoshone Park
SF-G	sampling station at Golconda District
SF-H	South Fork water supply to Hale Hatchery
SMAV	species mean acute value
South Fork	South Fork Coeur d′Alene River
SSC	site-specific criteria
USGS	US Geological Survey
Windward	Windward Environmental LLC
WWTP	wastewater treatment plant

Unless otherwise specified, all metals concentrations in this report are for waterborne “dissolved” (0.45 µm filtered) metals, in µg/L. “Hardness” refers to total hardness expressed in mg/L as $CaC0_3$

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Mr. Christopher A. Mebane of the Idaho Department of Environmental Quality contributed to this report.

Throughout the study, the State of Idaho has provided chemical analyses of water samples. In 1996, Mr. Barry Pharaoh at the Idaho Department of Health and Welfare (IDHW) laboratory in Boise analyzed zinc samples. Ms. Peggy Albertson, chemist principal at the IDHW laboratory in Coeur d'Alene, analyzed all cadmium and lead samples, as well as zinc samples from 1997 to 2000.

All toxicity testing conducted from June 1996 to October 2000 was been performed on site in the Silver Valley at the Hale Fish Hatchery, owned by the Shoshone County Sportsman's Association. Ms. Mary Von Broeke, Idaho Department of Fish and Game caretaker of the Hale Fish Hatchery, provided assistance over the course of the study, including care of overwintering broodstock in 1998, 1999, and 2000.

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1.0 Introduction

Site-specific water quality criteria (SSC) that reflect local environmental conditions are allowed by federal and state regulations. 40 CFR 131.11 provides states with the opportunity to adopt water quality criteria that are "…modified to reflect site specific conditions." An SSC is intended to come closer than a national criterion to providing the intended level of protection to aquatic life at the site, usually by taking into account the species composition and water quality characteristics at the site. Derivation of an SSC does not change the level of protection at a site that was intended by a national criterion. A "site" may be a state, region, watershed, waterbody, or segment of a waterbody depending on the scope of study and biological and chemical factors. If water quality effects on toxicity are not a consideration, the site can be as large as a generally consistent biogeographic zone permits. If water quality effects on toxicity are a consideration, then those effects may constrain the size of the site (EPA 1994).

SSC were derived for the upper reaches of the South Fork of the Coeur d'Alene River, Idaho (South Fork) for lead and zinc (Windward 2002) and for cadmium (Mebane 2002a). SSC were developed following extensive testing of species indigenous to the upper reaches of the South Fork. All tests were conducted using natural site waters so that the test results would have the greatest possible ecotoxicological relevance to the indigenous aquatic communities. This approach, the "resident species procedure," accounts for both differences in the sensitivities of indigenous species and differences in biological availability or the toxicity of the metals caused by variability in physical and chemical characteristics of a site water. This procedure is designed to compensate concurrently for differences between the sensitivity range of species used in the national data sets and for site water which may affect the biological availability and/or toxicity of the material of interest (EPA 1994).

The purpose of this report is to evaluate whether criteria developed for cadmium, lead, and zinc using species and water from the headwater reaches of the South Fork watershed, are appropriate to apply to the lower South Fork and tributaries. The criteria were by necessity derived in headwater reaches of the South Fork because a century of mining and milling in the Silver Valley have resulted in ambient cadmium and zinc concentrations in the lower South Fork being elevated over headwaters concentrations on the average of about factors of 40 and 150 (Section 3 of this report). These site waters would result in ambient toxicity, making them unsuitable for use to develop non-toxic SSC. However, because plans for comprehensive reductions in point and nonpoint sources of metals pollution are being developed (EPA 2002), it is desirable to have aquatic life criteria for metals in the South Fork basin reflect local biological and chemical characteristics.

The site-specific criteria developed for the South Fork are defined in terms of allowable magnitude, duration, and frequency of exposure to these metals. The concentrations are expressed as hardness-dependent equations (Table 1-1). The criteria maximum concentrations (CMC or "acute criteria") are the highest allowable 1-hour average concentrations in a 3-year period, and the criteria continuous concentrations (CCC or "chronic criteria") are the highest allowable 4-day average concentrations in a 3-year period. Example CMC and CCC concentrations over ranges of hardness values that commonly occur in the South Fork watershed are given in Table 1-2.

Table 1-1. Site-specific criteria for dissolved cadmium, lead, and zinc for the South Fork Coeur d'Alene River

METAL	CMC EQUATION (µG/L)	CCC EQUATION (µG/L)
Cadmium	$CMC=e^{(1.0166 \times \ln(\text{hardness})-3.924)*0.973}$	$CCC=1.101672-(\ln(\text{hardness}) \times 0.041838) \times e^{(0.7852*LN(\text{hardness})-3.49)}$
Lead	$CMC =e^{(0.9402 \times \ln(\text{hardness})+1.1834)}$	$CCC= e^{(0.9402 \times \ln(\text{hardness})-0.9875)}$
Zinc	$CMC=e^{(0.6624 \times \ln(\text{hardness})+2.2235)}$	$CCC=e^{(0.6624 \times \ln(\text{hardness})+2.2235)}$

Source: (Mebane 2002a; Windward 2002)

Table 1-2. Site-specific criteria calculated over a range of hardness values that commonly occur in the South Fork Coeur d'Alene watershed

METAL	CMC (µG/L)				CCC (µG/L)			
Hardness (mg/L)	10	30	50	100	10	30	50	100
Cadmium	0.20	0.61	1.0	2.1	0.18	0.42	0.62	1.0
Lead	28	80	129	248	3.2	9.1	14.7	28.3
Zinc	42	88	123	195	42	88	123	195

1.1 STUDY AREA FOR SITE-SPECIFIC CRITERIA DEVELOPMENT

The South Fork Coeur d'Alene drainage is defined as hydrologic unit code 17010302 and the South Fork is divided into three segments in Idaho's Water Quality Standards and Wastewater Treatment Requirements (IDAPA 58.01.01§110.09): segment P-13 is the reach from the source to Daisy Gulch, segment P-11 is the reach from and including Daisy Gulch to Canyon Creek, and segment P-1 is the reach from Canyon Creek to the mouth. The study area was logically divided at Canyon Creek, a tributary that increases the total metals loading to the South Fork by an order of magnitude (Section 3 of this report).

In order to generate the data needed to derive site-specific water quality criteria, site-specific toxicity testing with resident species and stream water was conducted at the Hale Fish Hatchery from 1996 to 2001. Based on site-specific data, SSC for lead and zinc were developed for the upper reaches of the South Fork, upstream from Canyon

Creek (Windward 2002). Because the dataset for cadmium was more limited than that for lead and zinc, site-specific cadmium criteria were not derived independently of the national criteria datasets. Rather, site-specific test results were primarily used to evaluate which of the existing or updated criteria would be least under- or overprotective of resident species (EPA 1984a, 2001a; Mebane 2002a).

There are a number of lakes in headwater tributaries of the South Fork, including Stevens Lakes, Lost Lake, Glidden Lakes, and Elsie Lake. Aquatic species that occur in lakes but not in flowing waters (lentic species) may be sensitive to metals (e.g., zooplankton). No lentic species were tested in the development of SSC. Therefore, SSC were not intended to apply to any lakes in the subbasin.

Figure 1-1 illustrates the study area, showing the South Fork Coeur d'Alene subbasin, and reference sites used for characterizing expected macroinvertebrate and fish assemblages and the sites of reference waters used for downstream toxicity testing (St Regis River, Montana).

1.2 DOCUMENT ORGANIZATION

The remainder of this document is divided into the following sections:

- Section 2 describes the study's rationale, objectives, and questions to be answered.
- Section 3 presents a data review of water quality factors that affect metals toxicity, and compares the sensitivity of organisms expected in the lower watershed to those tested in headwaters reaches.
- Section 4 presents the results of toxicity tests conducted with resident westslope cutthroat trout to verify the protectiveness of SSC in the lower South Fork.
- Section 5 presents a field validation of the protectiveness of SSC by comparing exceedances of SSC with fish and invertebrate occurrences at those locations.
- Section 6 summarizes our findings and presents our conclusions on the applicability of applying SSC developed for the reach of the South Fork above Wallace to other reaches and tributaries of the South Fork below Wallace.

Because of the disparate lines of evidence considered, methods and results are presented together in each section. Of the three main sections, (factors affecting toxicity, toxicity testing, and field validation) the field validation section is much longer and more interpretive than the others. It is effectively a report within a report. This is because current practices for field assessments of ecological condition and field validation are less standardized than for the interpretation of toxicity data. Instead of being able to simply cite standard methods for conducting and interpreting tests, field validation methods are defined and described for the first time in this report.

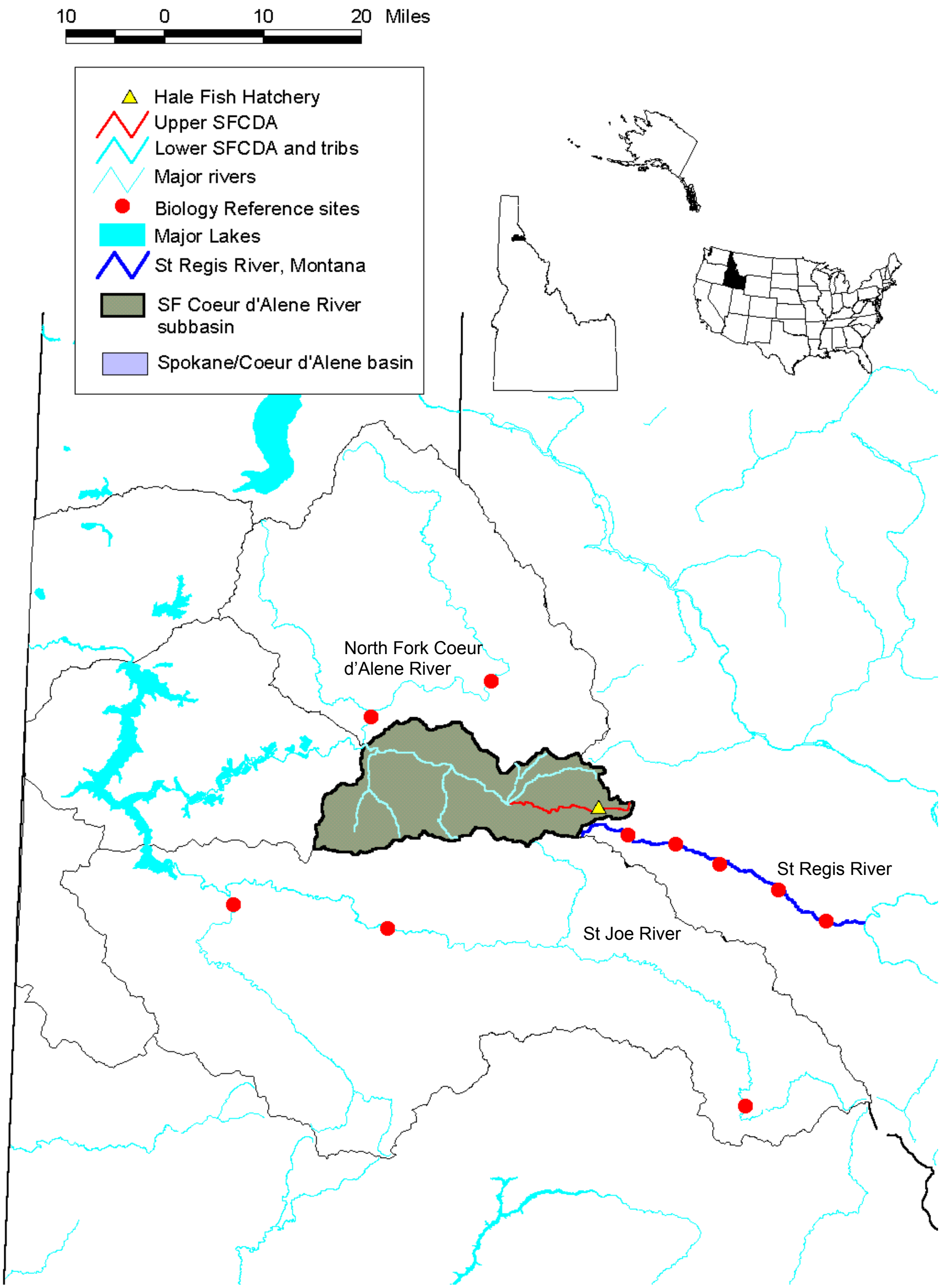


Figure 1-1. South Fork Coeur d'Alene subbasin study area

Illustrating the scope of the national criteria, scope of SSC, and regional reference sites used for evaluating expected biological communities.

2.0 Study Approach

2.1 RATIONALE FOR EVALUATING THE APPLICATION OF SITE-SPECIFIC CRITERIA TO WATERS IN THE LOWER SOUTH FORK WATERSHED

Part of the rationale for expanding site-specific criteria to downstream reaches of the South Fork is based on the application of site-specific chemical, biological, and toxicological data to factors affecting metals toxicity in freshwater (Bergman and Dorward-King 1997). The ecological principle of the stream continuum provides a context for understanding watershed biogeochemistry and species distributions, and factors into the evaluation (Vannote et al. 1980).

Numerous chemical and biological data have been collected for the South Fork below Canyon Creek, showing that poor habitat and metals loading to the stream impair water quality and limit aquatic biological communities. However, these data also indicate that key water quality parameters (i.e. alkalinity, hardness, organic carbon) that decrease metals bioavailability increase downstream. These water quality data suggest that a given concentration of metal in the downstream reaches would be no more toxic than the same concentration in upstream waters. This document will evaluate whether the exposure conditions of the toxicity tests used to derive SSC for the reach of the South Fork upstream of Canyon Creek are also representative of conditions in other lotic waters in the South Fork subbasin.

The purpose of the site-specific water quality criteria is to protect the resident species in the South Fork. The toxicity test data set generated using water from the reach of the South Fork above Canyon Creek provides the foundation for protecting the most sensitive resident species. This document will evaluate whether the proposed SSC will also protect the most sensitive species throughout the South Fork subbasin.

2.3 OBJECTIVES

- Identify reach segments for the South Fork and tributaries on the basis of water quality similarities and differences
- Evaluate whether more sensitive species than cutthroat trout occur or would be expected to occur in the South Fork watershed downstream of Canyon Creek
- Evaluate whether supplemental resident-species toxicity testing is necessary to verify that the proposed SSC are protective of the aquatic biota in the South Fork downstream of Canyon Creek
- Evaluate the toxicity to cutthroat trout at SSC in water with similar characteristics to that of the lower south Fork
- Evaluate biomonitoring data from throughout the basin to see if instream responses are similar to toxicity test responses, that is, whether instream effects are apparent at locations in relation to whether SSC are protective

2.4 QUESTIONS TO BE ANSWERED

This review and analysis of water quality, biological, and toxicological data provide the basis for evaluating whether it is warranted to apply SSC developed for the South Fork above Wallace to all lotic waters of the South Fork. Questions were formulated on two bases: water quality differences that modify toxicity to aquatic organisms, and organism sensitivity to lead and zinc. They include:

- Dissolved cadmium, lead, and zinc were considered the primary toxicants of ecological concern in SSC development for the South Fork upstream of Canyon Creek. Are these the toxicants of primary concern in other mining-affected areas of the South Fork?
- In lotic waters downstream of Canyon Creek, do factors that influence metals toxicity (e.g., water hardness, Ca/Mg ratios, organic carbon, alkalinity, and pH) change in ways that would increase metals toxicity?
- What aquatic species are present or expected to be present in the lotic waters of the South Fork watershed and which are the most sensitive to trace elements?
- Are the criteria predictive of toxicity in the lower South Fork?
- Would SSC be protective of cutthroat trout in waters with similar characteristics to the lower South Fork?
- Do field assessments of fish and invertebrates in the study area compare well with SSC predictions of instream responses? Are apparent instream community responses observed at sites that usually exceed or seldom exceed SSC?

2.4.1 Water quality

In order to apply SSC developed for the South Fork upstream of Canyon Creek to the other lotic waters of the South Fork watershed, it is necessary to examine factors that would change the toxicity of cadmium, lead, or zinc.

The toxicity of metals in the aquatic environment is modified by a number of abiotic factors such as the pH, calcium hardness, and dissolved organic carbon in the water. Waterborne metals generally show their greatest toxicity to aquatic organisms in soft water of low alkalinity, and low dissolved organic carbon. pH is an important factor as well, although conclusions have sometimes been contradictory (Sorensen 1991; Sprague 1985) These relationships are explained by the conceptual model of metal toxicity that considers the bioavailable forms (free metal ion, inorganic complexes, and weakly bound organic complexes) to be the toxic forms. Bioavailable free metal ions or complexes must adsorb to gills before they can either exert their toxic effect at the gill surface directly, or pass through the gills on their way to internal sites of toxic action. Any process that prevents the initial adsorption on the gill surface by reducing either the ambient available metals or the number of surface binding sites on the gill, will reduce toxicity of waterborne metals. Dissolved organic carbon can complex metals making them unavailable to interact with an organism, and calcium competes with metals for binding sites, as do hydrogen ions (H^{+}). H^{+} competition with metals for gill binding sites will tend to mitigate metals toxicity at low pH, but it also affects metal speciation (Bergman and Dorward-King 1997; Sprague 1985).

In addition to these factors, in the mining-influenced waters of the lower South Fork watershed, elevated concentrations of metals are expected to occur together. If the mechanisms of action are similar, different waterborne metals are generally toxic to aquatic organisms through similar physiologic processes. For example, cadmium and zinc are toxic due to the blockade of Ca^{2+} uptake; this ionoregulatory disruption results in the loss of ions down their electrochemical gradients from the fish to the water, and loss of cell function (Bergman and Dorward-King 1997). By jointly producing effects, the concentrations of metals in combination could be more toxic than if occurring individually.

These factors were evaluated as follows.

Water hardness

Toxicity of metals generally decreases as water hardness increases. Are the ranges of water hardness (and alkalinity) found in the South Fork and tributaries downstream of Canyon Creek similar to those measured in toxicity tests for development of SSC for the reach from Daisy Gulch to Canyon Creek? If dissimilar, do lower hardnesses frequently occur?

Calcium/magnesium ratios

Water hardness is a function of calcium and magnesium concentrations. However, calcium hardness probably contributes more protection to fish than magnesium hardness from cadmium, copper, nickel, and zinc toxicity (Alsop and Wood 1999; Carroll et al. 1979; Erickson et al. 1996; Heijerick et al. 2002; Naddy et al. 2002; Welsh et al. 2000a; Welsh et al. 2000b). If Ca/Mg ratios in the lower South Fork and tributaries were much lower than in the water used for toxicity testing to develop SSC, metals could be more toxic at a given hardness, and the criteria could be underprotective.

Are the Ca/Mg ratios found in the South Fork and tributaries downstream of Canyon Creek similar to those measured in the water sources used for toxicity tests for development of SSC for the upper reaches of the South Fork? If dissimilar, do lower Ca/Mg ratios frequently occur?

Dissolved organic carbon

Organic carbon in water may bind to dissolved metals, reducing the capacity of metals to bind to the gill surface of aquatic organisms where they disrupt ionic balances (Bergman and Dorward-King 1997; Sprague 1985). If organic carbon in the site waters of the upper South Fork used in toxicity testing were significantly higher than in the lower South Fork, metals could be more toxic in the waters with lower organic carbon.

Are organic carbon concentrations in the lower South Fork expected to be similar or higher than those in the upper reaches?

pH

Water pH also influences the toxicity of metals. If the ranges of pH in the lower basin are significantly different from the pH ranges occurring in the ambient waters of the upper reaches used for toxicity testing, there could be a difference in metals toxicity. Dissolved zinc appears to be most toxic at pH of about 7.0, and is less toxic both at lower and higher pHs (Bradley and Sprague 1985; Cusimano et al. 1986; Hansen et al. 2002c; Sorensen 1991).

Are ranges pH values found in the South Fork and tributaries downstream of Canyon Creek similar to the range of pH measured in toxicity tests for development of SSC using water from the upper reaches? If dissimilar, are natural pH values likely to increase or decrease toxicity?

Combined water and dietary exposure to metals

The SSC for the South Fork for cadmium, lead, and zinc are for waterborne metals and do not explicitly address exposure to metals from other routes, such as food-web exposure. If at sites that met the waterborne SSC, fish populations were still adversely affected from food-web exposure then further evaluation of bioaccumulation factors or sediment metals criteria, or revision to the waterborne criteria could be needed. Does the available information suggest fish would be adequately protected from combined water and dietary metals exposure at locations where the SSC are met?

2.4.2 Organism sensitivity

Metals criteria must be protective of the resident species in the South Fork, and the toxicity test dataset for the reach above Wallace provides the foundation for determining the most sensitive resident species. However, in addition to species residing in the headwaters of the South Fork, additional species may be expected to reside in the lower South Fork.

Based on suitable reference areas, what additional organisms are likely to be resident to the lower South Fork? Are these species likely more or less sensitive than cutthroat trout to cadmium, lead, or zinc?

2.4.3 Protectiveness of site-specific criteria

Additional testing was conducted to evaluate whether the proposed SSC would be protective of cutthroat trout in the lower South Fork.

Compared to controls with no added metals, does little or no mortality occur after exposures to metals at criteria concentrations?

2.4.3 Field validation

Many, if not most, ecotoxicologists consider real-world validation of the ecological relevance of laboratory-derived chemical toxicity criteria necessary or at least desirable (Cairns 1986; Carlson et al. 1984; Chapman 1983; Chapman 1995; Clements and Kiffney 1996; de Vlaming and Norberg-King 1999; Ferraro and Cole 2002). Should criteria exceedances frequently co-occur with apparent instream effects to fish or macroinvertebrates, and if at other locations that seldom exceed criteria, no instream effects are apparent, field observations would corroborate the toxicity tests-based SSC.

Do field surveys of fish or macroinvertebrates from locations where SSC are typically exceeded show effects that are consistent with the toxicity testing? For example, are cutthroat trout or other sensitive taxa scarce or absent? While the absence of effects can never be proven, are there no apparent effects at locations that seldom exceed SSC?

3.0 Water Quality and Organism Sensitivity

The following describes the data compilation process including the studies utilized for this report and the methods used to identify similar reaches in the South Fork and tributaries.

The resident species toxicity test dataset is the culmination of 6 years of site-specific toxicity testing at the Hale Fish Hatchery, located in the headwater reach of the South Fork (Windward 2002). This database includes analytical chemistry and organism response results for over 140 site-specific toxicity tests with resident and surrogate species. The purpose of this document is to evaluate whether these site-specific data are representative of water quality conditions and organism sensitivity throughout the South Fork watershed. Data review results are presented using the questions presented in Section 2.4 as a framework.

3.1 DATA SOURCES

Three main types of site-specific data will be used in this evaluation: water quality, biological monitoring, and toxicological data.

3.1.1 Water quality

The primary source for water quality data was a data compilation prepared by McCulley, Frick & Gilman (MFG 1999). This database included sampling conducted for the for the EPA Remedial Investigation/Feasibility Study and used in the Coeur d'Alene Basin TMDL (EPA 2000), water quality data collected by the State of Idaho, and other related studies that collected surface water data. The USGS also conducts water quality monitoring in the basin. While more limited in spatial scope than the EPA or DEQ data sets, the USGS data include time-series data, which provide information on water quality variability and time trends. In particular, the USGS/IDEQ cooperative surface water quality trends network provided a long term record for the station near Pinehurst near the mouth of the South Fork (http://idaho.usgs.gov/public/qwdata.html). In addition to the metals data routinely monitored by these programs, water samples were collected from the lower South Fork and the St Regis rivers for detailed inorganics analyses. These analyses were done to allow comparison of non-routine analytes with similar analyses of upstream waters.

3.1.2 Species occurrences

Taxa lists came from three primary sources:

- Fish and macroinvertebrate collections from Idaho Department of Environmental Quality Beneficial Use Reconnaissance Program (BURP)
- Fish, macroinvertebrate, and water quality surveys from comparing the South Fork to the St Regis River, Montana, a reference stream as part of a natural resource damage assessment (R2 1999; Stratus 2000)
- USGS National Water Quality Assessment Program (NAWQA) for the Northern Rockies-Intermontane Study Unit [(Brennan et al. 2001), also USGS unpublished data).

3.1.3 Toxicological comparison

Sources of toxicological data on organism sensitivity included the results of testing indigenous fish and invertebrates from the upper watershed, the EPA national data sets for the criteria documents, and the ecological risk assessment for the Coeur d'Alene Basin (EPA 2001b), which summarized acute and chronic toxicity data for relevant species. The risk assessment includes data in the ECOTOX database. Other toxicological information relevant to species of interest included published literature and, when methods were well described, unpublished laboratory reports.

The review sought reports that included quantitative data on survival, growth, or reproduction. These measures of toxicity are generally regarded as a suitable basis for projecting the potential acute or chronic toxic effects of pollutants to aquatic life populations and communities. Some studies have investigated endpoints such behavioral changes, swimming stamina, histopathological, hormonal or biochemical effects. With fish and other aquatic organisms the significance of the adverse effect can only be used in the derivation of criteria after demonstration of adverse effects at the population level, such as reduced survival, growth, or reproduction. To be used in criteria development, other less conventional endpoints would need to be quantitatively correlated with exposure or with effects on the survival, growth, or reproduction of the test organism; connections with adverse changes to populations and communities are needed(EPA 1999).

3.2 DATA REVIEW METHODS

The review consisted of evaluating the data within the context of the questions presented in Section 2.4. Prior to analyzing the data, data sources were screened to exclude older data. Only data obtained since 1990 were used in this evaluation. This cutoff ensures that measures of surface water quality and biological endpoints are reasonably relevant to existing conditions. In addition, the 1990 cutoff date helps ensure that water quality data and biological data were collected and analyzed using similar techniques.

3.2.1 Reach organization

The water quality of the South Fork and selected tributaries were assessed based on the reaches identified in the 1998 Idaho 303(d) listing of water-quality-limited segments. The proposed SSC would presumably be most useful for managing these reaches. Reaches not included on the list include numerous smaller tributaries and several larger tributaries including Willow Creek, Placer Creek, and Big Creek.

The reaches selected for evaluation included the main stem of the South Fork and the major tributaries feeding into it, Canyon Creek, Nine Mile Creek, and Pine Creek. Also evaluated are lesser tributaries including Moon Creek, Milo Creek, and Government Gulch. Table 3-1 presents the reaches of interest and the primary stations used to evaluate whether the site-specific water quality criteria can be reasonably applied to them.

Table 3-1. Summary of reaches and stations[a] used to assess water quality for the South Fork and tributaries

STREAM	REACH	STATIONS USE TO ASSESS WATER QUALITY
South Fork	Canyon Creek to Ninemile Creek	SF-7 (SF at Wallace)
	Ninemile Creek to Placer Creek	SF-7 (SF at Wallace)
	Placer Creek to Big Creek	SF-239 (SF at mouth of Revenue Gulch) SF-249 (SF at Osburn) SF-259 (SF above of Big Creek)
	Big Creek to Pine Creek	SF-3 (SF at Elizabeth Park) SF-2 (SF at Smelterville) SF-268 (SF at Elizabeth Park) SF-270 (SF at Smelterville)
	Pine Creek to Bear Creek	SF-271 (SF near Enaville)
	Bear Creek to confluence with North Fork Coeur d'Alene River	SF-1 (SF at Enaville)
Canyon Creek	Gorge Gulch to South Fork CdA River	CC-1, CC-1.5, CC2.5, CC-3 (stream mile of Canyon Ck) CC-278 (near Mace) CC-284 and CC-287 (Downstream of Gem) CC-288 (at mouth) CC-291 (between Mace and Gem)
Ninemile Creek	Headwaters to South Fork CdA River	NM-1 (below RV Park) ENM-2 (East Fk. Ninemile at Sunset) NM-293 (upper East Fork) NM-295 (mid East Fork)

STREAM	REACH	STATIONS USE TO ASSESS WATER QUALITY
		NM-296 (lower East Fork) NM-298 (main stem upstream of confluence with East Fork) NM-303 (main stem) NM-305 (above mouth)
Moon Creek	Headwaters to South Fork CdA River	MC-1 SF-262 (Mouth of Moon Creek)
Milo Creek	Headwaters to South Fork CdA River	MC-2 (at outlet)
Pine Creek	E. Fork Pine Creek to South Fork CdA River	PC-1 (Pine Creek at mouth) PC-2 and PC-3 (at Main Street bridge)
East Fork Pine Creek	Headwaters to Hunter Creek	PC-307 (mouth of Highland Creek) PC-308 (mouth of Denver Creek)
	Hunter Creek to Pine Creek	PC-312 (just upstream of confluence with Pine Creek)
Government Gulch	Headwaters to South Fork	GG-3 (near mouth)

[a] Stations with more than two samples

3.3 FACTORS THAT AFFECT METALS TOXICITY

3.3.1 Aquatic chemistry of the upper and lower South Fork

Elevated concentrations of cadmium, lead, and zinc are the substances that have been previously linked with adverse effects to aquatic life or criteria exceedances in the South Fork watershed (EPA 2001b; EVS 1995; Stratus 2000). Additionally, comprehensive analyses of major ions, trace elements, and organic carbon were made of samples from the upper reaches of the South Fork (EVS 1995). Similar analyses of water samples from the lower South Fork and from the lower St Regis River were made in the summer of 2001. The St Regis River was the reference water source used as an uncontaminated surrogate for the lower South Fork for toxicity testing. The analyses were intended to verify no other waterborne metals were likely of concern, and to evaluate factors that may affect the toxicity of metals.

Results show generally increasing concentrations of both major ions and metals from headwaters toward the mouth. Factors that mitigate metals toxicity (alkalinity, hardness, calcium, sodium) generally increased downstream, except for organic carbon, which was generally steady. Of the metals that are commonly considered to be potentially toxic to aquatic life (i.e. have had aquatic life criteria developed), only cadmium and zinc were significantly elevated at downstream sites above the concentrations near the headwaters (stations LNF and SF-10). Median natural background concentrations for the South Fork basin as a whole for dissolved cadmium, lead, and zinc have been estimated at about 0.06, 0.18, and 6.95 µg/L respectively (Maest et al. 1999). Cadmium and zinc were the only dissolved metals concentrations that increased steadily downstream.

Table 3-2. Aquatic chemistry results from the Upper South Fork and Lower South Fork reaches

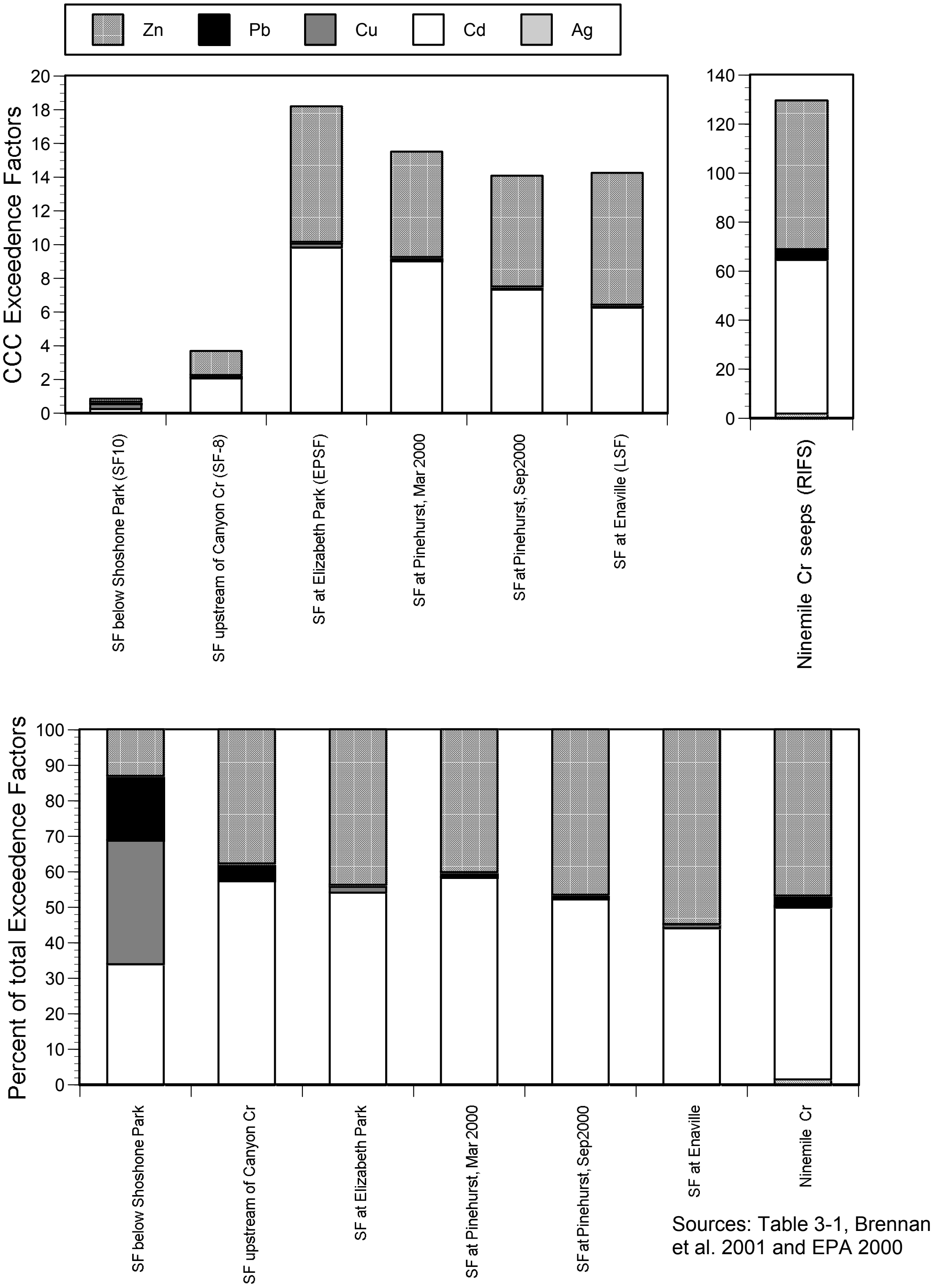
			Upper Reaches				Lower Reaches		
Parameter	**Sample Type**	**Units**	**LNF**	**SF-10**	**SF-9**	**SF-8**	**EPSF**	**LSF**	**StR**
River Mile (from mouth)		Miles	33	32	27	22	14	0.5	0.5
TOC	total	mg/L	na	<1	<1	<1	2.1	2.6	1.1
DOC	dissolved	mg/L	na	2	2	2	2.8	2.0	1.2
Alkalinity	total	mg/L	na	20	25	33	73.4	54.1	83.3
Hardness	calculated	mg/L	14	24	43	50	70	135	53
Calcium	dissolved	mg/L	3.36	6.28	11.7	13.2	18.8	34.0	15.8
Magnesium	dissolved	mg/L	1.40	1.93	3.37	4.03	5.68	12.1	3.24
Ca:Mg ratio	calculated	wt.:wt.	2.4	3.3	3.5	3.3	3.3	2.8	4.9
Bromide	dissolved	mg/L	na	0.08	0.05	0.06	<0.2	<0.2	<0.2
Chloride	dissolved	mg/L	na	1.17	3.09	2.29	5.3	4.6	2.4
Fluoride	dissolved	mg/L	na	0.05	0.05	0.04	<0.1	0.4	<0.1
Nitrate	dissolved	mg/L	na	0.51	5.7	0.67	0.3	1.05	<0.05
Potassium	dissolved	mg/L	0.33	0.44	0.70	0.66	1.4	1.9	<1
Silica	dissolved	mg/L	9.11	8.71	8.10	8.11	4.24	4.87	4.13
Sodium	dissolved	mg/L	0.55	0.70	1.51	1.32	6.0	5.6	2.3
Sulfate	dissolved	mg/L	na	2.47	9.38	33.8	33.5	118	1.8
Aluminum	dissolved	µg/L	6	9	12	10	<20	20	<20
Barium	dissolved	µg/L	17	27	55	55	66	50	26
Copper	dissolved	µg/L	2	1	<1	<1	<3	<3	<3
Iron	dissolved	µg/L	5	23	21	8	<20	40	<20
Manganese	dissolved	µg/L	1	6	51	29	34	755	<2
Nickel	dissolved	µg/L	3	2	8	<1	<10	<10	<10
Cadmium	total	µg/L	na	0.3	0.9	1.8	8	8.9	<0.2
Cadmium	dissolved	µg/L	<0.2	<0.2	0.9	1.3	7.8	8.1	0.2
Lead	total	µg/L	na	1.7	5.2	4.3	7	8	<1
Lead	dissolved	µg/L	<0.2	1.1	3	2.7	2	1	<1
Zinc	total	µg/L	na	7	102	170	1090	1660	<5
Zinc	dissolved	µg/L	<2	8	82	126	1230	1850	<5

LNF – Little North Fork of the South Fork Coeur d'Alene River
SF-10 – South Fork upstream of Mullan near Shoshone Park
SF-9 – South Fork downstream of Mullan
SF-8 – South Fork upstream of Canyon Creek
EPSF – South Fork near Elizabeth Park
LSF – Lower South Fork near Enaville
StR – St Regis River in St Regis (surrogate for contaminated lower South Fork)
na – not analyzed
TOC – Total organic carbon
DOC – Dissolved organic carbon
Hardness and alkalinity are mg/L as calcium carbonate

To evaluate the potential harm to aquatic life of mixtures of metals, their cumulative concentrations relative to a particular level of effect such as a criterion may be added together. Concentration additivity has commonly been treated as the nominal case for joint toxic action of chemical mixtures; at toxic concentrations the joint action of pollutants is commonly additive, and at concentrations below those considered safe there is circumstantial evidence for less-than-additive joint action (Suter et al. 1993). In Figure 3-1, site-specific chronic criteria exceedance factors are shown for several sampling events which included analyses of multiple metals. Added together, chronic criteria exceedance factors range from 4 – 18 in the mid to lower reaches of the South Fork. In the most highly contaminated record located, seeps feeding Ninemile Creek, criteria were exceeded by 130x. When examined as a percent of the total exceedance factors, cadmium and zinc accounted for 95 – 99% of the total chronic exceedances. Cadmium and zinc chronic criteria exceedances were evenly balanced in these data, accounting for 53% and 44% of the exceedances respectively.

These data indicate that the overwhelming risks of adverse effects from waterborne metals in the lower South Fork are from cadmium and zinc, and that the influence of other waterborne metals, including copper and lead, may be discounted. The contributions to risks to aquatic life from cadmium or zinc toxicity are approximately equal.

Spatial and temporal patterns of dissolved cadmium, lead, and zinc concentrations in the South Fork are shown in the box and whisker plots in Figure 3-2. The data are from three key South Fork monitoring stations that have been frequently sampled near the headwaters (Shoshone Park, n=34), middle (upstream of Canyon Creek, n=62), and in the lower reaches (near Smelterville, n=62). The plots show that the cadmium site-specific criterion was always exceeded in the lower and middle reaches, and the zinc chronic criterion was always exceeded in the lower reach and often exceeded in the middle reach. The lead chronic criterion was seldom exceeded, even in the lower reach.



Sources: Table 3-1, Brennan et al. 2001 and EPA 2000

Figure 3-1. Criteria exceedances of the most frequently detected metals, as factors (Σ metal/CCC) and as percent of total factors

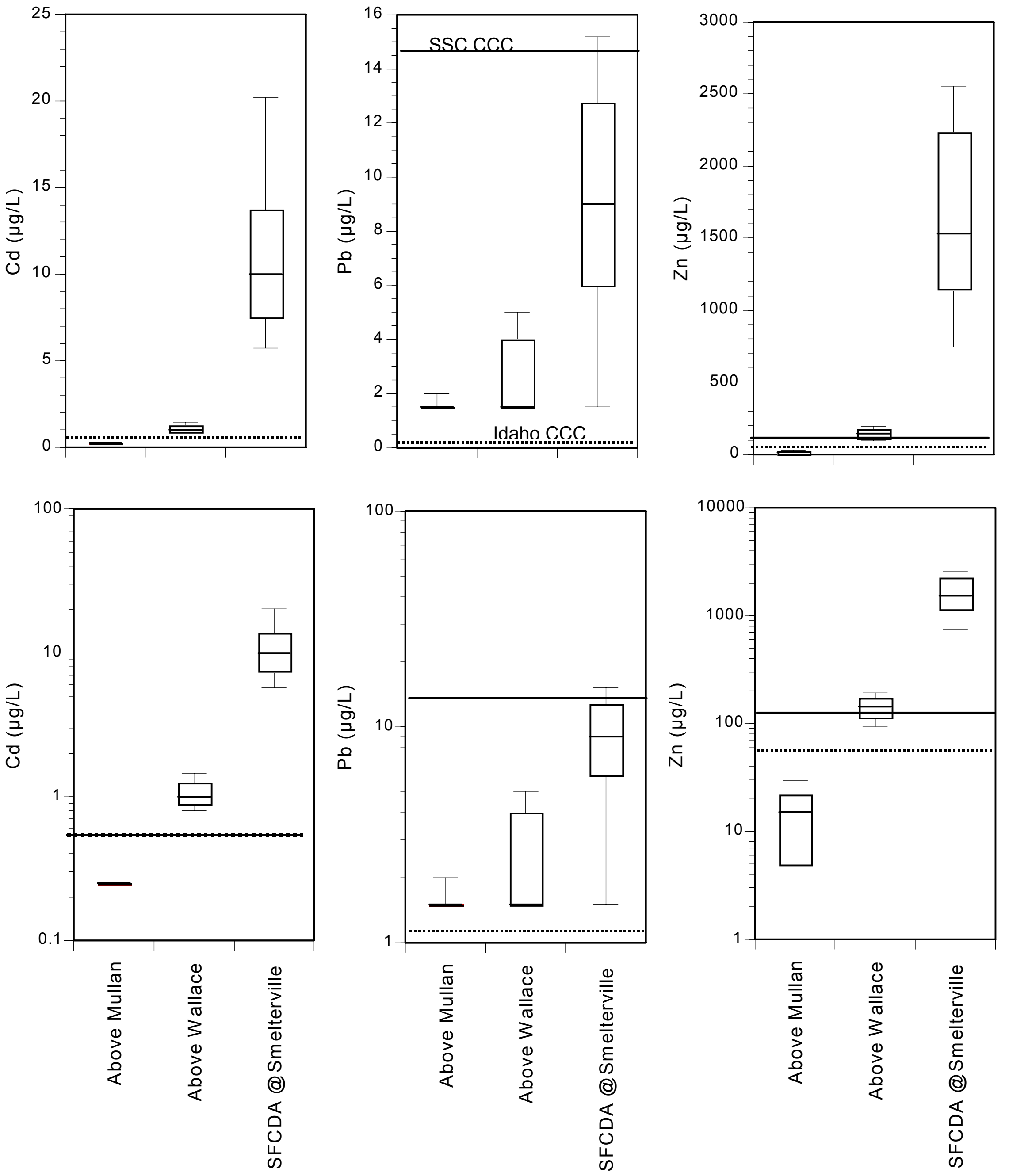


Figure 3-2. Statistical distributions of dissolved cadmium, lead, and zinc concentrations in comparison to Idaho and site-specific chronic criteria

Box and whisker plots show the 90th(whiskers), 75th (top of box), median, 25th and 10th percentile values, using linear (top) and log (bottom) scales. Solid horizontal lines indicate the SSC CCC values, dashed lines show the Idaho CCC values.

3.3.2 Water hardness

The water hardness for toxicity tests used to derive the proposed SSC ranged from 7.5 to 31 mg/L for cadmium, 11 to 67 mg/L for lead tests, and from 9 to 67 mg/L, for zinc tests, all as $CaCO_3$. Three main sources of water hardness data were summarized for this evaluation: IDEQ monitoring data, EPA RI/FS monitoring data (MFG 1999), and, where available, USGS data. Water hardness and flow correlated in the South Fork subbasin, with a pattern of lower hardness values corresponding to high-flow spring snow melt. The water hardness data presented in these figures is summarized in Tables 3-3 and 3-4.

IDEQ monitoring from 1996 to 1998 (Table 3-3) found the lowest average water hardness values in Pine Creek, the minimum being at site PC-1 (8 mg/L as $CaCO_3$). The next lowest water hardness value (12 mg/L as $CaCO_3$) was measured in Canyon creek and in the main stem of the South Fork at Elizabeth Park. The low hardness value in the South Fork at Elizabeth Park was measured during spring flow in 1998; the next lowest hardness value measured by IDEQ at this station was 30 mg/L as $CaCO_3$. For all stations measured by IDEQ, the average water hardness was within the range of, or greater than, the hardness of waters used for site-specific testing.

Data collected for the EPA RI/FS (MFG 1999) from 1993 to 1998 (Table 3-4) included the lowest average water hardness values in Canyon Creek, Nine Mile Creek, and Pine Creek, although Pine Creek stations with more than two samples were limited. Based on all available hardness data from this study, approximately 15% of the Pine Creek watershed samples had hardness less than 10 mg/L as $CaCO_3$; approximately 6% of Nine Mile Creek watershed samples had hardness less than 10 mg/L as $CaCO_3$; less than 4.5% of Canyon Creek watershed samples had a hardness less than 10 mg/L as $CaCO_3$; and less than 1% of South Fork subbasin samples had a hardness less than 10 mg/L as $CaCO_3$. For all stations with three or more data points measured by this study, the average water hardness was within the range of, or greater than, the hardness of waters used for site-specific testing.

Data collected for the EPA RI/FS (MFG 1999) in 1993 (Table 3-4) indicated that the lowest average and minimum water hardness values were found in Pine Creek. For all stations measured by this study, the average water hardness was within the range of, or greater than, the hardness of waters used for site-specific testing.

Table 3-3. Summary of water hardnesses (mg/L as CaCO3) measured from 1996 to 1998

STATION NUMBER	SITE DESCRIPTION	AVERAGE	MAXIMUM	MINIMUM	NUMBER OF SAMPLES	STANDARD DEVIATION
CC-1	Lower Canyon Cr,	49	72	12	19	15.68
CC-1.5, 2.5	Canyon at Grays Bridge	40	56	12	38	12.54
CC-3	Canyon at Tamarack Mine	34	48	24	4	10.58
12413118	Canyon near Burke	9.0	12	5.7	15	2.48
ENM-2	At Sunset	40	54	16	19	10.16
NM-1	Below RV Park	69	96	32	19	16.43
MC-1	At Mouth	31	44	20	18	6.80
PC-1	Pine Creek at Mouth	22	24	20	2	2.83
PC-2	Main St. at Bridge	17	42	8	15	7.98
12413445	Pine Cr near Amy Gulch	10	16	5.3	30	2.87
12413470	USGS ST near Pinehurst	72	191	18	91	39.8
SF-1	USGS ST at Enaville	80	144	32	17	33.76
SF-2	Smelterville	98	224	36	19	47.11
SF-3	Elizabeth Park	55	80	12	19	17.36
SF-7	Wallace	60	84	28	19	16.63
SF-8	Above Wallace	59	80	12	18	17.87

Source: MFG (1999), IDEQ monitoring except for USGS stations (8-digit station codes)

CC: Canyon Creek

ENM: East Nine Mile Creek

NM: Nine Mile Creek

MC: Moon Creek

PC: Pine Creek

SF: South Fork Coeur d'Alene River

Table 3-4. Summary of water hardnesses (mg/L as CaCO3) taken from 1993-1998, EPA RI/FS Study

STATION NUMBER	SITE DESCRIPTION	AVERAGE	MAXIMUM	MINIMUM	NUMBER OF SAMPLES	STANDARD DEVIATION
CC-278	Near Mace	27.92	46.0	8.6	18	11.64
CC-284	Downstream of Gem	33.29	56.0	11.9	17	13.35
CC-287	Downstream of Gem	43.16	72.0	13.2	18	17.41
CC-288	At mouth of creek	28.55	47.7	13.0	4	17.10
CC-291	Between Mace and Gem	30.69	48.0	12.0	17	12.09
NM-293	Upper East Fork	19.42	32.0	7.7	10	8.07
NM-295	Mid East Fork	20.27	28.0	9.1	8	6.74
NM-296	Lower East Fork	27.90	40.0	10.7	11	8.70
NM-298	Upstream of confluence with NM and ENM	35.05	56.0	9.8	18	12.96
NM-303	Mainstem of Nine Mile Creek	62.66	96.0	20.4	18	22.38
NM-305	Above mouth	62.73	96.0	24.6	19	22.15
PC-307	Mouth of Highland Creek	38.78	52.3	23.8	18	9.28
PC-308	Mouth of Denver Creek	44.86	72.0	25.9	16	13.08
SF-220	South Fork between Dry Creek and Gold Creek	47.11	66.0	24.4	18	13.75
SF-239	South Fork mouth of Revenue Gulch	48.47	72.0	25.8	16	13.96
SF-249	South Fork between Two Mile Creek and Osburn	48.47	76.0	27.2	15	15.91
SF-259	South Fork upstream of Big Creek	50.54	76.0	28.6	14	14.70
SF-262	South Fork at mouth of Moon Creek	34.36	60.0	26.0	18	7.50
SF-268	South Fork downstream of Montgomery Creek	67.36	104.0	24.0	18	28.36
SF-270	South Fork downstream of Government Creek	71.67	136.0	34.4	15	31.77
SF-271	South Fork downstream of Pine Creek	69.36	112.0	30.7	19	28.07

Source: MFG (1999)

3.3.3 Calcium-magnesium ratios

In addition to water hardness, calcium-to-magnesium (Ca/Mg, wt/wt) ratios were evaluated because for a given hardness, water with more calcium has a greater capacity to mitigate metals toxicity (Section 2.4). The Ca/Mg ratios of the waters of the main stem of the South Fork upstream of Wallace that were used in site-specific toxicity tests range from approximately 3.25 at SF-10 to 3.5 at SF-8 (EVS 1995). The Ca/Mg ratio in the Little North Fork was approximately 2.4.

The distribution of Ca/Mg ratios measured by EPA (MFG 1999) throughout the South Fork subbasin were compared to the Ca/Mg ratios measured in toxicity tests for the development of SSC. Figure 3-3 presents the distribution of Ca/Mg ratios in the four major subbasins of the South Fork watershed, the South Fork, Canyon Creek, Nine Mile Creek, and Pine Creek. In the Pine Creek subwatershed, approximately 27% of the Ca/Mg ratios measured were less than 2.4.

Additionally, Ca/Mg ratios for the USGS station on the South Fork near the mouth are shown in Figure 4-1. The Ca/Mg ratios for this location tended to be somewhat lower than for the majority of the South Fork. The median Ca/Mg ratio for the overall South Fork was 3.6 compared to 3.2 for the USGS station near Enaville. This could reflect the influence of Pine Creek, a large drainage, in this short, lower segment (2.1 miles) between Pine Creek and the mouth.

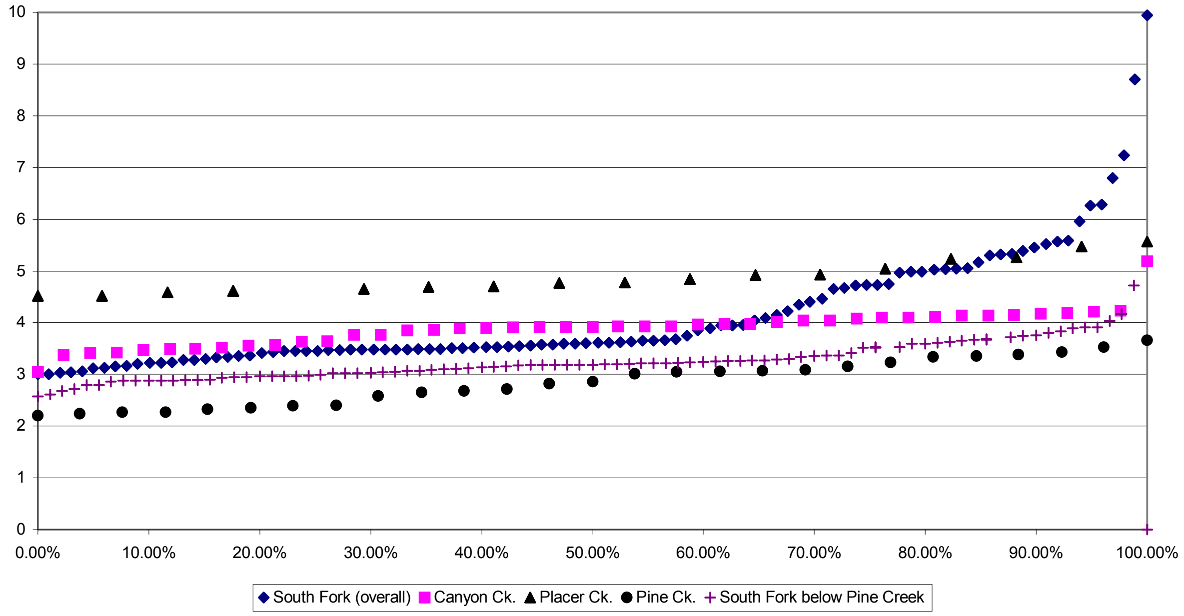


Figure 3-3. Distribution of dissolved calcium/magnesium ratios in surface water by waterbody

Source: MFG 1999, USGS (http://idaho.usgs.gov/public/qwdata.html)

3.3.4 Dissolved organic carbon (DOC)

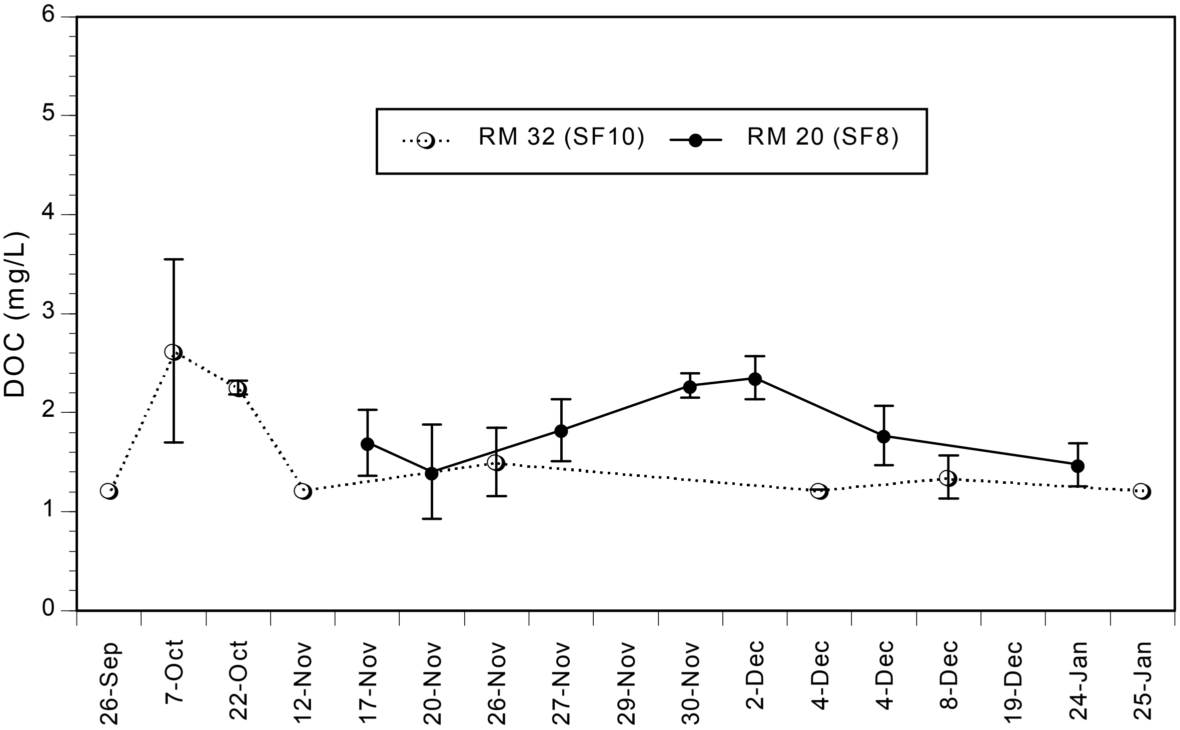
Fewer dissolved organic carbon data are available than for other constituents. However, stream ecosystem theory and regional investigations provide insight on expected dissolved organic carbon patterns in the study area.

Dissolved organic matter in forest streams is expected to generally increase from headwaters (1st to 3rd stream orders) to medium sized streams (4-6th order) such as the lower South Fork. In headwaters reaches, organic inputs are from terrestrial leaf litter, which are largely in a coarse particulate form. Further downstream, the particle size is broken down through physical and biological processes. These smaller particle sizes more readily become dissolved organic matter. In addition, as more light is available in wider, midsized streams than in the shaded headwaters, increased primary productivity releases more fine particulate and dissolved organic matter into the water (Vannote et al. 1980).

These expected patterns are generally supported by available data. Multiple DOC measurements were made in the upper reaches of the South Fork in the fall and winter of 1995-1996 (EVS 1996b). Values ranged from <1 mg/L to 4 mg/L DOC, averaging about 2.0 mg/L. Concentrations appeared to be slightly higher downstream (Figure 3-4). In summer 2001, DOC concentrations measured in the lower South Fork ranged from 2.0 to 2.8 mg/L (Table 3-3).

DOC patterns have been extensively researched in Panther Creek, Idaho, a similarly sized stream to the South Fork. Concentrations increased from winter into spring, and then declined. DOC concentrations tended to be somewhat higher downstream (Figure 3-4, data from (Maest et al. 1995). The upstream-downstream patterns in both the South Fork and Panther Creek are similar to results of 154 DOC samples across the Salmon River basin, Idaho that were collected as part of the river continuum studies (Minshall et al. 1992). DOC concentrations increased from 1.2 mg/L near the headwaters to 4.2 mg/L near the mouth of Panther Creek. The annual DOC concentrations in the entire Salmon Basin likely were in the range of 1.5 to 2 mg/L.

Together, both the site and regional data suggest that DOC concentrations either increase somewhat moving downstream from the headwaters, or remain similar. In general, the DOC concentrations observed or expected in the South Fork (≈ 1-4 mg/L) are at the low range of those that have been reported to significantly reduce waterborne metals toxicity (Erickson et al. 1996; Heijerick et al. 2002; Hollis et al. 1996; Marr et al. 1999; Richards et al. 1999; Welsh et al. 1993). This review suggests that DOC may be a less important factor influencing metals toxicity in the South Fork watershed than other factors such as hardness or calcium – magnesium ratios.



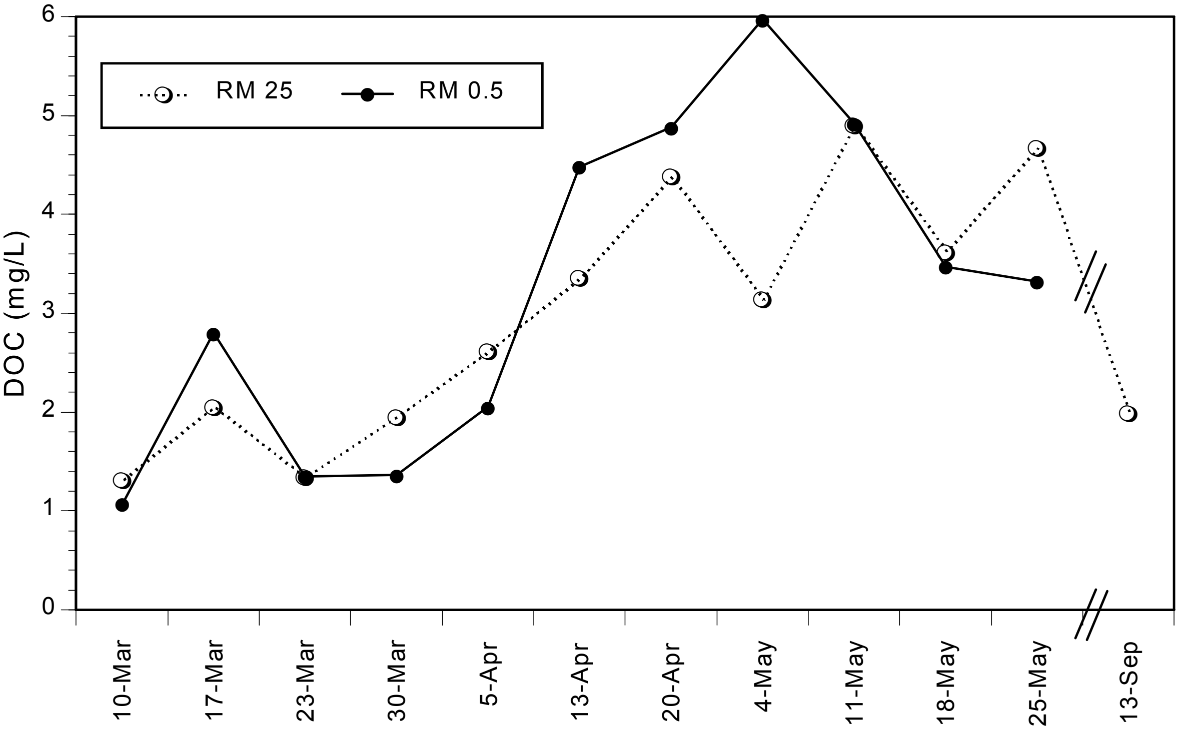


Figure 3-4. DOC patterns in headwater reaches of the South Fork compared with DOC patterns in lower reaches of a similar sized stream

3.3.5 Alkalinity

The distribution of alkalinity measured by EPA (MFG 1999) throughout the South Fork subbasin was compared to the alkalinity measured in toxicity tests for the development of SSC, which ranged from 8.5 in LNF water to 49.3 in SF-8 water. In the waters draining directly into the South Fork (South Fork face drainages), less than 2% (3 of 140) of the samples had alkalinity less than 8 mg/L as $CaCO_3$. In the Canyon Creek subwatershed, approximately 10% (4 of 43) of the samples had alkalinity less than 8 mg/L as $CaCO_3$,. In Nine Mile Creek, approximately 13% (7 of 53) of samples had alkalinity less than 8 mg/L as $CaCO_3$. In Pine Creek, approximately 9% (5 of 57) samples had alkalinity less than 8 mg/L as $CaCO_3$. All low alkalinity measurements were observed during spring snowmelt, high-flow conditions.

3.3.6 pH

The pH measured in toxicity tests used to derive the proposed SSC were circumneutral, averaging 6.9 in tests conducted in Little North Fork water, and 7.3 in tests conducted in South Fork water at the Hale Hatchery (Table 3-5). Average pH values at other monitoring stations were generally similar. The highest average pH value at monitoring stations was 7.55 at Station SF-8, above Wallace.

The lowest pH value was measured in Moon Creek (pH 3.89). This data point is questionable given that the next lowest pH value in Moon Creek is 6.85. The range of all other pH measurements made by IDEQ was circumneutral.

Table 3-5. Summary of pH values taken from 1996-1998

STATION NUMBER	SITE DESCRIPTION	AVERAGE	MAXIMUM	MINIMUM	NUMBER OF SAMPLES	STANDARD DEVIATION
LNF	Little North Fork	6.85	7.89	4.95	789	0.40
SFH	South Fork @ Hale	7.28	8.16	5.61	670	0.30
12413470	USGS ST at Enaville	7.17	7.8	6.2	77	0.23
SF-1	USGS ST at Enaville	7.04	7.44	6.59	15	0.22
SF-2	Smelterville	7.12	7.66	6.63	17	0.25
SF-3	Elizabeth Park	7.27	7.75	6.50	17	0.32
SF-7	Wallace	7.37	7.93	6.81	17	0.38
SF-8	Above Wallace	7.55	8.13	6.50	16	0.40
CC-1	Lower Canyon	7.32	7.79	6.83	18	0.28
CC-1.5	At Grays Bridge	7.34	7.91	6.71	18	0.33
CC-2.5	Gray Bridge	7.25	7.70	6.75	17	0.29
CC-3	Tamarack Mine	7.24	7.56	7.03	4	0.23
NM-1	Below RV Park	7.46	7.85	6.95	18	0.25
ENM-2	At Sunset	6.95	7.21	6.67	17	0.16
MC-1	Moon Creek at Mouth	6.97	7.68	3.89	17	0.82
PC-1	Pine Creek at mouth	6.90	7.00	6.79	2	0.15
PC-2	Main street at bridge	6.81	7.18	6.31	15	0.25
PC-3	Main Street at bridge	6.91	7.00	6.75	3	0.14

Source: MFG (1999) IDEQ monitoring except for USGS station 12413470 (1991-2001)

3.3.7 Combined influence of dietary and waterborne exposures of metals to fish

The SSC for the South Fork Coeur d'Alene River for cadmium, lead, and zinc are for waterborne metals and do not explicitly address exposure to metals from other routes, such as food chain exposure. Presently food chain exposure is not specifically addressed in national water quality criteria for metals other than for selenium and mercury. Currently there probably is little scientific consensus on the relative significance of waterborne or dietary exposure routes in water quality criteria, other than research for the next generation of criteria should consider dietary as well as waterborne exposures and meld water and sediment quality criteria (Bergman and Dorward-King 1997). Some investigations have found significantly reduced growth or survival when trout were fed invertebrate diets that were experimentally enriched with metals or that were field collected from metals contaminated sites (Farag et al. 1999; Grosell and Wood 2001; Hansen et al. 2002a; Woodward et al. 1995); others have found few adverse effects associated with elevated metals in diets of trout (Clements and Rees 1997; Mount et al. 2001).

If at sites that met the waterborne SSC, fish populations were still adversely affected from food chain exposure, then further evaluation of bioaccumulation factors, sediment metals criteria, or revision to the waterborne criteria could be needed. While the significance of dietary exposure of metals may not generally be resolved for regulatory use, for the South Fork Coeur d'Alene River, sufficient data are available to make some inferences regarding the potential for adverse dietary effects at sites meeting the waterborne SSC. Farag et al. (1999) collected benthic macroinvertebrates from two metals contaminated sites in the Coeur d'Alene River and a reference site, pasteurized them, and fed them to cutthroat trout for 90 days. The test sites were the South Fork Coeur d'Alene River near Pinehurst and the main Coeur d'Alene River at Cataldo, the reference diet was from the North Fork Coeur d'Alene River. The trout were also exposed to waterborne metals at about 0X or 4X the national chronic criteria concentrations for Cd, Pb, and Zn at a hardness of 50 mg/L. The nominal 4X dissolved concentrations were 2.5 µg/L Cd, 5.2 µg/L Pb, and 200 µg/L Zn. These concentrations are equivalent to site-specific chronic criteria ratios of 4X Cd, 0.35X Pb, and 1.6X Zn. No reductions in growth or survival resulted from the water-only exposures, although histopathological changes were observed. Independent of water-exposures, reduced growth and survival were observed with the Cataldo diet but not from the South Fork diet. Farag et al (1999) noted that this result was counterintuitive since the South Fork diet had higher concentrations of some metals, and speculated that at the relatively fast-water South Fork site metals were associated with inorganic particulates in the gut, whereas in the slow-water Cataldo site, metals were associated with invertebrate tissues.

Concentrations of metals in benthic macroinvertebrates have been measured at a number of sites in the area through the NROK investigations and by Farag et al. (1998). Metals concentrations measured in benthic macroinvertebrates from sites in the study area that generally meet the waterborne SSC were much lower than concentrations associated with adverse effects in the feeding study (Table 3.6). Concentrations at these sites were similar to the metals concentration in the reference diet from the feeding study. Measured invertebrate metals concentrations are separated by study in Table 3.6 since the Farag et al. (1998, 1999) values are from composited community collections and the NROK study targeted the large, metals tolerant caddisfly *Arctopsyche*. At the sites generally meeting the SSC, the *Arctopsyche* and community composite concentrations were similar, whereas at the contaminated sites exceeding SSC, the community composite values tended to be higher (Table 3.6). The two studies likely collected community composites or targeted single species because of their differing study objectives. The community composite data are probably more representative of dietary metals exposure that predatory fish such as trout or sculpin would encounter. However composite results may be highly variable due to differing bioaccumulation for different sized invertebrates and differing functional feeding groups (Farag et al. 1998). This variability is undesirable for monitoring programs focusing on trends over time or geographic comparisons. Targeting a single, widely distributed, abundant, and metals tolerant genus such as *Arctopsyche* improves comparisons of invertebrate metals residues between locations or over time by reducing variability inherent in community samples. Regardless, results from both surveys suggest adverse effects to fish from dietary exposure to metals are unlikely at locations that seldom exceed the SSC.

Table 3-6. Ranges of mean concentrations of metals in benthic invertebrates (whole body in mg/kg dry weight) from sites generally meeting or exceeding SSC

Condition	Cadmium	Lead	Zinc
Metals in invertebrate diets resulting in reduced growth and survival of cutthroat trout [a]	29.1	454	2119
Metals in invertebrates collected from sites generally **exceeding** SSC [b]	8.4 – 57	46 – 3,893	386 – 3,050
Metals in the caddisfly *Arctopsyche* collected from sites generally **exceeding** SSC in NROK surveys [c]	12 – 13	210 – 330	930 – 1,370
Metals in invertebrate reference diet used to compare with growth or survival of cutthroat trout fed from contaminated sites [a]	0.97	7.4	384
Metals in invertebrates collected from sites generally **meeting** SSC [b]	1.2 – 2.5	9 – 12	255 - 393
Metals in the caddisfly *Arctopsyche* collected from sites generally **meeting** SSC in NROK surveys [c]	<2.7	< 20	< 330

[a] Farag et al. (1999) [b] Farag et al. (1998) [c] T. Maret, USGS, personal communication; values were estimated from graphs.

3.4 ORGANISM SENSITIVITY

Biological data were reviewed to evaluate whether organisms expected to occur in downstream waters were likely more sensitive to metals than those headwaters species used to develop SSC. More species would be expected in the lower South Fork than in the upper South Fork based on river continuum predictions. As streams shift from their headwaters to mid-sized rivers (4th-6th order), their species richnesses tend to increase as new species are added in lower, warmer, and more productive middle reaches. Farther downstream, richness may decline as headwaters species are replaced by downstream species. However, in mid-sized rivers, species addition is expected rather than replacement (Vannote et al. 1980).

The screening consisted of identifying potentially sensitive species based on survey data and sensitivity rankings presented in the national dataset for deriving water quality criteria for cadmium, lead, and zinc (EPA 1984b, 1996, 2001a). Two questions were addressed: are there species potentially more sensitive than trout to cadmium, lead, or zinc, and if so, are those more sensitive species found or expected to be found in the South Fork watershed?

3.4.1 Organisms used to develop the site-specific criteria

To broadly protect aquatic communities, EPA guidelines for criteria development specify a diverse variety of taxa to be included in the national criteria dataset (Stephan et al. 1985). For site-specific criteria development using resident species, these guidelines are modified to focus on species that actually are expected to occur at a site (Carlson et al. 1984). During the development of the SSC, over 140 acute toxicity tests with 16 families and 7 chronic tests with 3 families were conducted. Table 3-7 compares the diversity of taxa specified in the EPA guidelines with the taxa tested in the upper South Fork.

Table 3-7. Comparison of organisms identified for criteria development with the indigenous species utilized for site-specific criteria development

ORGANISMS SPECIFIED FOR NATIONAL CRITERIA	RESIDENT ORGANISMS USED TO DEVELOP SSC	
The family Salmonidae in the class Osteichthyes	Westslope cutthroat trout (*Oncorhynchus clarki lewisi*)	
A second family in the class Osteichthyes	Shorthead sculpin (*Cottus confusus*)	
A third family in the phylum chordata	Not applicable[a]	
A planktonic crustacean	Not applicable[a]	
A benthic crustacean	Not applicable[a]	
An insect [b]	Ephemeroptera	Baetidae
		Ephemerillidae
		Heptageniidae
		Leptophlebidae
A family in any order of insect or any phylum not already represented	Plecoptera [b]	Perlodidae
		Chloroperlodidae
	Trichoptera [b]	Hydropsychidae
		Arctopsychidae
	Diptera [b]	Chironomidae
		Simulidae
		Tipulidae
	Coleptera [b]	Dytiscidae
	Gastropoda	Planorbidae
		Physidae

[a] Not expected to be present or not present in sufficient numbers to be feasible for use as test organisms.

[b] In high-gradient streams such as the South Fork, the benthic insect community is the foundation of nutrient cycling and provides the food base for fishes. Therefore, multiple families of these keystone organisms were tested.

Only two families of indigenous resident fish were found in the upper South Fork upstream of Canyon Creek: Salmonidae (westslope cutthroat trout and mountain whitefish [*Prosopium williamsoni*]) and Cottidae (shorthead sculpin). The trout and the sculpin were selected for study based on their prevalence in the upper watershed (mountain whitefish were only infrequently captured in the upper South Fork). Further, the distribution of sculpin in relation to mining disturbance in the study area suggested they may be sensitive to metals and should be studied (EVS 1996a). Two non-indigenous fish species were also found, brook trout (*Salvelinus fontinalis*) and rainbow trout (*Oncorhynchus mykiss*). The primary objective of the Idaho Department of Fish and Game (IDFG) is to manage the South Fork drainage for wild populations of cutthroat trout. The introduction of non-indigenous competing species has played a significant role in the decline of native cutthroat trout in the system. Harvest regulations and stockings are managed to attempt to limit these competing, introduced species. (Horner 1998; IDFG 2000). Non-indigenous species that can be invasive and compete with indigenous species were not considered resident species for the purposes of inclusion in site-specific criteria development.

Rainbow trout were used in the site-specific criteria development to establish hardness-toxicity relationships and in early-life stage tests as a surrogate species for cutthroat trout. Similarly, hatchery cutthroat trout that originated outside of the South Fork basin and cutthroat trout that were field-collected from within the basin but were not of a known age were only used in comparative rangefinding tests to determine the most sensitive species. A broodstock of cutthroat trout captured from the South Fork basin was established at the Hale Fish Hatchery. Only cutthroat trout that were hatched from this captive broodstock, were of a known age, and had no pre-test exposure and potential acclimation to elevated metals were used to establish criteria values. This likely reduced variability in test results by using a consistent stock of test fish and increased confidence in the relevance of the results to site waters. In hindsight, toxicity values obtained with westslope cutthroat trout from the Sandpoint hatchery were mostly within the ranges of values obtained from the South Fork broodstock (Windward 2002). This suggests that the South Fork population of westslope cutthroat trout may not be inherently more tolerant of metals than other populations.

The following sections review the reported sensitivity of fish and invertebrates that may occur in the lower South Fork with those tested in the upper South Fork.

3.4.2 Fish

Recent fish data were generated by the Northern Rockies Intermontane Basins (NROK) study of the National Water-Quality Assessment (NAWQA) Program[2] and by R2 Resource Consultants (R2 1999) for the US Fish and Wildlife Service. Surveys throughout the basin were conducted from 1994 to 1996. For the purposes of this report, the fish data collected from the St Regis River, Montana, and the St Joe River, Idaho, were used to evaluate whether indigenous fish species other than cutthroat trout were expected to be present in the South Fork. Table 3-8 summarizes the fish species documented in the South Fork and reference river basins. Sixteen species were reported from the South Fork basin and 14 species from the reference river basins. All families considered native to these basins were represented in both the South Fork and reference rivers. Two species of suckers (family Catastomidae) and one species of dace (family Cyprinidae) were found in the South Fork but not the reference rivers. One species each of sucker, shiner (family Cyprinidae) and salmonid were collected in the reference rivers but not in the South Fork. Bull trout (*Salvelinus confluentus*) were

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[2] http://montana.usgs.gov/nrok/nrokpage.htm

found in the upper reaches of the St Joe River and historically occurred in at least Big Creek and Placer Creek in the South Fork watershed (Maclay 1940). Bull trout are not currently believed to be resident in the South Fork watershed, since none have been reported despite extensive fish surveys in recent years.

Table 3-8. Comparison of site specific criteria and toxicity values of fish species found in the South Fork and reference river basins

Family	Common Name	Species	Origin	Present in South Fork	Present in Reference Rivers	Taxa Mean Acute Value (µg/L)[a]			Source
						Cd	Pb	Zn	
Site-specific criteria (CMC)						1.0	129	123	d
Salmonidae									
	Coho Salmon	*Oncorhynchus kisutch*	Alien	X		6.2	5,373	1,628	b,c,e
	Kokanee Salmon	*Oncorhynchus nerka*	Alien	X	X			1,502	
	Chinook Salmon	*Oncorhynchus tshawytscha*	Alien	X		4.31		446	b, c
	Cutthroat trout	*Oncorhynchus clarki*	Native	X	X	2.13	226	245	d
	Rainbow trout	*Oncorhynchus mykiss*	Alien	X	X	2.17	169	150	d
	Bull trout	*Salvelinus confluentus*	Native		X	2.16		162	b,f
	Brook trout	*Salvelinus fontinalis*	Alien	X	X	<1.79	4,820	2,100	b,c,e
	Brown trout	*Salmo trutta*	Alien		X	1.61			
	Mountain whitefish	*Prosopium williamsoni*	Native	X	X	>8.2		2,424	g,h
Cottidae									
	Shorthead sculpin	*Cottus confusus*	Native	X	X	3.1		>275	d
	Torrent sculpin	*Cottus rhotheus*	Native		X				
Cyprinidae						**3,837**	**25,440**		b,e
	Longnose dace	*Rhinichthys cataractae*	Native	X	X				
	Speckled dace	*Rhinichthys osculus*	Native	X					
	Redside shiner	*Richardsonius balteatus*	Native		X				
	Northern pikeminnow	*Ptychocheilus oregonensis*	Native	X	X	2,221		6,580	b,c
	Tench	*Tinca tinca*	Alien	X					
Catostomidae						**3,136**		**5,228**	b,c
	Mountain sucker	*Catostomus platyrhynchus*	Native	X					
	Longnose sucker	*Catostomus catostomus*	Native	X					
	Bridgelip sucker	*Catostomus columbianus*	Native		X				
	Largescale sucker	*Catostomus macrocheilus*	Native	X	X				
Percidae									
	Yellow perch	*Perca flavecens*	Alien	X					
Ictaluridae									
	Brown bullhead	*Ameiurus nebulosus*	Alien	X		5,055			

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[a] 96-hour EC50 values normalized to a hardness of 50 m/L as $CaCO_3$; site-specific values normalized using site-specific hardness slopes, other values normalized using slopes from respective criteria documents.

Sources: b - (EPA 2001a); c – (EPA 1996); d - (Windward 2002); e – (EPA 1984b); f – (Hansen et al. 1999), g – (Stubblefield 1990a), h –(Stubblefield 1990b)

A comparison of the EPA aquatic life criteria documents indicates that cutthroat trout are likely as sensitive or more sensitive than other fish species expected to be present in the South Fork. This is based on the species rankings from the national dataset for deriving water quality criteria for cadmium, lead, and zinc (EPA 1984b, 1996, 2001a). For zinc, *Oncorhynchus* was the fourth most sensitive genus although the three more sensitive species—striped bass, longfin dace, and tilapia—are not indigenous to the Northern Rocky Mountain ecoregion. For zinc, the GMAV for *Oncorhynchus* was 1,030 µg/L, as compared to 2,100 µg/L for *Salvelinus* (char), 5,228 µg/L for *Catostomus* (suckers), and 6,580 µg/L for *Ptychochelius* (pikeminnows). For cadmium and lead, *Oncorhynchus* was the most sensitive fish genus.

The SMAV for rainbow trout obtained from site testing can be normalized to a hardness of 50 m/L as $CaCO_3$ and compared to the rainbow SMAV from the national criteria documents for all three metals. For cadmium, the values were nearly identical, with mean acute values of 2.17 vs. 2.11 µ/L from the site-specific testing and EPA (2001a) respectively. For lead and zinc, the site-specific values were much lower than the values from the criteria documents. Lead mean acute values in the national criteria were 2,448 µ/L versus 169 µ/L for mean of site-specific tests. Zinc mean acute values from the national criteria were 931 µ/L versus 150 µ/L in the site-specific tests (EPA 1984b, 1996). The reason for the higher sensitivity to lead and zinc of the rainbow trout used our tests is unknown but may be related to low concentrations of DOC in our test water or the consistent use of the sensitive swim-up fry life stage in our testing. The rainbow trout acute values were not used directly in developing SSC because rainbow trout are neither an indigenous nor a desired species in the South Fork. However, the rainbow trout results suggest that the tests conducted at the Hale Hatchery were more sensitive than some used in the national criteria datasets. This in turn suggests that other tests conducted similarly to the rainbow trout tests, were also sensitive SSC derived from sensitive tests are likely to be protective.

Studies were conducted at the University of Wyoming Red Buttes laboratory to examine the relative zinc and cadmium sensitivity of bull trout to rainbow trout, an intensely studied species of salmonid (Hansen et al. 1999; Hansen et al. 2002c). In 14 of 15 tests, rainbow trout were more sensitive to cadmium and zinc than were bull trout. On average, bull trout were about twice as tolerant of cadmium exposure and 50% more tolerant of zinc exposure than rainbow trout (Hansen et al. 2002c). Similarly, in our site-specific testing using cutthroat trout and rainbow trout, cutthroat trout were 60% more tolerant of zinc exposure than rainbow trout. This suggests that resident cutthroat and bull trout may have proportionally similar sensitivities to zinc. Resident cutthroat trout tested in site water were slightly more sensitive to cadmium than were rainbow trout (2.13 and 2.17 µg/L respectively). Since Hansen et al. (2002c) found bull trout to be about twice as tolerant of cadmium as rainbow trout, this suggests that bull trout would likely also be more tolerant than cutthroat trout to cadmium. Overall, this comparison suggests that criteria based on resident cutthroat may be suitable for bull trout.

The studies are not directly comparable to the site-specific testing with cutthroat trout, because the well water used as dilution water for the tests conducted at Red Buttes, Wyoming had lower Ca/Mg ratio (average ~1.9 wt/wt) than is commonly found in the South Fork (>3.0) or that was used for the site-specific toxicity testing with cutthroat trout (~2.4-3.5). This suggests that the lethality values obtained from the bull trout testing are likely lower than would be expected if tests were conducted in waters typical of the South Fork watershed.

Prior to applying the site-specific zinc criteria to waters occupied by bull trout, more definitive testing using site waters may be appropriate. We suggest not expanding SSC to occupied bull trout streams without either testing in natural waters, or incorporation of existing bull trout toxicity data into a different SSC for those streams

3.4.3 Benthic macroinvertebrates

Invertebrates that might potentially be more sensitive than cutthroat trout were screened for using the national dataset for deriving water quality criteria for cadmium, lead, and zinc (EPA 1984a, 1984b, 1996) and literature on metals sensitivity of macroinvertebrates in lotic systems, emphasizing studies of systems contaminated by cadmium, zinc, and lead. Locations of macroinvertebrate collections from reference river sites that were evaluated are shown in Figure 1-1. Table 3-9 lists benthic macroinvertebrate families collected in the South Fork and the reference rivers.

Table 3-9. Comparison of benthic macroinvertebrate families found in the South Fork and reference river basins

ORDER	FAMILY	TAXA TESTED	PRESENT IN SOUTH FORK	PRESENT IN REFERENCE RIVERS	ACUTE VALUE (µg/L)		
					Cd	**Pb**	**Zn**
Odonata	Coenagrionidae			X			
Enchytraedia	Enchtraeidae			X			
Ephemeroptera							
	Baetidae	*Baetis tricaudatus*	X	X	>73	1,363	6,800
	Ameletidae		X	X			
	Ephemerellidae	*Drunella* sp.	X	X		646	
	Heptagenidae	*Epeorus* sp.				>346	
		Rhithrogena sp.	X	X	>50	1,838	680
	Leptophlebiidae	*Paraleptophlebia* sp.		X		>346	
	Siphlonuridae		X	X			
	Tricorythidae		X				
Plecoptera							
	Capniidae			X			
	Chloroperlidae	*Sweltsa* sp.	X	X	>5130	1,213	3,002
	Leuctridae		X	X			
	Perlidae		X	X			
	Perlodidae		X	X	>5000		

Order	Family	Taxa Tested	Present in South Fork	Present in Reference Rivers	Acute Value (µg/L)		
					Cd	Pb	Zn
	Pteronarcyidae			X			
	Nemouridae			X			
Hemiptera							
	Gerridae			X			
	Corixidae			X			
	Saldidae			X			
Trichoptera							
	Arctopsychidae	*Arctopsyche grandis*	X	X	>458	2,709	
	Bracycentridae		X	X			
	Glossosomatidae		X				
	Hydropsychidae	*Hydropsyche* sp.	X	X			6,800
	Hydoptilidae						
	Lepidostomatidae			X			
	Limnephilidae		X	X			
	Leptoceridae			X			
	Polycentropodidae		X	X			
	Philopotamidae		X				
	Rhyacophilidae		X	X			
	Uenoidae			X			
Coleoptera							
	Dytiscidae	*Dytiscidae*	X	X		1,306	
	Dryopidae		X				
	Elmidae		X	X			
	Hydrophilidae			X			
Diptera							
	Athericidae		X	X			
	Empididae		X	X			
	Simuliidae	*Simulium* sp.	X	X		1,881	
	Tipulidae	*Antocha* sp.	X	X		1,306	
	Blephariceridae		X	X			
	Tabanidae		X	X			
	Pelecorhynchidae		X	X			
	Psychodidae			X			
	Ceratopogonidae			X			
	Chironomidae	*Chironomus*	X	X		3,828	
Non-Insect Species							
	Planaria		X				
	Acari			X			
	Margaritiferidae			X			
	Nematoda			X			
	Nematomorpha			X			
	Oligochaeta		X	X			
	Ostracoda			X			
	Sphaeriidae			X			
	Physidae		X	X		2,416	
	Planorbidae	*Gyraulus* sp.	X		>73	1,363	3,028

Review of national criteria datasets

For zinc, the lowest GMAV was for *Ceriodaphnia* and the fourth lowest GMAV was for *Daphnia*. These two cladocerans are planktonic and therefore are not adapted to lotic waters. Therefore, cladocerans would not occur in the South Fork.

For cadmium, the GMAVs for two cladocerans (*Daphnia* and *Moina*) were less than the GMAV for *Oncorhynchus*. Because these cladocerans are planktonic, they are not adapted to lotic waters and would not occur in the South Fork.

For lead, three invertebrates potentially more sensitive than *Oncorhynchus* were identified in the national dataset: a snail (*Aplexa*), a cladoceran (*Daphnia*), and an amphipod (*Gammarus*). Cladocerans would not be expected to occur in the South Fork. Two families of snails were identified in the South Fork, planorbidae (*Gyraulus* sp.), and Physidae. Although initial site-specific testing identified snails as one of the most sensitive species, follow-up testing found that cutthroat trout were more sensitive. Therefore, it is likely that a criteria protective of cutthroat trout will be protective of resident species of snails.

Amphipods were not found in the St Regis River (R2 1999; NROK unpublished data), nor were they found during surveys of the St Joe River at Red Ives for three successive years. Macroinvertebrates were also collected from river sample sites in the Northern Rockies ecoregion as a part of the USGS/IDEQ co-op Idaho Surface Water Quality Monitoring network, 1996-98. No amphipods were found in the North Fork Coeur d'Alene River (North Fork) near Enaville, the St Joe River at Calder, the South Fork Clearwater River at Stites, or the Spokane River near Post Falls (Maret et al. 2001). Based on the absence of amphipods from these non-metals-contaminated rivers located in the same Northern Rockies ecoregion, it is unlikely they were ever resident species in lotic waters of the South Fork. Thus, it is unlikely that macroinvertebrates with published toxicity values lower than those determined for cutthroat trout with lead occur in the lotic waters of the South Fork watershed.

Field and experimental stream studies of macroinvertebrates and metals

Macroinvertebrate community structure analyses have been shown to be reliable and sensitive indicators of metals pollution in the water column. Shifts in benthic community structure commonly associated with adverse effects of metals include declines in the abundance of mayflies, reduced number of different mayfly species, reduced overall numbers of species, and increased dominance by caddis flies, midges, true flies, and worms. Declines in mayfly abundance and loss of mayfly taxa have consistently been reported as sensitive and reliable indicators of metals pollution. Some stonefly taxa are sensitive to metals. Of the macroinvertebrate taxa, mayflies have repeatedly been reported to be some of the most sensitive invertebrate taxa to metals (Carlisle and Clements 1999; Clements et al. 2000; Clements et al. 1992; Kiffney and Clements 2003; Richardson and Kiffney 2000). Among the generally sensitive mayfly taxa, the Heptageniid mayflies have been the most sensitive group to metals in field and experimental studies of montane, lotic systems (Clements et al. 2000; Kiffney and Clements 1994). Ephemerella mayflies have also been reported to be among the more sensitive mayflies (Clements et al. 1992). The reported sensitivity of Baetid mayflies is more variable; experiments in stream microcosms and field studies have shown them to be sensitive to metals (Deacon et al. 2001; Kiffney and Clements 1994; Richardson and Kiffney 2000), although in other cases they were abundant in streams with elevated metals. Their dispersal ability may make them a less consistent field indicator of metals pollution than other taxa (Clements 1994). Overall, it is likely that Heptageniid, Ephemerellid, and Baetid mayflies are among the sensitive macroinvertebrate taxa expected the South Fork watershed.

The mayflies *Rhithrogena* sp. (Heptageniidae) and *Baetis tricaudatus* and the stonefly *Sweltsa* (Chlorperlidae) were tested for toxicity to cadmium, lead, and zinc. For lead, the mayflies *Epeorus* sp. (Heptageniidae), *Drunella* (Ephemerellidae), *Paraleptoplebia* (Leptophlebiidae) were additionally tested, along with several less sensitive macroinvertebrate taxa (Windward 2002).

The effects of metals on macroinvertebrate assemblages at different altitudes has been studied in field and experimental results (Clements and Kiffney 1995; Kiffney and Clements 1996a). In all instances, effects of metals were greater on macroinvertebrate assemblages from small, high-altitude streams compared to those from large, low-altitude streams. Overall, invertebrate assemblages from high-altitude sites were 12-85% more sensitive to metals. In one experiment, a Heptageniid mayfly from a high-altitude stream was more sensitive to zinc than the same species from a low-altitude stream. Kiffney and Clements (1996a) suggest that the relatively greater effect of metals on macroinvertebrates from smaller, high-altitude streams may be the result of these organisms have evolved under more constant temperature regimes, and thus possessing less genetic and/or phenotypic diversity than populations from larger, low-altitude streams. They also hypothesized that smaller insect body sizes that may occur in higher, colder sites may play an important role affecting an insect's response to metals. It has been shown that smaller individuals of aquatic insects are more sensitive to contaminants that larger individuals of the same species (Diamond et al. 1992; Kiffney and Clements 1996b).

In summary, representatives of the generally metals-sensitive macroinvertebrate taxa that have been documented for montane, lotic systems were collected and tested in the upper South Fork River subbasin. Effects of metals are expected to be more severe to macroinvertebrates at higher-elevation sites than at lower-elevation sites. The macroinvertebrates were collected from and tested high in the South Fork subbasin, a location selected to be upstream of metals contamination. The South Fork at that point is a second-order stream, determined with 1:100,000 scale hydrography.

The pattern of smaller, more metals-sensitive individuals being associated with smaller, high-elevation streams suggests that for a given species, individuals would be less sensitive to metals in the lower South Fork mainstem than those tested in the upper segment. Individuals in tributaries to the lower South Fork are likely similar in sensitivity to those taxa tested at the Hale facility, or less sensitive, depending on their elevation.

3.4.4 Other data

Other data were reviewed to see if, while not directly usable in criteria derivation, they were pertinent to whether adverse effects to species found in the South Fork Coeur d'Alene subbasin were expected at SSC conditions. The metals contamination in the Coeur d'Alene River basin has provided fertile grounds over the years for investigations of the effects of metals on aquatic life. Investigations reviewed included cumulative effects of metals on fish health from combined dietary and waterborne exposures, behavioral effects of metals on fish and invertebrates, growth and survival of tadpoles, and field studies. None of the tests reviewed met the explicit test acceptability requirements of the EPA guidelines for direct use in developing site-specific aquatic life criteria. Such data could, however, affect a criterion if test concentrations were measured, the endpoint was biologically important, and if the data were obtained with a biologically important species (Stephan et al. 1985).

Several studies of behavioral changes in response to elevated metals in water or soils and that were that were directed to the Coeur d'Alene River basin were reviewed. The preference-avoidance of juvenile Snake River cutthroat trout to zinc was studied in aquaria tests. When given the choice of swimming to the side of an aquarium containing 52 µg/l zinc or the side with no zinc, the trout chose the side with no zinc (Woodward et al. 1997). While these results were statistically significant, they are difficult to relate to conditions in the wild where many factors affect fish behavior such as cover, flow, temperature, availability of food, predation risk, and differences in behavior between juvenile and adult fish.

In an effort to monitor avoidance responses of salmonids to metals in more realistic conditions, Goldstein et al. (1999) monitored adult Chinook salmon movements with radio telemetry in the vicinity of the South Fork and North Fork Coeur d'Alene River confluence. A total of 45 adult male Chinook salmon were captured from Wolf Lodge Creek (a tributary to Lake Coeur d'Alene) and after harvesting their milt, were transported to the Coeur d'Alene River and released about 2 km downstream of the confluence of the South Fork and North Fork. 51% of the released salmon moved upstream; of the 51% that moved upstream, 70% ascended the North Fork which had a zinc concentration of about 9 µg/L. 30% ascended the South Fork, which had a zinc concentration of about 2200 µg/L. The authors concluded that their study demonstrated that avoidance of metals can disturb critical spawning migrations and may displace or preclude fish from preferred habitats (Goldstein et al. 1999). However, migrating spawning salmon home on their natal stream by chemoreception, and it is unclear what the migratory instincts would be of post-spawning salmon that had been trucked from their natal stream and released in a different stream. Further, since the North and South Forks make up around 70% and 30% of the Coeur d'Alene River flows respectively (Brennan et al. 2001), an alternative conclusion might be that the salmon were simply moving in proportion to flow, rather than in response to metals.

Due to protection and limited numbers of native adfluvial westslope cutthroat and bull trout in the CDA basin, Goldstein et al. (1999) used introduced Chinook salmon in their study. Direct evidence on the effects of metals on the migration of resident cutthroat trout is limited, however some information on migration of native adfluvial cutthroat trout in relation to SSC exceedances can be inferred from fish trapping studies. A total of 35 migrant trout were captured during two months of migrant trapping in Pine Creek in the spring of 1995 (EPA 2001c). To reach Pine Creek, the fish had to swim through zinc concentrations ranging from 499 – 1250 µg/L in the South Fork below Pine Creek (range of 6 values from March 7 to May 23 1995 (MFG 1999)). Concurrent hardness values were not measured, but during other years hardnesses at that location during springtime are often in the 20 – 40 mg/L range. At those hardnesses, zinc SSC values range from 67 – 106 µg/L, indicating that the fish captured did not avoid zinc concentrations at 7X – 11X the SSC concentrations. Further upstream, over a shorter trapping period from April 20 to May 10, 1995, 6 migrant trout were captured in the South Fork above Canyon Creek. In a one-week trapping period in mid-June 1995, two migrant fish were captured in lower Canyon Creek (EPA 2001c). At those times, zinc concentrations ranged from 489 - 1210 µg/L in the South Fork downstream of Canyon Creek, and from 906 – 1260 µg/L in lower Canyon Creek (MFG 1999). This also indicates that zinc concentrations at 7X – 11X did not block all adfluvial cutthroat trout spawning migrations, and subsequent reproduction in upstream areas. Conversely, the presence of migrant fish upstream of reaches with zinc at 7X – 10X SSC does not rule out the possibility that some reduction in fish migration, short of total blockage, due to elevated zinc could occur. Such reductions, if present, do not seem quantifiable from the information reviewed. Overall, the fish movement and migration studies suggest to us that if at least some fish migration occurs at zinc concentrations 7X – 10X greater than the SSC, it would be unlikely that measurable reductions in fish migration would occur at zinc concentrations at or below the SSC.

Studies of the behavior of aquatic snails when held in aquaria containing different metals-contaminated terrestrial soils from the banks of the South Fork have been conducted (Lefcort et al. 2000; Lefcort et al. 1999). Lefcort et al. (2000) studied the speed of the movements of snails in containers placed in metals contaminated lakes and reference lakes. They reported that when they placed an extract of crushed snails in the containers, the snails in reference lakes showed a slight reduction in movement (< 1.2X difference) whereas the snails from polluted lakes did not. Concentrations of metals in water were not measured.

The survival and development of Columbia spotted frog tadpoles in self-sustaining "mini-ecosystems" was studied with water and soils metals exposure. Reduced survival was reported following a five-week exposure to "low zinc" concentrations. Zinc concentrations were reported as 50 µg/l and 15 µg/l at the beginning and end of the treatment respectively, although the authors cautioned that reliable detection limits for the water chemical analyses were reported as >100 µg/l. Between weeks 3 and 5 of the tests, the test tadpoles were removed from their growth tanks for fright response experiments to determine their responses to rainbow trout odors, and then returned (Lefcort et al. 1998). The amount of time that the tadpoles were removed from their test chambers for use in a separate experiment was not given but was probably on the order of hours. The nonstandard methods and sparsity of some methodological details (e.g. hardness not measured, few details on chemical methods, carrying out two overlapping tests using the same individual organisms) would likely preclude the study from meeting guidelines for inclusion in a criterion database. However, the tests do suggest Columbia spotted frog tadpoles may be sensitive to zinc. The Columbia spotted frog is generally found in or near ponds, wetlands, and other standing waters (Nussbaum et al. 1983). Therefore they are not expected to be significant species in the flowing waters of the South Fork Coeur d'Alene subbasin.

The influence of combined dietary and waterborne exposure routes of metals to fish in relation to the SSC were described in Section 3.3. Field studies relevant to the SSC are examined in detail in Section 5.

4.0 Toxicity Testing

Toxicity tests were conducted in 2000 and 2001 to assess the protectiveness of the site-specific criteria developed for use above Canyon Creek, for use throughout the South Fork basin. In 2000, cutthroat trout were exposed to water collected from the Lower South Fork of the Coeur d'Alene River (LSF) near Smelterville. Zinc concentrations in the LSF were expected to be acutely toxic to trout. Because of this, the toxicity of lead and zinc could not be determined in the usual way, by spiking dilution water with metal salts. Therefore, a two-part test design was used:

1. A dilution series of LSF water using a non-toxic surrogate water to assess zinc toxicity
2. A lead-spiked series in a non-toxic surrogate water with similar characteristics to the LSF water

The lower St Regis River, Montana, was selected as the surrogate water source for the LSF for two reasons:

- The North Fork water chemistry is dissimilar to that of the LSF (hardness and alkalinity are much lower)

- The St Regis River had been extensively compared to the South Fork during the selection process for a reference stream to the South Fork for natural resource injury determination. Based on a number of watershed, hydrologic, habitat, and comparative anthropogenic factors, the St Regis was considered to be the best available reference stream to the South Fork for the purpose of comparing fish populations and invertebrate assemblages (Stratus 2000).

The hardness, alkalinity, and pH concentrations of the water collected from the lower St Regis were within the ranges of values reported from the lower South Fork. Dissolved organic carbon concentrations in the St Regis sample were lower than in water samples collected from the lower South Fork. Details of these tests can be found in Windward (2001).

In 2001, four tests were conducted using a study design similar to that used in the 2000 tests. Tests were conducted in water collected from the South Fork between Kellogg and Osburn, and between the mouth of the South Fork and the Page wastewater treatment plant (WWTP). These tests were conducted using a dilution series with St Regis water, due to the high ambient cadmium and zinc found in the South Fork at these sites. These two reaches bracket the Bunker Hill Superfund Site and, at low flow, are likely to be reasonable worst-case scenarios for metals loading in the South Fork downstream of Wallace. The reach between the mouth of the South Fork and Page WWTP may be atypical because of organic carbon inputs to the South Fork from the treatment plant. Details regarding these tests can be found in the 2001 Data Report (Windward 2001).

The LSF and Elizabeth Park South Fork dilution series test were conducted using:

- Cutthroat trout fry
- St Regis River water for dilution water and control
- Five treatments: 100%, 50%, 25%, 12.5, and 6.25% site water

Two tests were conducted in water from the East Fork of Pine Creek (EFPC). Pine Creek is a major tributary to the South Fork and generally has lower hardness, lower Ca/Mg ratios, and lower pH values than other waters in the South Fork watershed. If the SSC is protective in EFPC water, it should be protective throughout the South Fork watershed. Because lower Pine Creek is mining influenced and has elevated metals concentrations, it was necessary to collect test water from high in the Pine Creek watershed to avoid potential ambient toxicity. For these tests water from East Fork of Pine Creek was spiked with lead or zinc at and above the proposed SSC. The East Fork Pine Creek tests were conducted using:

- Cutthroat trout fry
- LNF water for control
- a second ambient control

- Four treatments each for lead and zinc that bracketed their proposed site-specific criteria

Because these tests provided results at the low end of the hardness range (i.e., 11.4 mg/L as $CaCO_3$) that also occurs in the reach of the LSF above Canyon Creek, and because they were single metals tests, they were included in the data set used to derive SSC.

With the completion of the 2000-2001 test series, the toxicity of metals had been tested in site waters across much of the South Fork watershed. Test waters have included waters from headwaters reaches where background metals concentrations are very low, waters with intermediately elevated concentrations, and waters from the lower South Fork where ambient metals concentrations were elevated >10x above SSC (Figure 4-1).

As previously stated, the objective of the verification testing was to assess whether SSC developed for the LSF above Canyon Creek would be protective throughout the South Fork basin. In order to accomplish that, each test treatment was examined separately. The percent mortality relative to control for each treatment was compared to the calculated site-specific CMC for the given treatment hardness. Due to the nature of the tests, i.e., dilutions of LSF with St Regis water, the hardness varied among treatments for a given test. Tables 4-1 and 4-2 present the results from LSF stations and Pine Creek stations respectively.

The results of the tests conducted on water collected from near Smelterville show no toxicity in treatments with concentrations of cadmium up to 1.1x the proposed criterion and zinc up to 1.6x the proposed criterion. Low levels of effects (i.e., 17% mortality or 5 of 30 individuals) were seen in a treatment with 2x the proposed cadmium criterion and 3x the proposed zinc criterion. Control survival was 100%.

Tests conducted in LSF water collected near Elizabeth Park show moderate effects (i.e., 40% mortality or 13 of 30 individuals) at 2.5x the proposed cadmium criterion and 3x the proposed zinc criterion. Low mortality relative to control was observed uniformly in all lower treatments. Control survival was 93%.

The tests conducted in water collected from the LSF near Enaville show no toxicity in a treatment with 0.7x the proposed cadmium criterion and 1.1x the proposed zinc criterion. The next highest treatment contained 1.1x the proposed cadmium criterion and 1.4x the proposed zinc criterion, but showed only low levels of effects (i.e., 14% mortality or 4 of 30 individuals). Control survival was 90%.

The results of the St Regis lead-spiked tests show no mortality in the highest treatment tested, which contained lead at 3.7x the proposed criterion. No mortality occurred in any of the lower treatments or controls.

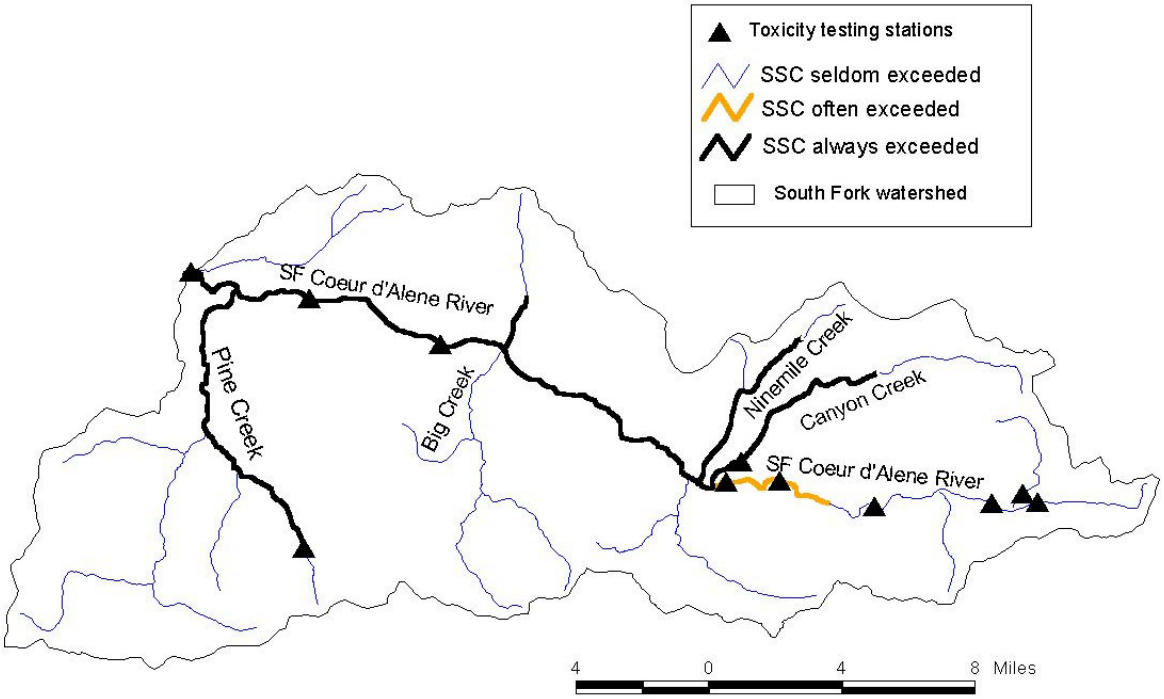

Figure 4-1. Sample locations for SSC toxicity testing

The objective of the Pine Creek lead- and zinc-spiked tests was to verify the protectiveness of the proposed SSC in waters with extremely low hardness. As noted above, these tests were included in the data set used to generate the proposed SSC. The results of the zinc-spiked tests show no toxicity in a treatment with zinc at 0.8x the proposed criterion. The next highest treatment had 54% mortality with zinc at 1.8x the proposed criterion. For the lead-spiked test, low levels of effects (i.e., 17% or 4 of 24 individuals) were seen in a treatment with lead at 1.1x the proposed criterion. Control survival was 100%.

An alternative approach to assessing the protectiveness of the proposed SSC is to compare the test results expressed as an acceptable effects concentration to the proposed criterion for the given test hardness. An acceptable low effects concentration (i.e., ECx, the concentration at which x% of the individuals are predicted to respond) is one that would be assumed to result in little or no measurable mortality and that is statistically different from control treatments (to account for the inherent variability seen in any toxicity testing program). As is the case with significance levels in statistical testing (e.g. $p < 0.1$, 0.05, or 0.01), there is no set ECx value for estimating low-level effects. Examples of ECx values for estimating low-thresholds of adverse effects include EC25s for whole-effluent toxicity (EPA 1991), EC20s for responses of benthic macroinvertebrates in mesocosms to metals (Hickey and Golding 2002), EC20s for deriving a chronic ammonia criterion (EPA 1999), and EC10s in a statistical comparison of regression based and hypothesis testing based low toxic effects thresholds(Moore and Caux 1997). EPA (1999) concluded that while the most precise estimate of effects concentrations is usually an EC50, such a major reduction is not necessarily consistent with criteria providing adequate protection. In contrast, a concentration that caused a low level of reduction, such as an EC5 or EC10, is rarely statistically significantly different from the control treatment. As a compromise, the EC20 was used as representing a low level of effect that is generally significantly different from the control treatment across the useful chronic datasets that were available (EPA 1999). An EC10 was selected for our assessment, acknowledging that these values are not necessarily statistically different from controls. The results of this comparison are presented in Table 4-2. The results show that the EC10s were mostly greater than the proposed criteria (8 of 9 cases). The EC10 to CMC ratio for zinc ranged from a high of 2.7 to a low of 1.1. For cadmium the ratios ranged from 1.8 to 1.2, and for lead the ratios ranged from >3.6 to 0.77.

The results of the verification testing indicate that few if any sensitive individuals would be killed by exposure to CMC concentrations, even in combined cadmium and zinc exposures.

Table 4-1. Summary of the results of the criteria verification tests

TEST	TEST DATE	EXPOSURE	TREATMENT HARDNESS	MORTALITY RELATIVE TO CONTROL	GEOMETRIC MEANS OF EXPOSURE CONCENTRATIONS			SITE-SPECIFIC CMC			EXPOSURE CONCENTRATIONS/CMC		
					Cd	Pb	Zn	Cd	Pb	Zn	Cd	Pb	Zn
LSF Near Smelterville	9/27/2000	T1	41	0%	0.2	<3	26	0.83	nc	108	0.24	nc	0.24
LSF Near Smelterville	9/27/2000	T2	41	0%	0.2		47	0.84	nc	108	0.24	nc	0.44
LSF Near Smelterville	9/27/2000	T3	42	0%	0.5		93	0.86	nc	110	0.58	nc	0.85
LSF Near Smelterville	9/27/2000	T4	43	0%	0.95		179	0.89	nc	112	1.07	nc	1.60
LSF Near Smelterville	9/27/2000	T5	46	17%	1.85		362	0.94	nc	117	1.97	nc	3.09
LSF Near Smelterville	9/27/2000	T6	52	77%	3.45		734	1.06	nc	126	3.25	nc	5.83
St Regis Lead-spiked	9/27/2000	T1	41	0%	<0.2	61	<10	nc	106		nc	0.58	nc
St Regis Lead-spiked	9/27/2000	T2	41	0%		107		nc	106		nc	1.01	nc
St Regis Lead-spiked	9/27/2000	T3	41	3%		148		nc	106		nc	1.40	nc
St Regis Lead-spiked	9/27/2000	T4	41	0%		387		nc	106		nc	3.65	nc
LSF near Elizabeth Park	8/27/2001	T1	54	10%	0.35	<3	49	1.11	nc	130	0.32	nc	0.38
LSF near Elizabeth Park	8/27/2001	T2	55	10%	0.8		110	1.13	nc	131	0.71	nc	0.84
LSF near Elizabeth Park	8/27/2001	T3	57	7%	1.75		254	1.18	nc	135	1.48	nc	1.88
LSF near Elizabeth Park	8/27/2001	T4	62	43%	3		431	1.21	nc	142	2.48	nc	3.04
LSF near Elizabeth Park	8/27/2001	T5	70	70%	6.5		905	1.45	nc	155	4.48	nc	5.84
LSF near Enaville	8/27/2001	T1	58	7%	0.4	<3	68	1.19	nc	136	0.34	nc	0.50
LSF near Enaville	8/27/2001	T2	63	0%	0.9		161	1.3	nc	144	0.69	nc	1.12
LSF near Enaville	8/27/2001	T3	73	14%	1.6		215	1.51	nc	159	1.06	nc	1.36
LSF near Enaville	8/27/2001	T4	94	40%	3.4		666	1.94	nc	187	1.75	nc	3.57
LSF near Enaville	8/27/2001	T5	135	77%	6.7		1340	2.8	nc	237	2.39	nc	5.65

Test	Test Date	Exposure	Treatment hardness	Mortality relative to control	Geometric Means of Exposure Concentrations			Site-Specific CMC			Exposure Concentrations/CMC		
					Cd	Pb	Zn	Cd	Pb	Zn	Cd	Pb	Zn
Pine Creek Lead-spiked	9/6/2001	T1	11.4	0%	<0.2	7	<10	0.30	31	45	nc	0.23	nc
Pine Creek Lead-spiked	9/6/2001	T2	11.4	4%		16			31			0.52	
Pine Creek Lead-spiked	9/6/2001	T3	11.4	17%		33			31			1.06	
Pine Creek Lead-spiked	9/6/2001	T4	11.4	100%		78			31			2.52	
Pine Creek Lead-spiked	9/6/2001	T5	11.4	83%		161			31			5.19	
Pine Creek Zinc-spiked	9/6/2001	T1	11.4	0%	<0.2	<3	10	0.30	31	45	nc	nc	0.22
Pine Creek Zinc-spiked	9/6/2001	T2	11.4	0%			13			45			0.29
Pine Creek Zinc-spiked	9/6/2001	T3	11.4	0%			37			45			0.82
Pine Creek Zinc-spiked	9/6/2001	T4	11.4	54%			80			45			1.78
Pine Creek Zinc-spiked	9/6/2001	T5	11.4	92%			127			45			2.82

nc – not calculable

Table 4-2. Low toxic effects thresholds (EC10s) from verification tests compared to site-specific criteria

Test	Test Date	Hardness	EC10 as			Site-Specific CMC			EC10/CMC		
			Cd	Pb	Zn	Cd	Pb	Zn	Cd	Pb	Zn
LSF Near Smelterville	9/27/2000	~45	1.7	nc	314	0.92	na	115	1.8	nc	2.7
St Regis Lead-spiked	9/27/2000	41	nc	>387	nc	na	106	nc	nc	>3.6	nc
LSF near Elizabeth Park	8/27/2001	~57	1.65	nc	244	1.2	na	135	1.4	nc	1.8
LSF near Enaville	8/27/2001	~70	1.7	nc	325	1.4	na	154	1.2	nc	2.1
Pine Creek Lead-spiked	9/6/2001	11	nc	24 +	nc	na	31	nc	nc	0.8	nc
Pine Creek Zinc-spiked	9/6/2001	11	nc	nc	51	na	na	45	nc	nc	1.1

+ calculated as an EC10 by linear interpolation (Norberg-King 1993) because data were too heterogeneous for probit analysis

nc – not calculable, na – not applicable

5.0 Field Validation of the Site-Specific Criteria

The purpose of this section is to evaluate the protectiveness and ecological relevance of SSC by comparing biological survey results to criteria exceedances in the study area. The South Fork has recently been the focus of several environmental assessments, and large chemical and biological data sets have been collected in the study area in the last several years. Here we have compiled and matched chemical and biological data over a gradient of conditions to seek associations between criteria exceedances and apparent adverse effects.

One approach to determining whether criteria would protect natural stream communities is to compare the occurrence of apparent instream effects to criteria exceedances at that location. The absence of apparent effects at sites that do not often exceed criteria, or the presence of apparent effects at those sites where criteria are frequently exceeded would support the relevance of the criteria. The converse of either would call in question the protectiveness or relevance of criteria.

Criteria were developed through toxicity testing of indigenous organisms in stream water; if instream effects could be predicted based on criteria exceedances, that would be strong evidence of their environmental relevance. There are limitations, however, in the ability to "validate" criteria in this manner. "Validation" is the process of comparing the overall result or output of a method, toxicity test, or model with observed effects in natural systems(Cairns et al. 1995). In this case, the SSC that resulted from many toxicity tests, calculations and decisions are compared to field observations of instream biological conditions and criteria exceedances. Toxicity test results can never truly be validated or refuted based on field comparisons and vice versa. Toxicity tests are conducted in ecologically unrealistic environments, where all variables other than that being tested are held constant. This is the only means by which causality can be assigned to the test variable. In field conditions, multiple biological, physical, and chemical variables interact; with many variables changing, only correlations between variables can be established, not causality.

Instream studies have been criticized because they are often restricted to a single system, and inferences about other streams are not statistically valid. In contrast, the use of replicated "natural experiments" to measure the effects of anthropogenic disturbance on community structure allows researchers to make broader inferences about a larger population of impacted systems. This experimental design is more powerful than studies with individual streams (Clements and Kiffney 1996). Thus, an effort was made in the South Fork field validation was to include data from its tributaries and streams from adjacent watersheds, in addition to performing upstream-downstream comparisons.

Because it is impossible to prove that no biological effects are occurring in the field, the only way to validate laboratory tests directly is to show similar responses in the field and laboratory

The best possible outcome when seeking to "validate" toxicity test results with field observations is that similar types of apparent effects are observed in the field as resulted in toxicity tests at similar concentrations (Chapman 1995; Clements and Kiffney 1996; de Vlaming and Norberg-King 1999; Ferraro and Cole 2002; Suter et al. 2002). For example, if a concentrations of zinc caused mortality to cutthroat trout relative to controls in toxicity tests, and if similar concentrations were measured in a stream location with low abundance of cutthroat trout relative to abundance at reference conditions with low zinc concentrations but otherwise similar habitat conditions, then the toxicity-test predictions would be considered "validated." While potentially powerful, there are fundamental limitations to these comparisons. First, the absence of instream effects can never be proven; effects may be present that are too subtle to detect by field surveys. Second, the presence of apparent effects cannot be proven to have been caused by the stressor of interest. Other unmeasured or correlated variables could be the cause. Thus, we here qualify instream biological effects as "apparent" effects. Acknowledging the strengths and limitations of the approach, at locations with suitable data, we made comparisons of criteria exceedances and biological effects.

5.1 FIELD VALIDATION METHODS

5.1.1 Data sources

The primary data set evaluated was from the US Geological Survey National Water Quality Assessment, Northern Rockies and Intermontane Valleys study unit "NROK data" (http://montana.usgs.gov/nrok/nrokpage.htm). Strengths of this data set for comparing instream conditions to criteria exceedances include,

- Chemical, physical habitat, macroinvertebrate, and electrofishing collection methods were synoptic, clearly described, suitably rigorous, and consistent.
- Sample sites were selected to include a ranged of conditions from nearly undisturbed reference sites to highly disturbed mining sites.
- Open source data: the USGS monitoring data were collected to provide information on environmental conditions and trends. The data are publicly available. In contrast, some other data sets were difficult to obtain because they were collected to support litigation or were proprietary, and repeated requests over months were required to locate and obtain data.

The NROK fish community data have been previously analyzed in relation to metals concentrations and habitat variables. Maret and MacCoy (2002) observed that streams located downstream from the areas of intensive hard-rock mining in the Coeur d'Alene River basin contained fewer native fish and lower abundances as a result of metal enrichment, not physical habitat degradation. Typically, salmonids were the predominant species at test sites where zinc concentrations exceeded the Idaho acute criteria. Cottids were absent at these sites, which suggests that they are more severely affected by elevated metals than are salmonids (Maret and MacCoy 2002). Since the South Fork SSC for zinc are about 2x higher than the Idaho zinc criteria, these findings raised concerns regarding whether SSC were adequately protective of sculpin. These concerns were the main impetus for making a detailed comparison of site-specific criteria exceedances and biological conditions.[3]

The NROK data set had two important limitations for the purposes of our analysis, however:

- Cadmium laboratory reporting limits in water (≥ 1.0 µg/L) were up to 5x greater than the acute cadmium SSC in waters of low hardness, and were higher than concentrations that had resulted in significant mortalities to cutthroat trout and shorthead sculpin in South Fork water (LC50s of 0.9 – 1.3 µg/L, respectively, (Windward 2002). Thus, it is possible that adverse effects to cutthroat trout or sculpin could have been caused by cadmium toxicity and not have been detected, or that undetected cadmium toxicity could have been attributed to zinc. Cadmium and zinc co-vary and may occur at approximately equi-toxic units in the South Fork (Section 3).
- Matched chemical and biological samples were only collected at one point in time, during base-flow conditions in August – September, 2000. If significantly higher concentrations of metals occur at other times, apparent instream biological responses might reflect recent more extreme conditions rather than concentrations present at the time of sampling. Biological samples integrate and reflect the past environmental history at a location, not just conditions present at the time of sampling. In particular, relatively sessile macroinvertebrates and sculpin may have a longer environmental "memory" than the more vagile trout.

Additional data were sought to 1) estimate cadmium concentrations occurring in the vicinity of mining influenced NROK sites with undetected cadmium; 2) estimate ranges of maximum metals concentrations expected at NROK sites, and 3) locate additional relevant data, with an emphasis on locations with metals concentrations that were moderately elevated to near SSC concentrations. The sites of most interest for our analysis were those with intermediate metals concentrations that were near criteria conditions. Biological conditions at sites with either very low metals concentrations (reference sites) or at severely disturbed sites where criteria are exceeded by many times

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[3] These concerns were also the impetus for re-testing the relative sensitivity of cutthroat trout and shorthead sculpin to zinc in side-by-side tests using newly emerged fry, which was expected to be the most sensitive life stage (Windward 2001a).

provide little insight by themselves whether sites with metals elevated to about criteria concentrations would be protective.

Additional biological data located and analyzed included fish and macroinvertebrate surveyed from the IDEQ beneficial use reconnaissance program database and fish surveys conducted by natural resource trustees (NRT) as part of a natural resource damage assessment (Podrabsky et al. 1999a; Podrabsky et al. 1999b). The analysis of fish data was greatly facilitated by a comprehensive EPA compilation and standardization of fish population and metals data for the Coeur d'Alene basin and reference areas (EPA 2001c). Original data were used in favor of review data whenever possible. Only data from similarly sized streams to those in the South Fork watershed were used. Data from the North Fork, main Coeur d'Alene, lower St Joe River, and Spokane River were excluded because those river sites are much larger than the South Fork. Naturally different fish and macroinvertebrate communities would be expected in these larger waters.

5.1.2 Comparison methods

Extensive chemistry data have been collected in the study area for many years. Because the water chemistry collections have been so widespread, in many cases chemical and biological sampling stations were located in the same stream reaches. For the present purposes of estimating concentrations likely experienced by fish and macroinvertebrate communities at a site, the following rules were followed:

- Biological and chemical samples were considered matching if they occurred within the same stream reach between two mapped tributaries. Thus if the samples occurred between tributaries that could potentially dilute or load metals, they were considered reasonably matched.
- To estimate ranges of metals that the instream biota at a site could at least episodically be exposed to, all dissolved cadmium and zinc data collected from 1991 to date for a site were used to calculate median and 95th percentile values for the entire period of record. The median concentrations at a site were used as the estimate of chronic exposures that organisms experience and the 95th percentile concentrations were used to reflect typical, episodic high exposures.

The SSC are hardness-dependent, and vary by more than a factor of 10 over the range of hardnesses encountered in the study area. For the field validation data, sample hardnesses ranged from 6 to 120 mg/L as $CaCO_3$. The corresponding CMCs for those hardnesses range from 0.12 to 2.5 µg/L for cadmium and 30 – 220 µg/L for zinc. This wide range of what are supposed to reflect the upper bounds of safe instream metals concentrations would confound field validations. For example, at average hardnesses 100 µg/L dissolved zinc in a low-hardness stream such as Pine Creek would be 2.4X SSC and would likely be acutely toxic, yet 100 µg/L zinc in the lower South Fork would be 0.6X SSC and no measurable adverse effects would be predicted. Hence, to make meaningful comparisons between instream biological conditions and waterborne metals concentrations, it was necessary to normalize the metals to their hardness-adjusted criteria.

5.1.3 Field metrics used to compare with instream SSC criteria exceedances

Several biological metrics (i.e. biological endpoints that are expected to respond to a stressor in a predictable way) were compared to cadmium and zinc concentrations throughout the South Fork watershed and vicinity. Since an almost limitless number of biological endpoints could potentially be examined, the comparisons focused on metrics that were expected to be sensitive to metals, and could be calculated with the available data. The descriptions and rationale for using each metric to evaluate apparent effects are given in the following subsections.

Trout density

Resident westslope cutthroat trout were the most sensitive organisms to cadmium and zinc under controlled testing conditions using South Fork water (Windward 2002). Thus in locations with cadmium or zinc concentrations greater than those toxic in controlled testing, cutthroat trout densities would be expected to be depressed. In some reference streams in the study area, such as the St. Regis River, the Little North Fork Coeur d'Alene River, and the North Fork Coeur d'Alene River, alien trout species have become established, particularly brook trout in cool, upper reaches of streams, and rainbow trout in warmer, downstream waters. Thus numbers of all trout present in samples were used, not just the native trout. The factors controlling whether brook trout or rainbow trout successfully invade cutthroat trout habitats are complex and incompletely understood. Factors such as life history differences in relation to hydrologic regimes, behavioral differences, competitive advantages at different temperatures, proximity to release sites or to source populations may be important (Dunham et al. in press; Fausch 1989; Fausch et al. 2001). Differences in water quality tolerances have not been shown to be a significant factor in cutthroat trout interactions with brook trout or rainbow trout. In rankings of organism sensitivity in the cadmium and zinc water quality criteria, the genera common in the study area, *Oncorhynchus* and *Salvelinus*, were ranked among the more sensitive genera (EPA 1996, 2001a). For the SSC studies, rainbow trout were often used as a surrogate for cutthroat trout to compare acute to chronic responses and to test spatial variability in metals toxicity. Their sensitivities were mostly similar.

Trout density is an indicator of trout populations. The SSC are intended to delineate levels safe for sensitive organisms based on testing at the individual level of organization. In nature, the collective effects of toxicity to individuals should be reflected at the population level of organization. However, quantitative relationships between trout populations and environmental quality are notoriously elusive. Interactions among water quality, habitat, species interactions, and management manipulations often make relationships between environmental variables and trout densities less than obvious ((Fausch et al. 1988; Mebane 2002b; Rose 2000). Streams change over a gradient from headwaters to mouth and their ecology changes with it (Vannote et al. 1980). In analyses of several hundred fish samples from streams and rivers in Idaho and vicinity, densities of coldwater fish, relative to sampling effort, were highest in mid-sized streams, ≈ 3rd order, and lower in both smaller and larger streams (Mebane 2002b; Mebane et al. in press). In larger streams, reduced electrofishing efficiency probably contributes to the apparent reductions in density.

Percent sculpin

Shorthead and torrent sculpins, the species occurring in the study area, require well-oxygenated rubble or rubble/gravel substrate, and are absent from or rare in streams with high percentages of fine-grained substrates or elevated metals (Maret and MacCoy 2002; McCormick et al. 1994; Mebane 2001). Larvae of these species and some adults burrow into the interstitial spaces of cobble substrate for refuge (Bond 1963; Haro and Brusven 1994). Sculpin have similar physiological needs as many salmonids, but relatively sessile habits make them excellent water-quality indicators (Bond 1963; Carline et al. 1994). Sculpin are usually abundant, and often numerically dominant in mid-sized forest streams in Idaho, relatively less abundant in rivers, and may be completely absent from small, high gradient (>≈ 4% slope) or high elevation streams ((Mebane 2002b; Mebane et al. in press).

Small-bodied fish may be superior to large-bodied fish as “sentinel” species for detecting effects from discrete disturbances in open receiving environments. Smaller fish species, such as cottids, exhibit limited mobility relative to many larger species and typically possess a smaller home range. Many small species also show territorial behavior, particularly in lotic systems. This characteristic increases the probability that a sentinel species will not move extensively, and the observed response of that species will more likely reflect the local environment in which it was caught. In addition, small fish species tend to be more numerous than larger, more predatory species, which facilitates sampling; they have a shorter life span and therefore show alterations in reproduction and growth faster than longer-lived species; and they are not subject to commercial or sport fishing (Gibbons et al. 1998; Munkittrick and McMaster 2000).

Stream fish IBI

The index of biotic integrity (IBI) was developed to address the need for operational definitions of Clean Water Act terms such as “biological integrity” and “unreasonable degradation.” The IBI was intended to provide a broadly based and ecologically sound tool to evaluate biological conditions in streams, incorporating many attributes of stream communities to evaluate human effects on a stream and its watershed. Those attributes cover the range of ecological levels from the individuals through population, community and ecosystem (Karr 1991). The IBI framework was used to develop an index for coldwater forest streams in Idaho that gauges a stream against an expectation based on minimal disturbance in the ecoregion. The IBI developed for fish communities in Idaho streams is an additive index consisting of the following six metrics (Mebane 2002b):

Coldwater native species - Species richness frequently changes in response to environmental stress. This metric is limited to native coldwater species to exclude confounding introduced or tolerant native species. Reference coldwater streams typically have one to three native coldwater species. As habitats shift from cold to cool water, total species richness may increase as cool and warm water species' ranges overlap. Most fish assemblages appear to be somewhat unstable and fluctuate more in terms of species abundances than species presence or absence.

Percent coldwater individuals - This metric acknowledges widespread establishment of non-indigenous trout populations that have become part of the resident fishery in Idaho. Introduced trout often displace native trout but are still intolerant of degraded water quality conditions. Low representation of coldwater species may indicate degraded conditions.

Percent sensitive native individuals – Tolerances to environmental stress have been listed for many species (Zaroban et al. 1999). Stream systems that are similar to natural reference conditions will include sensitive native individuals. Conversely, sensitive natives will be the first to decline in a system that is highly turbid, silty, or warmer than historic conditions

Trout age classes – This metric reflects suitability and stability of conditions in a surveyed location for salmonid spawning, juvenile rearing, and adult salmonids. Age classes are inferred from measured size classes and typical length-at-age relationships (same for sculpin age class metrics). Year-class failures may be reflected in fewer age classes captured; these are frequently responses to different stressors, such as exploitation, recruitment failure, food limitation, or niche shifts (Munkittrick and Dixon 1989). Larger trout may be more resistant to chemical stressors than smaller fish

Sculpin age classes – This metric is based on similar concepts as salmonid spawning and reflects the presence of suitable cobble substrate required for cavity nesters and juvenile refuge. Sedentary life histories result in adult home ranges of <50-150m (Hendricks 1997). Their low dispersal distances are advantageous for assessing site conditions over several years.

CPUE (catch per unit effort) – This metric reflects the relative abundance of coldwater fishes in a sample, normalized to electrofishing effort. Coldwater fish should be more abundant at locations with favorable conditions for coldwater biota. However, a myriad of natural and anthropogenic factors that limit the abundance of fish complicates interpretation, particularly with trout that are subject to harvest. Defining this metric as coldwater instead of salmonid abundance may lessen potential confounding harvest effects. Since abundances of all fish may increase in response to some types of degraded water quality (the paradox of enrichment), limiting the metric to coldwater individuals may avoid that response.

Estimates of density or biomass can be difficult to measure. For example, sampling efficiency drops in larger waters and density estimates are difficult in complex habitats (e.g. logjams). Abundance needs to be normalized to compare different-size habitats, different fishing efforts, etc. The metric is calculated as the number of coldwater fish captured for the first electrofishing pass divided by the current-on times in seconds.

Macroinvertebrate taxa richness

Total taxa richness measures are widely used in field assessments of streams and may be sensitive measures of ecosystem disturbance. Most studies have reported declines in taxa richness in response to elevated metals concentrations in streams sensitive measures of ecosystem disturbance (Carlisle and Clements 1999; Clements et al. 2000; Clements et al. 1992; Deacon et al. 2001; Fore 2003; Kiffney and Clements 2003; Mebane 2001, 2003). Carlisle and Clements (1999) found that in terms of sensitivity, variability, and statistical power, richness measures were superior to other commonly used metrics. However, the response may not always be consistent in situations with intermediate disturbances or because of the replacement of sensitive taxa such as mayflies with more tolerant taxa such as caddisflies or stoneflies (Clements and Kiffney 1996; Hickey and Golding 2002).

Mayfly taxa richness

This richness measure is limited to the generally metals sensitive mayfly (Ephemeroptera) taxa. The studies listed above on macroinvertebrate taxa richness that found overall taxa richness to decline in response to metals also found that the effects of metals were generally greater on mayflies than other macroinvertebrate groups.

Metals-intolerant macroinvertebrate density

As a group mayflies are generally sensitive to and caddisflies and true flies are often tolerant of elevated metals concentrations (Section 3.4.3). If closely related species have similar sensitivity to the same stressors, then aggregating species into higher taxonomic groups may reduce sampling and analysis variability. However, within aggregate taxonomic groups (e.g. order, family), individual taxa vary in their sensitivity to metals. Several taxa were consistently sensitive to heavy metals in a regional survey of Colorado mountain streams (Clements et al. 2000; Fore 2003). This metric measures the abundance of only these metals-intolerant taxa. Abundance is measured instead of taxa richness in this metric, because taxa richness reflects only presence of a taxon. If a taxon is severely depressed but still present in reduced numbers, taxa richness counts will not reflect that. The metric consists of the sum of the densities of the following ten genera in four orders: the mayflies *Cinygmula, Drunella, Epeorus, Paraleptophlebia,* and *Rhithrogena;* the stoneflies *Skwala, Suwallia, and Sweltsa;* the caddisfly *Rhyacophila,* and the dipteran *Pericoma*. (List of metals intolerant taxa was provided by W.H. Clements, personal communication with CAM, 22 May 2002).

Stream Macroinvertebrate Index (SMI)

The SMI is a benthic macroinvertebrate index of biotic integrity (B-IBI) that was developed for Idaho streams (Jessup and Gerritsen 2002). Similar to IBIs for fish communities, the SMI and related B-IBIs consist of several metrics that reflect the community composition or structure or functions of the community and are generally predicted to respond in a predictable way to environmental stress. The sum of the metrics is supposed to reflect the biological condition of that site relative to reference conditions. The various published B-IBIs all have similar form, although the specific metrics used and scoring vary depending whether the index is intended to respond to specific stressors, such as metals or urbanization, and vary regionally (Karr and Chu. 1999). For example, Fore (2003) developed a B-IBI specifically calibrated to respond to elevated zinc and other metals in the Eagle River, CO. The SMI is a general index that was developed by based on discriminating between a priori disturbed and reference sites (Jessup and Gerritsen 2002). Mebane (2003) tested the response of the general B-IBI model to copper concentrations in an Idaho stream and found strong and consistent index responses. The SMI shares most metrics with the general B-IBI model so would be expected to perform about as well with metals. The SMI is the sum of the following nine metric scores, each of which is respectively based on similarity to reference conditions: # Total taxa, # mayfly taxa, # stonefly taxa, # caddisfly taxa, % stoneflies, Hilsenhoff Biotic Index, % dominance by the 5 most abundant taxa, # scraper taxa, and # of clinger taxa (Jessup and Gerritsen 2002).

5.2 FIELD VALIDATION RESULTS AND DISCUSSION

5.2.1 Temporal variability in metals exposures to aquatic life

Figure 5-1 illustrates temporal variability in zinc concentrations and SSC at three representative sites from the mining-influenced portions of the South Fork watershed.

At the USGS monitoring station near the confluence of the South Fork and the North Fork, zinc concentrations vary 10x, ranging from 200 to >2,000 µg/L. Maximum zinc concentrations occurred during winter base flows, and lowest concentrations occurred during spring snowmelt. The SSC rose and fell in step with zinc concentrations, as hardnesses rose and fell in response to changes in groundwater-base flows or runoff (Figure 5-1, top). The temporal variability in concentrations was less extreme at two sites with intermediately elevated zinc concentrations: the South Fork upstream of Canyon Creek and Pine Creek (Figure 5-1, bottom). At these sites zinc concentrations ranged over factors of 3-5x, in contrast to the noted factor of >10x.

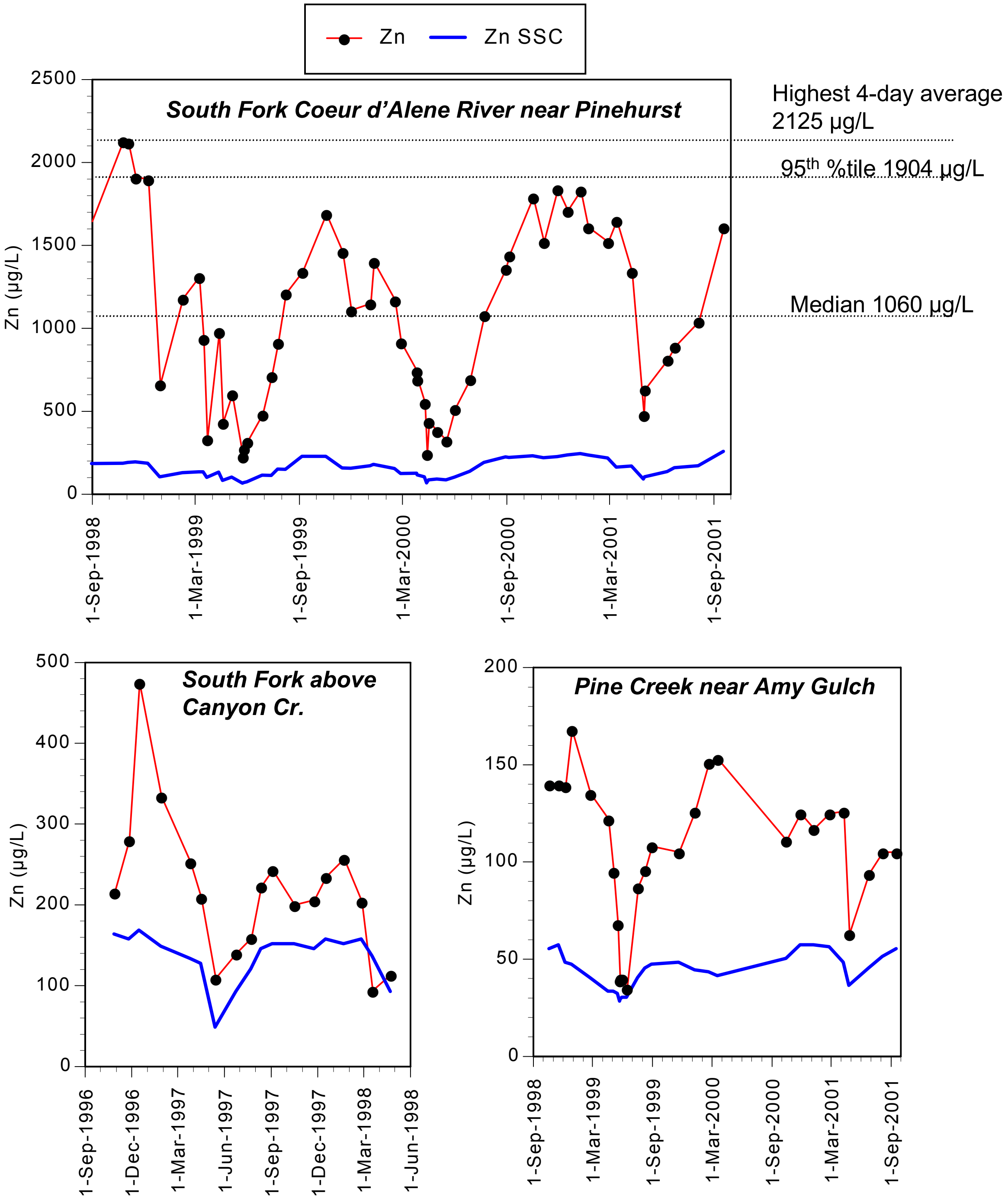

Figure 5-1. **Variability of dissolved zinc concentrations at the South Fork near the mouth (top), South Fork upstream of Canyon Creek (bottom left), and Pine Creek (bottom right); note difference in vertical scales**

For the South Fork upstream of Canyon Creek (Figure 5-1, bottom left), the maximum concentration in a <3-year period was 480 µg/L; for comparison with the CCC, the highest average concentration spanning 4+ days was 405 µg/L; the 95th percentile was 355 µg/L, and the median concentration was 212 µg/L. For Pine Creek (Figure 5-1, bottom right), the maximum concentration over the 3-year period of record was 168 µg/L, the highest average concentration spanning 4 days was 152 µg/L, the 95th percentile was 152 µg/L, and the median concentration was 110 µg/L. At all three sites, cadmium showed a similar temporal pattern to zinc, and lead was usually below detection limits

This examination of patterns from sites with the best data records suggests that the 95th percentile concentration is a reasonable, if slightly low, estimate of the highest 4-day concentration expected at a site in the South Fork. On the average, 95th percentile cadmium and zinc concentrations listed in Appendix B were 2.1x higher than the median concentrations.

The record is limited to the most recent 3-year period to correspond with the SSC recurrence frequency. For the purpose of the SSC field validation analysis, the median concentrations for a location were thought of as the “chronic” exposures even though the chronic criteria are really defined as the highest 4-day average concentration occurring in a 3-year period. The highest average of any two consecutive samples bracketing a 4-day period would more closely represent the highest 4-day average concentration than the grand average for the site. In this dataset, the highest average concentration spanning 4+ days would be about twice as high as the median concentration (2,125 vs. 1,060 µg/L). Similarly, the CMC would be applied to the maximum value in the 3-year record, not the 95th percentile (2,130 vs. 1,904 µg/L). These deliberate choices to low-bias the instream metals concentrations in the field comparisons were made for two reasons: 1) for a field validation, if no effects are apparent at somewhat low-biased estimates of SSC concentrations and durations, they would not be apparent at higher (but unknown) concentrations either; 2) avoiding the use of single-extreme values in a dataset reduces the chance of using a spurious single value. The exceedance frequency allowed for SSC is one per 3-year period. By chance, the range of sampling dates for the bulk of the available chemical data sources at most sites tended to cover three years or less, e.g. the IDEQ intensive monitoring from 1996-1998.

The cadmium and zinc concentrations from the NROK data set (single grab samples from August-September 2000) were reasonably similar to the long-term median concentrations for those locations, usually ±30% of the site median. This suggests that late-summer base flow grab samples may reasonably approximate median concentrations in the South Fork. At the Pine Creek site, the NROK zinc concentrations were 110 µg/L with an sample hardness of 10 mg/L. The median zinc concentration for the USGS dataset (Figure 5-1) was 110 µg/L, with an average hardness of 10 mg/L.

5.2.2 Patterns of instream biological responses associated with criteria exceedances

Patterns of apparent biological responses to criteria exceedances are graphed in Figures 5-2, 5-3, and 5-4. Tabular data supporting these figures are presented in Appendix B. Biological metrics values are plotted with cadmium, zinc, and cumulative criteria unit exceedances (CCUs), where an exceedance factor $(\mathrm{EF}) = \frac{\mathrm{Metal}\ (\mu\mathrm{g/L})}{\mathrm{CMC}\ (\mu\mathrm{g/L})}$ was calculated for the hardness of the sample. If no sample hardness were available, the CMC was calculated with the average hardness for the location. Since cadmium and zinc were usually both elevated in samples, if the metals were only examined individually, effects that might actually be caused by cadmium could be misattributed to zinc or vice versa. Thus, CCUs were calculated to identify apparent effects from cadmium and zinc mixtures (dissolved lead and other metals were seldom elevated above their lowest criteria or even detection limits, see Section 3). The CCU exceedance factor is simply the sum of the cadmium and zinc EFs, or

$$\mathrm{CCU\ EF} = \sum \frac{\mathrm{Cd}\ (\mu\mathrm{g/L})}{\mathrm{Cd\ CMC}\ (\mu\mathrm{g/L})} + \frac{\mathrm{Zn}\ (\mu\mathrm{g/L})}{\mathrm{Zn\ CMC}\ (\mu\mathrm{g/L})}\ .$$

Obviously EFs could be calculated with either CMCs or CCCs; CMCs were chosen because some sites only had one data point, which would not be appropriate to compare with the 4-day average for CCCs. Cadmium EFs calculated with CCCs would be about 1.6x higher than CMC EFs at a hardness of 50 mg/L. The zinc CMC and CCC concentrations are equal (Table 1-1).

Hereafter, we refer to sites as having low or high EFs. "Low" EFs refer to sites with median EFs less than or equal to 1.0 individually or with median CCU EFs less than or equal to 2.0. "High" EFs are greater than 1.0 or 2.0 respectively.

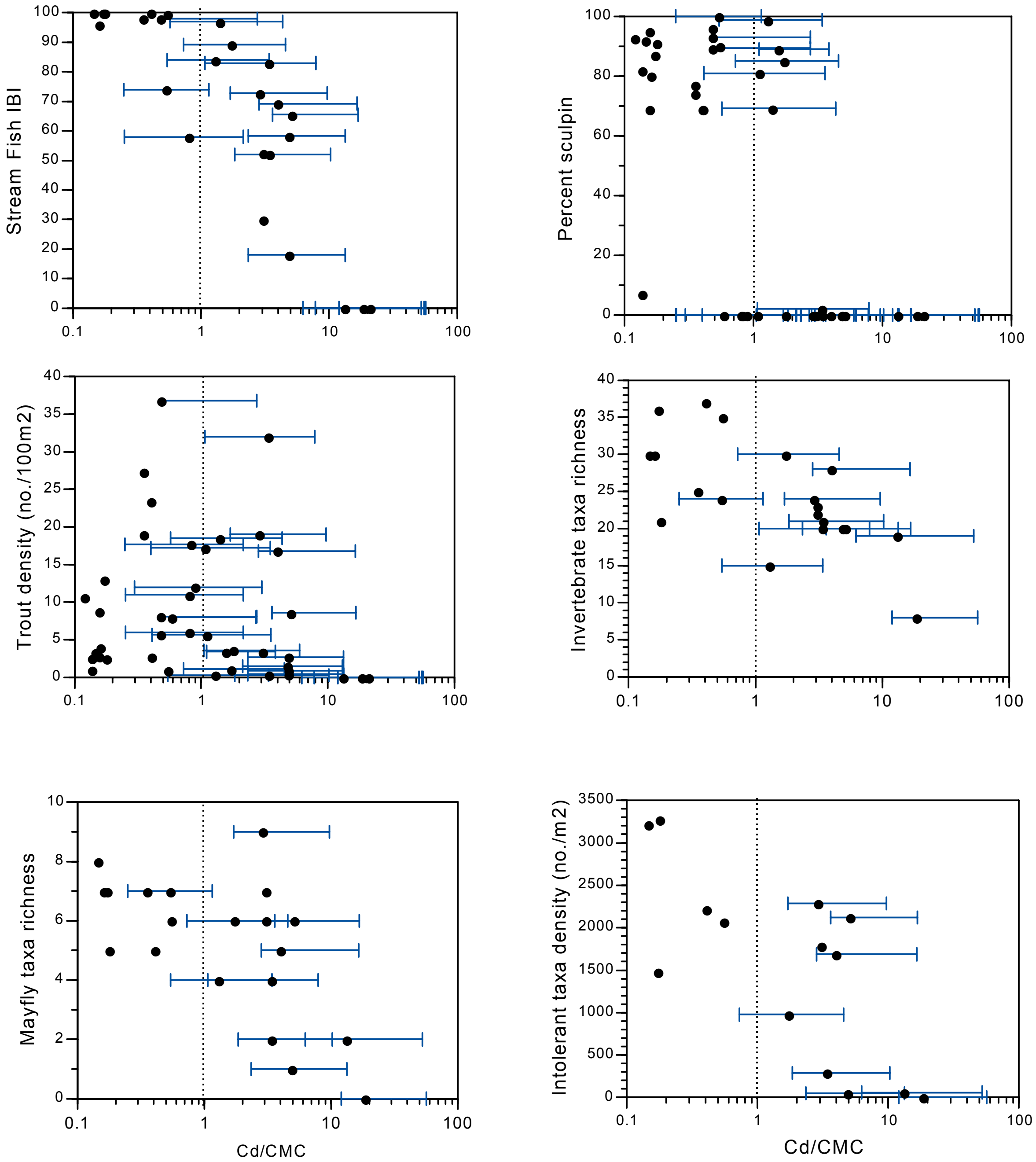

Figure 5-2. Comparison of instream cadmium SSC exceedance factors and corresponding fish and macroinvertebrate metrics

Error bars show the 5th and 95th percentile exceedance factors for sites with multiple chemistry values.

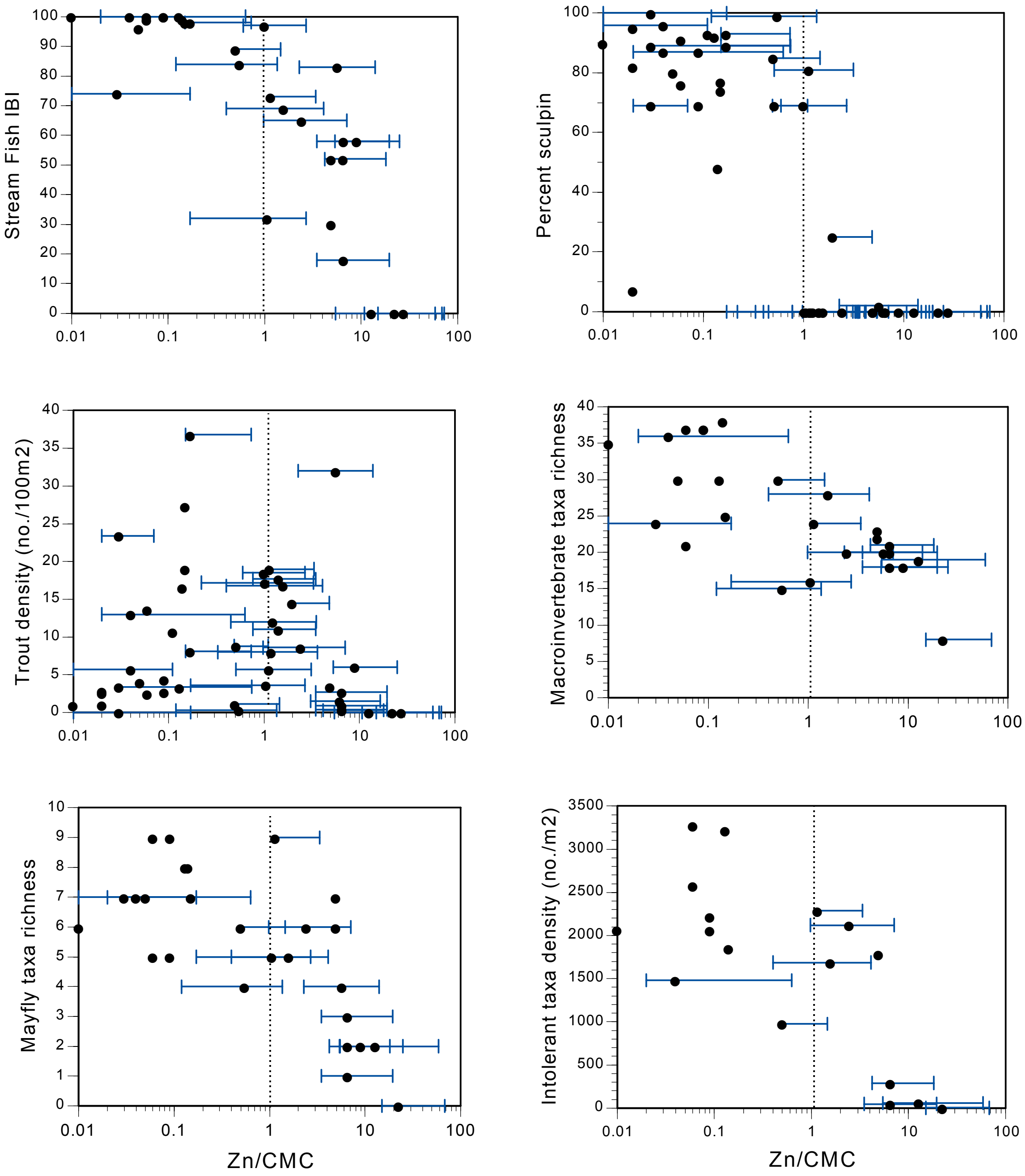

Figure 5-3. Comparison of instream zinc SSC exceedance factors and corresponding fish and macroinvertebrate metrics

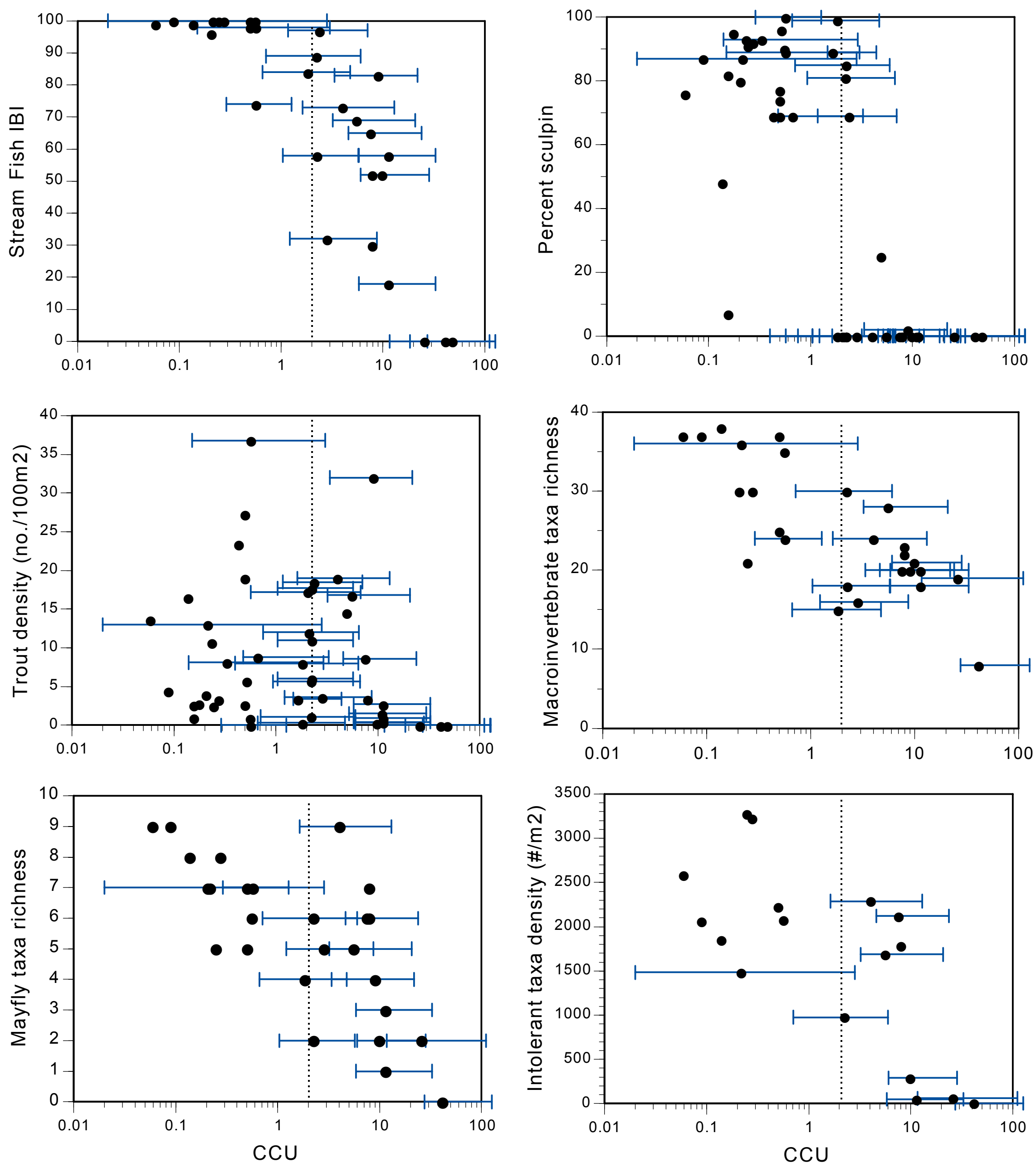

Figure 5-4. Comparison of cumulative criteria unit (CCU) exceedance factors and corresponding fish and macroinvertebrate metrics

Fish community composition

Stream Fish IBI scores at sites with median cadmium or zinc exceedance factors <1 or the cumulative EFs <2 were very high, indicating the fish community composition at study sites that usually met cadmium or zinc criteria was similar to that at reference streams. IBI scores showed a general graded decline as individual EFs increased much above 1.0 or CCU EFs increased much above 2.0 (Figures 5-2 – 5-4). The idea behind a multimetric additive index is that at least some metrics would respond to most stressors. This appears to have been the case with these data. At sites with CCU EFs > 2.0, IBI scores declined as the *Coldwater Native Species* and *Sculpin Age Classes* metric scores declined. At metals concentrations <≈ 10 CCUs, reduced relative densities and fewer trout age classes resulted in lower scores. The *Percent Coldwater* and *Percent Sensitive Native Species* metrics were not responsive metrics in these streams with elevated metals concentrations, but generally cool temperatures.

Percent sculpin

Sculpin showed remarkably consistent threshold responses to elevated cadmium or zinc. Sculpin were abundant at all sites that seldom exceeded zinc SSC, and were often abundant at sites where the cadmium criteria seldom exceeded 2x (Figures 5-2 – 5-4). One data point with low metals and only 7% sculpin, St Regis River at Haugen, NRT 1996 data, was discounted as a likely sampling artifact, since the NROK sampling found 91% sculpin at that location. Almost no sculpin were found at any site where the median zinc concentrations exceeded SSC, and no sculpin were found at sites that exceeded 2x cadmium criteria. (Figures 5-2 and 5-3). Several sites with cadmium EFs <1.0 had no sculpin (Figure 5-2), however those sites also had zinc EFs >1.0. In combination, all sites with median CCU EFs >2.4 had sculpin absent. The lowest median EF for a site with sculpin absent was 1.9 CCUs; the episodic (95th percentile) exposure for that site was > 3.45 CCUs.

There was almost no overlap in the percent sculpin values for sites with greater or less than 1.0 zinc EFs, little overlap in with cadmium, and very little overlap with CCU EFs greater or less than 2.0. The strength and consistency of the field patterns between percent sculpin and exceedance factors is extraordinary, particularly since data were collected by different programs at different times with chemical and biological data only roughly matched in time.

Trout densities

There were no obvious relationships between trout densities and cadmium, zinc, or CCU EFs until individual EFs exceeded about 5x for cadmium and zinc and CCU EFs exceeded 10x. These depressed densities were common in the South Fork below Canyon Creek. Only lower Canyon Creek and portions of Ninemile Creek were completely devoid of trout (Appendix B). Grouping river sites and stream sites in an effort to account for expected stream size differences in densities (Section 5.1.3) did not obviously improve metals density patterns.

Some cutthroat trout were found at all sampled sites in the lower South Fork, albeit at lower densities than at similar sized reference sites in most cases. Between two and five age classes of cutthroat trout were collected from the lower South Fork, indicating conditions in those sites may be tolerated by juvenile to adult trout for several months to years at a time (data not shown). However, when resident South Fork cutthroat fry were tested in water collected from three lower South Fork sites, almost all died (Section 4.0). This apparent incongruity between toxicity test predictions and field observations seems likely due at least in part to acclimation and mobility. When salmonids are acclimated to elevated but sublethal concentrations of cadmium, zinc, and other metals, survivors may become much more resistant to later exposure. Several tests have found cadmium and zinc resistance increased 2 – 3x after acclimation, but in some tests resistance increased >10x (Alsop et al. 1999; Alsop and Wood 2000; Chapman 1978; Grosell and Wood 2001; Hollis et al. 1999, 2000; Stubblefield et al. 1999). Acclimation to one metal may enhance tolerance of different metals that have similar physiologic processes (Hansen et al. 2002b). Cutthroat trout typically ascend to the upper reaches of watersheds to spawn, and during their first year of life are thought to disperse from areas of high density in the spawning areas to areas of lower density (Behnke 1992). This pattern may avoid exposing the most vulnerable life stage (newly emerged fry) to lethal metals concentration, and the dispersal may afford acclimation opportunity.

Macroinvertebrate taxa richness

Macroinvertebrate richness showed a generally declining pattern with increasing cadmium, zinc, or cumulative EFs. Sites with low EFs averaged about 30 taxa and several sites had >35 taxa present. Sites with individual EFs much over one or CCUs much over two seldom had more than 25 taxa present, averaging about 20.

Mayfly taxa richness

Mayfly richness also showed generally declining patterns with increasing EFs. Most sites with low EFs had 5 – 9 mayfly species present with an average of about 7 species, and most sites with high EFs had 0- 7 mayfly species present with an average of about 4 species. Almost all sites with high EFs had some mayfly species present. These results support previous findings (Section 5.1.3) that while the effects of metals may generally be greater for mayflies than other macroinvertebrate groups, at least a few taxa may tolerate, or develop tolerances to, elevated metals.

Density of metals-intolerant macroinvertebrate taxa

The highest densities of taxa that were expected to be intolerant of elevated metals were in fact found at sites with low EFs. However, densities were highly variable at sites with low metals concentrations, so only at sites with individual EFs greater than about 5x or CCUs greater than about 8x were densities lower than the range at reference sites. Analyses using this metric were limited by small sample size; only NROK data were analyzed because of taxonomic enumeration differences between the NROK and IDEQ data sets; these differences make density metrics generally incomparable between different data sets (Carlisle and Clements 1999; Fore 2003).

Stream Macroinvertebrate Index (SMI)

SMI scores were significantly higher at sites where zinc SSC were seldom exceeded than at sites where SSC were frequently exceeded. The average SMI scores were 68 and 41 (n = 21 and 14), respectively, with a $p < 0.01$. We interpret these scores as suggesting that the function and composition of macroinvertebrate communities are often compromised at sites that frequently exceed the zinc SSC. At sites where the zinc SSC were seldom exceeded, macroinvertebrate community composition and function was generally similar to that of the reference conditions for the vicinity. The 25th percentile SMI score for reference conditions in the Northern Mountains bioregion was 64 (Jessup and Gerritsen 2002), which is similar to average scores for sites generally meeting the SSC.

Data are not plotted with the other metric and exceedance factor plots because SMI scores could not be easily calculated for the NROK sites, and cadmium data were often missing or were non-detects with detection limits that were higher than the cadmium CMC values.

Statistical summaries of field validation data

The scatter plots in Figures 5-2 – 5-4 show patterns in the data and allow inspection of individual data points in relation to criterion exceedance ranges for that site. They are informative for visual patterns and identifying specific data points to inspect further, such as apparent responses specifically at, slightly above, or below criterion values. In contrast, comparing the statistical distributions of biological metric values occurring at sites that seldom or frequently exceed SSC reduces and simplifies the data and allows testing of statistical differences between groups.

Distributions of metric values at sites with low or high EFs are illustrated with box and whisker plots in Figure 5-5. The top whiskers show the 90th percentile, the top of the box is the 75th percentile, the line across the box is the median (50th percentile), the bottom of the box the 25th and bottom whisker is the 10th percentile value for each group. The dots are the arithmetic means; p values for difference of the means, i.e. the likelihood apparent differences are just from chance, are from Student's one-sided t-test.

The *Percent Sculpin* metric with zinc showed the greatest separation of distributions, with no overlap and the lowest p value. *Percent Sculpin* metric with cadmium or cumulative cadmium and zinc also had strong separation, although not as complete as with zinc, since sculpin were abundant at some sites with cadmium EFs of about 1-2, unless the sites also had zinc EFs above 1.0 (Figure 5-2). This suggests that in field conditions in the South Fork, zinc criterion exceedances may limit sculpin distributions more than moderate cadmium criterion exceedances do. Fish community composition, as scored by the *Stream Fish IBI* metric also showed a strong separation between sites with low or high EFs. For this metric, expressing criterion exceedance factors as CCUs greatly increased the separation in scores between the two groups.

When grouped by EFs, *Trout Densities* were statistically similar between groups of sites where criteria were seldom or usually exceeded. As discussed, the most plausible explanation for the lack of obvious patterns between trout densities and exceedance factors is the influence of acclimation and life history traits of resident trout. However, these statistical summaries lose the detail that at sites with high EFs (>≈ 5) trout densities are consistently low.

All nine of the macroinvertebrate metric comparisons with the three EFs were highly statistically significant between low and high EF sites and had little overlap in the main body of their distributions. The *Macroinvertebrate Taxa Richness* metric had the least spread in values at sites with high EFs. *Mayfly Taxa Richness* had some overlap in the boxes, which might be because this metric has the smallest and most discrete range of values (integers from 0-9). The *Density of Metals Intolerant Macroinvertebrate Taxa* metric was also significantly high at high metals sites than low metals sites (average of about 1,000/m^2 vs. about 2,300/m^2 at sites with low and high EFs respectively). The ranges are fairly large, reflecting inherent variability in macroinvertebrate densities, plus the fact that densities were still fairly high at sites with EFs between 1 and about 5.

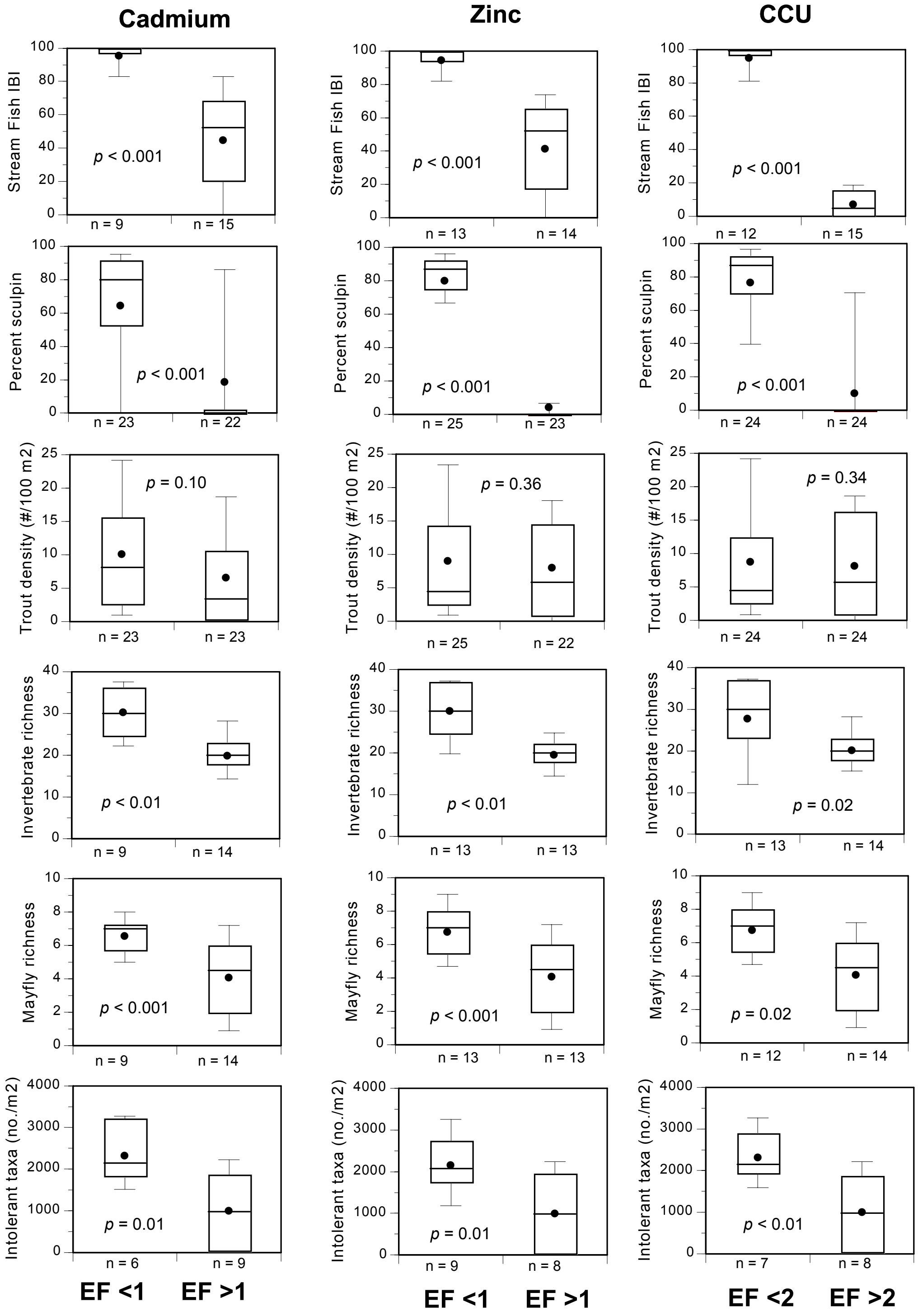

Figure 5-5. Statistical summaries of instream biological metrics at sites where SSC are seldom or frequently exceeded

5.2.3 Apparent effects thresholds from the field validation

A complementary approach to the descriptive pattern analysis of responses associated with criteria exceedances is to calculate indices of biological effects based on field studies. An approach using apparent effects thresholds (AETs) was designed to estimate threshold concentrations of contaminants above which biological effects would be expected. The AET approach was based on empirically defined relationships between measured concentrations of a contaminant in sediments and observed biological effects. This approach was intended to define the concentration of a contaminant in sediment above which significant biological effects are always observed. As developed, these biological effects included, but are not limited to, toxicity to benthic and/or water-column species (as measured using sediment toxicity tests), changes in the abundance of various benthic species, and changes in benthic community structure. Some authors refer to the approach as the "no effect concentrations (NEC)" (Cirone and Pastorak 1993; MacDonald et al. 2000).

Here, the AET approach is applied to the water-column criteria exceedance and field metric responses from the field validation dataset. The approach was developed with contaminated sediment (Cirone and Pastorak 1993), but is modified here for waterborne exposures. An AET is defined here as the criteria factor above which statistically significant biological effects (relative to reference conditions) would be expected. The AET approach matches data on criteria exceedances and fish or benthic macroinvertebrate community effects. To derive an AET value, sampling stations were arranged in a sequence according to the individual EFs for cadmium and zinc or the CCU. Next, adverse effects were defined for a given biological endpoint as a statistically significant difference (<= 10th percentile value from reference sites) between conditions in mining influenced sites in the study area relative to conditions in reference sites. Stations that exhibit adverse effects were identified. The AET value was set by the no-effect station with the highest EF or CCU (i.e. all stations with criteria exceedance factors above an AET showed significant biological effects for the given endpoint.

Values from reference sites are given in Table 5-1. Reference sites for the South Fork watershed were limited to locations on streams with minimal present or historical mining disturbance, or were upstream of disturbed locations. Sites assigned to the reference or mining influenced groups are listed in Appendix B; assignments were generally consistent with similar assignments by Maret and MaCoy (2002) and Stratus (2000).

Table 5-1. Reference values for biological metrics

METRIC	MINIMUM	10TH PERCENTILE	MEDIAN	MAXIMUM	N SITES
Fish community (IBI)	74	92	100	100	9
Percent cottids	7	69.0	88	100	20
Trout density (number/100 m^2)	0	0.99	4.2	36.8	20
Invertebrate richness	21	23	35	38	9
Mayfly richness	5	5	7	9	9
Metals-intolerant taxa density (number/ m^2)	1483	1829	2220	3275	7

Data from Appendix B

Using overall 95th percentile concentrations for sites, AETs were calculated (Table 5.3). The lowest AET values for cadmium, zinc, and combined cadmium and zinc exposures were for the *Percent Cottids* and *Fish community* endpoints (2.1 – 2.9X for single metals to 4.6X combined). Trout density and macroinvertebrate endpoints were mostly higher.

Table 5-2. Apparent effects thresholds as SSC exceedance factors for episodic exposures (95th percentile site concentrations) to cadmium and zinc

METRIC	CADMIUM CMC EXCEEDANCE FACTORS	ZINC CMC EXCEEDANCE FACTORS	CCU CMC EXCEEDANCE FACTORS
Fish community (IBI)	2.9	2.2	4.6
Percent cottids	2.9	2.1	4.6
Trout density	12.5	10.3	21.3
Macroinvertebrate richness	12.5	2.9	16.2
Mayfly richness	12.5	4.7	16.2
Metals-intolerant taxa density	11.5	4.7	16.2

The strong threshold responses of sculpin in relation to exceedances of the cadmium, zinc, or combined SSC give strong support to the ecological relevance of the SSC. There was an abrupt transition from sculpin being numerically dominant to being absent when episodic zinc concentrations exceeded about 2X to 3X the zinc or cadmium SSC concentrations respectively (calculated from overall 95th percentile zinc concentrations at a location). The overall site 95th percentile exceedance factors were used in these calculations to approximate the highest concentration spanning a 4-day period with a 3-year return interval (section 5.2.1). This approximates the magnitude, duration, and frequency provisions of the CCC.

5.2.4 Previous fisheries and criteria EF comparisons

A previous comparison of fish composition in relation to elevated metals that was done to set benchmarks for incremental biological improvements that would likely result from incremental cleanup efforts in the study area (EPA 2001c). The present results differ somewhat from the EPA (2001c) results. A tier system representing a qualitative gradient of fishery conditions from very poor conditions (no fish present) to a fully functional fishery was developed. The description of "Tier 4" seems to most closely correspond with conditions at sites with median EFs <1.0 or CCU <2. A "Tier 4" fishery was defined as having three or more year classes of native or introduced salmonids present at a location, salmonid densities are generally high (>10 fish/100m^2), and young-of-the year are present which indicates successful spawning and rearing. Sculpin are present at high to moderate densities. The criteria range suggested to support a Tier 4 fishery was 1X to 3X the cadmium or zinc chronic ALC that were derived in EPA's 1995 ALC updates (EPA 1996, 2001c). Averaging periods for the criteria factors were not specified (i.e. maximum, average, or highest 4-day average, etc), but from the context of their usage appear to be overall averages for a location. Lower tiers are distinguished by the absence of sculpin, and progressively lower densities. A Tier 5 fishery was also described. The principal differences with Tiers 4 and 5 are that the Tier 4 community consists of native or introduced salmonids and the Tier 5 community only consists of natives, and "is typically found in undisturbed streams with metals concentrations below the chronic ALC." However, EPA (2001c) noted that the achievability of Tier 5 fisheries was likely related to fisheries management and habitat factors, rather than water chemistry.

The 1995 cadmium and zinc ALC are different from either the Idaho statewide criteria or the South Fork SSC; the SSC cadmium criteria are lower and the SSC zinc criteria are higher than 1995 EPA ALC. The Tier 4 fishery EFs of 1X to 3X the 1995 EPA chronic ALC are equivalent to 2.2X to 6.5X the chronic site-specific cadmium criterion, and are equivalent to 0.53X to 1.6X the chronic site-specific zinc criterion (calculated at a hardness of 50 mg/L as $CaCO_3$). The present field validation results suggest that these Tier 4 EFs would be associated with adverse effects to instream fish assemblages. The present results suggest that a Tier 4 fishery would be unlikely to occur at locations where median concentrations are >3.0X the chronic site-specific cadmium criterion, or >1.0X the chronic site-specific zinc criterion. Expressed as multiples of the 1995 EPA chronic ALC, the upper range of the "Tier 4" benchmarks would be 1.4X the cadmium CCC and 1.9X the zinc CCC.

5.2.5 Differing responses of trout and sculpin to metals in field conditions

The close agreement between SSC predictions derived from toxicity testing with indigenous organisms in site water and the most sensitive apparent field effects supports the relevance of the resident species approach to setting SSC. What is puzzling though, is that in field conditions sculpin were more severely affected by elevated metals than were salmonids. Yet, in two controlled side-by-side exposures of cutthroat trout and shorthead sculpin, the cutthroat trout were somewhat more sensitive to elevated metals. This pattern has been noted elsewhere (Carline et al. 1994; Gagen et al. 1993), and two general hypotheses might explain the paradox:

1. Sculpin may be less tolerant of metals than trout, but the limited testing with sculpin has failed to detect this sensitivity ("lower tolerance hypothesis").
2. Sculpin and trout may be physiologically similar in metals sensitivity, but differing life histories and behavior make sculpin more vulnerable to episodic disturbances or multiple exposures ("differing life history hypothesis").

Reasoning for the two hypotheses follows; some life history features and metals toxicity values are summarized in Table 5-3.

Supporting reasoning for the "lower tolerance hypothesis"

Despite their widespread distribution and importance in northern and mountain aquatic ecosystems of North America, little toxicity testing has been reported with freshwater cottids. Most testing that has been done may not have used the most sensitive life stages. A review of several tests showed that tested sculpin were usually collected by electrofishing and were >30 mm in total length, or else lengths were not reported (EVS 1996c; Gagen et al. 1993; Thurston and Russo 1981; Woodling et al. 2002). For the species tested, sculpins 30 mm in length are usually about 1-year old (Mebane et al. in press). Newly emerged swim-up fry (≈ 30 days post hatch) are usually thought to be the life stage most sensitive to metals, not 1-year old fish. In response to concerns that side-by-side range-finding tests with field collected cutthroat trout and shorthead sculpin underestimated zinc sensitivity, (Windward 2001) specifically targeted newly emerged young-of-year shorthead sculpin for side-by-side testing of cutthroat trout swim-up fry with zinc. While the tests were not definitive due to high control mortality and minimal dose response, they suggested that the sculpin fry were less sensitive than cutthroat trout fry to zinc in acute exposures. These results also suggested sculpin fry (8 – 12 mm total length) are probably more sensitive to zinc than older sculpin. It is possible that for sculpin, standard 96-hour acute toxicity tests are of insufficient duration to accurately assess zinc toxicity. In extended duration acute tests Woodling et al. (2002) found that with mottled sculpin (*Cottus bairdi*), mortality only plateaued at about 9 days, and speculated that mottled sculpin have a later onset of mortality than trout when exposed to metals.

Table 5-3. Comparison of typical life-history characteristics and metals sensitivities of cutthroat trout and shorthead sculpin

Characteristic	Cutthroat trout	Shorthead sculpin
Adult size (cm)	25-46	9-13
Home range (km)	0.3 – 3 (stream resident forms) up to 160 (adfluvial/fluvial forms)	0.05 – 0.15
Spawning habits	Migrate upstream from adult habitat in larger streams into headwaters or tributaries to spawn in gravelly areas. Nests not guarded.	No migration from adult habitats. Spawn in crevices and cavities under rocks. Male guards nest until hatching.
Juvenile habitat	Pools, stream margins, and other quiescent areas.	Interstices under cobbles in the well oxygenated, high velocity riffles.
Adult habitat	Water column. Stream-resident fish may make downstream migrations of several km at onset of winter.	Benthic, occupying rubble and gravel riffles of fast moving streams and rivers. Adults have low dispersal distances.
Age to sexual maturity	4 – 6 years (females)	2 years
Life Span	7 – 10 years	4 – 5 years
Adult food	Invertivore	Invertivore
Median recovery time following disturbance (extirpation to first re-appearance)	0.17 years	2 years
Cd EC50 (µg/L)	0.85 – 2.3 (4 tests)	3.1 (1 test)
Zn EC50 (µg/L)	200 – 639 (6 tests)	>275 – >2100 (2 tests)

EC50s normalized to hardness 50 mg/L as $CaCO_3$.

(Behnke 1992; Bjornn and Reiser. 1991; Hendricks 1997; Hilderbrand and Kershner 2000; Jakober et al. 1998; Mebane et al. in press; Niemi et al. 1990; Windward 2002)

If trout have a greater capability to acclimate to metals in field conditions than do sculpin, then perhaps trout could develop a higher tolerance to metals, even though non-acclimated sculpin may be no more sensitive than non-acclimated trout. Several tests of acclimation of salmonids to cadmium or zinc have resulted in increased tolerance on the order of 2 – 3x (Alsop et al. 1999; Chapman 1978; Grosell and Wood 2001; Stubblefield et al. 1999). In contrast, an experiment of zinc acclimation with minnows only increased tolerance by 1.3x (Hobson and Birge 1989). However, acclimation induced increases in trout tolerance to cadmium or zinc ranged from 1x (no protection conferred) to 20x, even within the same set of experiments (Hollis et al. 2000; Stubblefield et al. 1999). Thus, these possible differences may reflect experimental differences more than inherent taxon differences.

Supporting reasoning for the "differing life history hypothesis"

Restricted sculpin distributions in relation to trout cannot be explained by chemical tolerances, and thus other factors need to be examined (Carline et al. 1994). Gagen et al. (1993) exposed brook trout, mottled sculpin, and slimy sculpin (*Cottus cognatus*) to episodes of elevated aluminum and decreased pH in nine, 20-day *in situ* side-by-side field exposures. In all cases, the brook trout experienced higher mortality than either sculpin species. The 20-day exposures were long enough to make delayed onset of sculpin mortality in relation to trout an unlikely explanation of the higher trout mortality.

Interspecific differences in avoidance behavior during exposure episodes could make sculpin more vulnerable to episodically elevated metals than trout. Trout and salmon may make downstream movements to avoid episodically elevated metals, whereas no reports of avoidance behavior were found for sculpin (Gagen et al. 1994; Saunders and Sprague 1967). Sculpin are sedentary fish, and during episodes of acidity and elevated aluminum exhibited hypoactivity and failed to spawn (Kaeser and Sharpe 2001). Smaller-bodied fish such as cottids have fewer year-classes capable of reproduction than larger-bodied fish, so populations are susceptible to dramatic loss from recruitment failure. Recruitment failure is a commonly reported cause of fish population declines associated with acidification or elevated metals (Munkittrick and Dixon 1989; Munkittrick and McMaster 2000).

Differing metals exposure in sculpins and trout – Differing habitat preferences may result in sculpins experiencing higher metals exposure than trout. Sculpin larvae and some adults burrow into the interstices of the substrate and could be exposed to elevated metals from both contaminated sediment and water. In the NROK study, bulk sediment samples were collected from depositional areas in the same reaches where the fish and invertebrate samples were collected. At all sites where sculpin were absent, sediment concentrations of cadmium, lead, and zinc exceeded sediment quality guidelines for probable effects to benthic communities (MacDonald et al. 2000; Maret and MacCoy 2002).

In a study in Panther Creek (Idaho) relating copper in sediment and water with effects to instream benthic macroinvertebrates and sediment toxicity testing, the metals in sediment were toxic to benthic invertebrates (Mebane 2003). For sediment toxicity testing, sediments taken from the stream were tested for toxicity to a benthic invertebrate with clean overlying water. Co-occurring loss of richness from the benthic macroinvertebrate community could not be attributed specifically to metals in sediment or water because they were strongly correlated. However, toxicity of the sediments to benthic test organisms suggests that either sediment or water exposures of metals could result in adverse biological effects, and in combination might be more severe. In surveys of contaminated sediments, sampling is often targeted to depositional zones where metals are likely to be concentrated in fine-grained sediments. In the Panther Creek study, instead of collecting contaminated sediments only from depositional zones, sediments were also collected with a turkey baster from the crevices between cobbles in the fast water in the center of the stream channel. These sediments from fast water were more toxic than sediments from slow water. The fast water sediments had 0% survival, despite having copper concentrations that were less than half the concentrations from the slow water stream margins of the same transect, which had up to 58% survival (Mebane 2003). This could be significant for sculpin, which spawn in the crevices between cobbles, where conditions could be toxic to eggs or emergent fry independent of water-column concentrations. Both westslope cutthroat trout and shorthead sculpin feed primarily on invertebrates, so dietary exposures to metals are likely similar.

In summary, there are two hypotheses that might explain the absence of sculpin in locations with elevated metals and where cutthroat trout were present or even abundant (the “lower tolerance of sculpin hypothesis” and the “differing life history hypothesis”). From the information available, we think the “differing life history hypothesis” is likely the more important. In particular, the patterns of brook trout and sculpin distribution and mortality in acidic episodes mirror the patterns observed in the South Fork. Recruitment failure following the failure of stressed adults to complete spawning seems as plausible a mechanism in western streams that have episodes of elevated metals as in the eastern streams that have episodes of elevated aluminum and acidity. In the acidified streams, the stressed adult sculpin did not necessarily die, but failed to complete spawning (Kaeser and Sharpe 2001). This suggests that further acute side-by-side tests with cutthroat and shorthead sculpin or even early-life stage tests may not adequately explain distribution in the wild. Instead, full life cycle testing or field tests similar to that of Kaeser and Sharpe (2001) using transplanted fish may be needed.

The mechanism explaining sculpin and trout distributions in relation to elevated metals is arguably moot for the main purpose of this report. That purpose is to evaluate whether site-specific criteria that are based on cutthroat trout as the most sensitive species are adequately protective of sculpin and other indigenous aquatic life in the South Fork watershed. Since at sites that seldom exceed SSC, no depressions of sculpin populations or any other metric were apparent, the criteria appear to be protective.

Summary of field validation findings

Comparisons of a large set of matched instream biological survey data with metals concentrations showed no apparent adverse effects at sites that seldom exceeded cadmium or zinc SSC. In contrast, significant adverse effects (extirpation of sculpin) were almost always observed at sites that frequently exceeded SSC. These field comparisons of median metals concentrations in streams usually reflected a 2-4 year averaging period of metals concentrations. Those periods would encompass several generations of macroinvertebrates, more than one generation of sculpin, and about one cutthroat trout generation. Thus, the field validation could in effect be thought of as chronic, metal-mixtures field tests. These results give powerful support to the protectiveness and relevance of developing SSC through the approach of testing indigenous species in site water.

6.0 Conclusions

The weight of the evidence available indicates that the site-specific criteria that were developed in the upper reaches of the South Fork watershed would likely be as protective to resident species throughout the watershed. That conclusion is based on the following factors:

1. Factors that affect the toxicity of metals to aquatic life either vary in ways that make metals toxicity less severe in downstream reaches than in the upper reaches where the toxicity testing was conducted (e.g. hardness), or are similar in upper and lower reaches (such as pH, Ca:Mg ratios, and DOC) (Section 3).
2. An examination of ambient water metals concentrations in the study area on a site-specific toxic units basis showed that the overwhelming risks of adverse effects from waterborne metals in the lower South Fork are from cadmium and zinc. Cadmium and zinc accounted for 95 – 99% of the total chronic exceedances. Cadmium and zinc chronic criteria exceedances were evenly balanced in these data, accounting for 53% and 44% of the exceedances respectively. Any risks of toxicity to aquatic life from other waterborne metals, including copper and lead, are overwhelmed by risks from cadmium and zinc in the lower South Fork (Section 3).
3. Benthic communities from headwater streams are generally more sensitive to metals than are communities with similar species composition from larger rivers (Section 3).
4. South Fork tributaries have similar characteristics to the upper reaches of the South Fork (e.g. lower hardness and colder temperatures than the mainstem lower South Fork River). Thus, effects of metals on stream communities and the protectiveness of SSC would be similar in tributaries as in headwaters (Section 3).
5. A review of the different aquatic organisms that could potentially occur in the lower South Fork watershed did not identify any species that are likely more sensitive to metals than the species occurring in the upstream reaches. The available evidence suggests bull trout are generally similar in metals sensitivity to cutthroat trout, or slightly more sensitive. Bull trout do not presently occur in the South Fork watershed (Section 3).
6. Verification toxicity testing of waters from the lower South Fork and uncontaminated reference water indicated that little if any mortality would be likely at cadmium, lead, or zinc SSC conditions. Dissolved cadmium and zinc are usually elevated in combination in the lower South Fork. Little if any mortality would be expected from joint cadmium and zinc exposures at criteria maximum concentrations. The protectiveness of the criteria was tested in a tributary that was expected to represent the most metals-toxicity-vulnerable area in the watershed, based on very low calcium hardness, neutral pH, and low alkalinity.

Test results were incorporated into the criteria dataset and the resulting criteria revised. Little mortality would be likely even under these severe conditions at criterion concentrations (Section 4).

7. Comparisons of a large set of matched instream biological survey data with metals concentrations showed no apparent adverse effects occurred at sites that seldom exceeded cadmium or zinc SSC. In contrast, significant adverse effects (extirpation of sculpin) were almost always observed at sites that frequently exceeded SSC. These results give powerful support to the protectiveness and relevance of developing SSC through the approach of testing of indigenous species in site water (Section 5).

In sum, the several lines of evidence considered – variations in factors that affect toxicity, expected organism sensitivity, toxicity testing, and field surveys – all indicate that criteria for cadmium, lead, and zinc developed using indigenous fish and invertebrates, collected from and tested in upper reaches of the South Fork, would likely be protective of aquatic life communities in the lower South Fork and tributaries as well.

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Appendix A: Species list of benthic macroinvertebrates collected from the South Fork subbasin, and reference rivers

			Present in South Fork	Present in Reference Rivers	Taxa Mean Acute Value (µg/L)		
Order	Family	Species			Cd	Pb	Zn
Odonata	Coenagrionidae	*Coenagrionidae*		X			
Enchytraedia	Enchtraeidae	*Enchtraeidae*		X			
Ephemeroptera							
	Baetidae	*Acentrella* sp.	X	X			
		Acentrella insignificans		X			
		Acentrella turbida		X			
		Baetidae	X	X			
		Baetis tricaudatus	X	X	>73	1,363	6,800
		Callibaetis sp.		X			
		Centroptilum sp.		X			
		Diphetor hageni	X	X			
		Plauditus sp.		X			
	Ameletidae	*Ameletus* sp.	X	X			
	Ephemerellidae	*Attenella margarita*		X			
		Caudetella sp.	X	X			
		Drunella coloradensis/flavilinea	X	X		646	
		Drunella doddsi2		X			
		Drunella grandis/spinifera		X			
		Ephemerella inermis/infrequens	X	X			
		Serratella tibialis	X	X			
		Timpanoga hecuba	X	X			
	Heptagenidae	*Cinygmula* sp.		X			
		Epeorus albertae		X			
		Epeorus deceptivus2	X	X			
		Heptagenia sp./*Nixe* sp.	X	X			
		Ironodes	X	X			
		Rhithrogena sp.	X	X	>50	1,838	680
		Stenonema sp.	X				
	Leptophlebiidae	*Paraleptophlebia* sp.		X			
	Siphlonuridae	*Siphlonurus*	X	X			
	Tricorythidae	*Tricorythodes* sp.	X				
Plecoptera							
	Capniidae	*Capniidae*		X			
	Chloroperlidae	*Chloroperlidae*	X	X			
		Paraperla sp.	X	X			
		Suwalia sp.	X	X			
		Sweltsa sp.	X	X	>5130	1,213	3,002
	Leuctridae	*Calineuria californica*	X	X			
		Despaxia augusta		X			
		Leuctridae		X			
		Paraleuctra sp.	X	X			
	Perlidae	*Claassenia sabulosa*		X			

Order	Family	Species	Present in South Fork	Present in Reference Rivers	Taxa Mean Acute Value (µg/L)		
					Cd	Pb	Zn
		Hesperoperla pacifica	X	X			
	Perlodidae	*Cultus* sp.		X			
		Isoperla sp.	X	X			
		Perlinodes sp.		X			
		Skwala sp.		X			
	Pteronarcyidae	*Pteronarcys californica*		X			
	Nemouridae	*Zapada* sp.		X			
Hemiptera							
	Gerridae	*Gerris* sp.		X			
	Corixidae	*Sigara* sp.		X			
	Saldidae	*Saldula* sp.		X			
Trichoptera							
	Arctopsychidae	*Arctopsyche grandis*	X	X	>458	2,709	
		Parapsyche sp.		X			
	Bracycentridae	*Brachycentrus americanus*	X	X			
		Brachycentrus occidentalis		X			
		Amiocentrus aspilus	X	X			
		Micrasema sp.	X	X			
	Glossosomatidae	*Agapetus* sp.	X				
		Glossosoma sp.	X	X			
		Culoptila sp.		X			
	Hydropsychidae	*Cheomatopsyche* sp.	X				
		Hydropsyche sp.	X	X			6,800
		Diplectrona sp.		X			
	Hydoptilidae						
		Ochrotrichia sp.	X				
	Lepidostomatidae	*Lepidostoma-sand case larvae*		X			
		Lepidostoma-turret case larvae		X			
	Limnephilidae	*Apatania* sp.		X			
		Dicosmoecus atripes	X	X			
		Dicosmoecus gilvipes	X	X			
		Psychoglypha subborealis		X			
		Onocosmoecus unicolor	X				
	Leptoceridae	*Mystacides* sp.		X			
	Polycentropodidae	*Polycentropus* sp.	X	X			
	Philopotamidae						
		Dolophilodes sp.	X				
	Rhyacophilidae	*Rhyacophila*	X	X			
	Uenoidae	*Neophylax rickeri*		X			
Coleoptera							
	Dytiscidae	*Dytiscidae*	X	X		1,306	
		Agabus sp.		X			
	Dryopidae		X				
	Elmidae	*Zaitzevia* sp.		X			
		Optioservus sp.	X	X			
		Microcylleopus sp.	X	X			
		Lara sp.		X			
		Heterlimnius sp.	X	X			

Order	Family	Species	Present in South Fork	Present in Reference Rivers	Taxa Mean Acute Value (µg/L)		
					Cd	Pb	Zn
		Narpus concolor		X			
	Hydrophilidae	*Laccobius* sp.		X			
Diptera							
	Athericidae	*Atherix* sp.	X	X			
	Culicidae	*Culicidae*					
	Empididae	*Chelifera* sp.		X			
		Clinocera sp.	X	X			
		Hemerodromia sp.	X	X			
	Simuliidae	*Simulium* sp.	X	X		1,881	
		Prosimulium sp.	X	X			
	Tipulidae	*Antocha* sp.		X			
		Hexatoma sp.		X			
		Limnophila sp.		X			
		Tipula sp.	X	X		1,306	
		Dicranota sp.		X			
		Hesperoconopa sp.		X			
		Oreogeton sp.		X			
		Pedicia sp.	X	X			
	Blephariceridae	*Blephariçera* sp.	X	X			
	Tabanidae	*Chrysops* sp.	X	X			
	Pelecorhynchidae	*Glutops* sp.	X	X			
	Psychodidae	*Psychodidae*		X			
	Ceratopogonidae	*Probezzia*		X			
	Chironomidae	*Ablabesmyia* sp.		X		3,828	
		Brillia sp.		X			
		Cardiocladius sp.	X				
		Chironomidae-pupae	X	X			
		Cladotanytarsus sp.		X			
		Corynoneura sp.		X			
		Cricotopus sp.	X	X			
		Cryptochironomus sp.		X			
		Diamesa sp.	X	X			
		Eukiefferiella sp.	X	X			
		Heleniella sp.	X				
		Hydrobaenus sp.		X			
		Limnophyes sp.		X			
		Micropsectra sp.	X	X			
		Microtendipes sp.		X			
		Odontomesa sp.		X			
		Orthocladius Complex	X	X			
		Pagastia sp.		X			
		Paratanytarsus sp.		X			
		Paratendipes sp.		X			
		Pentaneura sp.		X			
		Pentaneurini		X			
		Phaenopsectra sp.		X			
		Polypedilum sp.	X	X			
		Potthastia gaedii gr.	X	X			

ORDER	FAMILY	SPECIES	PRESENT IN SOUTH FORK	PRESENT IN REFERENCE RIVERS	TAXA MEAN ACUTE VALUE (µg/L) Cd	Pb	Zn
		Rheocricotopus sp.		X			
		Rheotanytarsus sp.		X			
		Stempellinella sp.		X			
		Stictochironomus sp.		X			
		Stilocladius sp.		X			
		Thienemanniella sp.		X			
		Thienemannimyia gr. sp.	X	X			
		Tvetenia sp.	X	X			
		Zavrelimyia sp.		X			
Non-Insect Species							
	Planaria		X				
	Acari	*Acari*		X			
	Margaritiferidae	*Margaritifera*		X			
	Nematoda	*Nematoda*		X			
	Nematomorpha	*Nematomorpha*		X			
	Oligochaeta	*Oligochaeta*	X	X			
	Ostracoda	*Ostracoda*		X			
	Sphaeriidae	*Pisidium*		X			
		Sphaeriidae		X			
	Planorbidae	*Gyraulus* sp.	X		>73	1,363	3,028

Table B-1 Dissolved zinc concentrations (µg/L), criteria exceedances, and corresponding fish and benthic macroinvertebrate assemblage metrics

Site No.	Group	Description (data source)	Sample hard-ness	Mean hard-ness	Sample Zn	Median Zn	Zn 95%-tile	CMC	Zn/ CMC	95%-tile/ CMC	n	Trout density (no./100 m2)	% Cottids	SFI	Total invert. taxa	Mayfly taxa	Total metal sensitive invert density
1996SCDAA060	M	Beaver Creek at Carbon Cr, IDEQ (2,5)		38		589	848	103	5.70	8.21	35	32	2	83	20	4	
1996SCDAB039	M	Beaver Creek near mouth (2)		40	16			113	0.14			27.3	74	98	25	7	
NROK-9	M	Beaver Creek near mouth (1)	44	40	16			113	0.14		2	16.5	48	99	38	8	1850
BVL	M	Beaver Creek near mouth, NRT 10/3/98 (3)		40		16		108	0.15		2	19.0	77				
Big96	R	Big Creek lower, 8/7/96 (2,5)		40		12		106	0.11		1	10.7	93				
1998SCDAB002	R	Big Creek 10/29/97 (2,5)		30		4		88	0.05		1	4	80	96	30	7	
NROK-13	M	Canyon Creek at Woodland Park, (1)	47	49	1,510	2640	5437	118	12.76	45.93	64	0	0	0	19	2	59
1996SCDAB038	M	Canyon Creek at Woodland Park, (2)		49		2640	5437	118	22.3	45.93	64	0	0	0	8	0	3
NROK-12	R	Canyon Creek near Burke, ID (1)	6	9	2.8	8	12	30	0.09	0.40	16	4.4	87	100	37	9	2059
NROK-6	M	EF Eagle Creek near mouth (1)	10	13	67	67	107	42	1.58	2.51	23	16.8	0	69	28	5	1687
USBM1	R	EF Pine Creek above Constitution mine (6)	10		5.1			42	0.12		1	2.9	91				
NROK-15	M	EF Pine Creek above Nabob Creek (1)	19		320			65	4.93		1	3.4	0	52	22	6	1786
1996SCDAA028	M	EF Pine Creek above Nabob Creek (2)	19			320		65	4.93				0	30	23	7	
USBM3	M	EF Pine Creek below Douglas Cr (6)	10		128			42	3.01		1	14.5	25				
LNU	R	LNF Coeur d'Alene River, NRT 10/8/98		30	3.2	2.2	5.2	88	0.04	0.06	4	5.7	96				
1999SCDAA002	R	LNF SF Coeur d'Alene River (2)		18		2	9	63	0.03	0.14	21	0	100	74	24	7	
NM-1	M	Nine Mile Cr (below RV park) (4,5)		50		3410	5540	123	27.65	44.92		0.0	0	0			
NROK-16	M	Pine Creek below Amy Gulch near Pinehurst, ID (1)	11	10	110	100	211	45	2.43	4.66	34	8.6	0	65	20	6	2121
PLL	R	Placer Creek lower, NRT 10/3/98		30		2.3	5.2	88	0.04	0.06	20	23.4	69				
NROK-8	M	Prichard Creek at Prichard (near mouth) (1)	12	17	24	32	46	48	0.50	0.96	6	1.1	85	89	30	6	977
1996SCDAB032	M	Prichard Creek at Prichard (near mouth) (2,5)		16		32	46	58	0.55	0.80	7	0.3	99	84	15	4	
NROK-7	M	Prichard Creek near Murray, ID (1)	10	16	49	62	94	42	1.15	2.21	11	19	0	73	24	9	2288
1996SCDAB030	M	Prichard Creek near Murray, ID (2)		16		62	94	58	1.06	1.62		3.6	0	32	16	5	
sfcdamorn	M	SF Coeur d'Alene R above Canyon Cr near		55		149	263	131	1.13	2.00		5.7	81				

Site No.	Group	Description (data source)	Sample hard-ness	Mean hard-ness	Sample Zn	Median Zn	Zn 95%-tile	CMC	Zn/ CMC	95%-tile/ CMC	n	Trout density (no./100 m2)	% Cottids	SFI	Total invert. taxa	Mayfly taxa	Total metal sensitive invert density
		Morning District (4,5)															
IDFG92	M	SF Coeur d'Alene R above Canyon Cr		57		193	280	135	1.43	2.08	62	17.7	0				
SF_8	M	SF Coeur d'Alene R above Canyon Cr (4,5)		57		193	280	135	1.43	2.08	62	11	0				
1998SCDA020	M	SF Coeur d'Alene R below Canyon Cr (2)		57		1220	2137	135	9.0	15.9	62	6.0	0	58	18	2	
sfcdacomp	M	SF Coeur d'Alene R above Canyon Cr near Compressor District, 1996 (2)	76	57	160	181	330	135	1.19	2.45	1	8	0				
SF_228,NRT94	M	SF Coeur d'Alene R above Canyon Cr near Golconda, 1994 (2)		64		148	330	145	1.02	2.27	24	17.2	0				
SF_228_NRT95	M	SF Coeur d'Alene R above Canyon Cr near Golconda, 1995 (4,5)		64		181	330	145	1.25	2.27	24	12	0				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT94 (4)		30	43	15	49	84	0.51	0.59		8.8	69				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT95 (2)		30		15	49	88	0.17	0.56	34	8.1	93				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT96 (2)	21	30	2	15	49	69	0.03	0.71	34	3.4	89				
US4	R	SF Coeur d'Alene R above Mullan near Highway Department, (3)		30		15	49	84	0.04	0.59	34	36.8	89				
US3	M	SF Coeur d'Alene R below Mullan, using SF-9 chemistry (3)		46		117	195	117	1.00	1.68	34	18.5	69				
NROK-11	R	SF Coeur d'Alene River above Mullan, ID (1)	28	30	3.4	15	49	84	0.04	0.59		13	87	100	36	7	1483
NROK-14	M	SF Coeur d'Alene River at Silverton, ID (1)	68	68	990	1020	1953	151	6.55	12.92	34	2.7	0	58	20	1	48
1998SCDA030	M	SF Coeur d'Alene River at Silverton, ID (2)		68		1020	1953	151	6.55	12.92	34	0.4	0	18			
SF-5	M	SF Coeur d'Alene River at Silverton, ID (3)		68		1020	1953	151	6.55	12.92	34	0.9	0				
SF-2		SF Coeur d'Alene River near Elizabeth Park (3)		65		920	1516	147	6.27	10.3	62	1.5	0				
NROK-17	M	SF Coeur d'Alene River near Pinehurst, ID (1)	120	72	1,440	1345	2539	220	6.54	11.53	85	0.3	0	52	21	2	290
NROK-18	R	St Joe River at Red Ives Ranger Station, ID (1)	22		0.5			72	0.01		1	0.9	90	100	35	6	2070
strrdeer	R	St Regis near Haugen, NRT 8/13/96 (4)	35		2			97	0.02		1	2.6	7				
strrsalt	R	St Regis near Saltese, NRT 8/12/96 (4)	36		2			99	0.02		1	1	82				
strrhead	R	St Regis R. near headwaters, NRT 8/8/96 (4)	31		2			90	0.02		1	2.8	95				
NROK-1	R	St Regis River above Rainy Ck, MT (1)	33		12			94	0.13		2	3.3	92	100	30	8	3218

Site No.	Group	Description (data source)	Sample hard-ness	Mean hard-ness	Sample Zn	Median Zn	Zn 95%-tile	CMC	Zn/ CMC	95%-tile/ CMC	n	Trout density (no./100 m2)	% Cottids	SFI	Total invert. taxa	Mayfly taxa	Total metal sensitive invert density
NROK-2	R	St Regis River near Haugan, MT (1)	27		5.28			82	0.06		2	2.5	91	100	21	5	3275
NROK-3	R	St Regis River near St Regis, MT (1)	12		4.49			48	0.09		4	2.7	69	100	37	5	2220
NROK-5	R	West Fork Eagle Creek below Settlers Grove, ID (1)	12		3.1			48	0.06		1	13.6	76	99	37	9	2581

Group: R – Reference site; M – Mining influenced site. NRT – Natural Resource Trustee natural resource damage assessment sampling

Biological data sources: 1- USGS Northern Rockies/Intermontane Valleys NAWQA database; 2- IDEQ Beneficial Use Reconnaissance Program (BURP) database; 3 – Podrabsky et al. 1999a; 4 – Podrabsky et al. 1999b, 5 – EPA 2001a; 6 – Stratus 2000

Table B-2 Dissolved cadmium concentrations (µg/L), criteria exceedances, and corresponding fish and benthic macroinvertebrate assemblage metrics

Site No.	Group	Description (data source)	Sample Hardness	Mean Hardness	Sample Cd	Median Cd	Cd 95%-tile	CMC	Cd/CMC	95%-tile/CMC	N	Trout Density (No./100 m2)	% Cottids	SFI	Total Invert Taxa	Mayfly Taxa	Total Metal Sensitive Invert Density
1996SCDAA060	M	Beaver Creek at Carbon Cr, IDEQ (2,5)		38		2.70	3.47	0.78	3.46	4.4	35	32	2	83	20	4	
NROK-9	M	Beaver Creek near Mouth (1)	44		< 1.0			0.90			1	16.5	48	99	38	8	1850
BVL	M	Beaver Creek near mouth, NRT 10/3/98 (3)		40		0.3		0.84	0.36		1	19.0	77				
1996SCDAB039	M	Beaver Creek near mouth (2)		40		0.3		0.84	0.36		1	27.2	74	98	25	7	
Big96	R	Big Creek lower, 8/7/96 (2,5)		40		0.10		0.82	0.12		1	10.7	93				
Big97	R	Big Creek lower, IDEQ 10/29/97 (2,5)		30		0.10		0.61	0.16		1	4	80				
NROK-13	M	Canyon Creek at Woodland Park, ID (1)	47		13	19.00	37.50	0.96	13.49	38.9	64	0	0	0	19	2	59
1996SCDAB038	M	Canyon Creek at Woodland Park, (2)		49		19.00	37.50	0.96	19.7	38.9	64	0	0	0	8	0	3
NROK-12	R	Canyon Creek near Burke, ID (1)	6		< 1.0			0.12			1	4.4	87	100	37	9	2059
NROK-6	M	EF Eagle nr mouth (1)	10	13	< 1.0	0.81	2.50	0.20	4.08	12.5	23	16.8	0	69	28	5	1687
USBM1	R	EF Pine Creek above Constitution mine (6)	10									2.9	91				
NROK-15	M	EF Pine Creek above Nabob Creek (1)	19		1.2			0.38	3.13		1	3.4	0	52	22	6	1786
1996SCDAB028	M	EF Pine Creek above Nabob Creek (2)		19		1.2		0.38	3.13		1		0	30	23	7	
USBM3	M	EF Pine Creek below Douglas Cr (6)	10			0.40		0.20	2.00			14.5	25				
LNU	R	LNF Coeur d'Alene River, NRT 10/8/98	30			0.25		0.51	0.49		1	5.7	96				
1999SCDAA002		LNF SF Coeur d'Alene River		18		0.2	0.2	0.36	0.55	0.6	26	0	100	74	24	7	
NM-1	M	Nine Mile Cr (below RV park) (4,5)		50		22.00	34.70	1.03	21.44	33.8	63	0.0	0	0			
NROK-16	M	Pine Creek below Amy Gulch near Pinehurst, ID (1)	11		< 1.0	1.15	2.54	0.22	5.22	11.5	13	8.6	0	65	20	6	2121
PLL	R	Placer Creek lower, NRT 10/3/98		30		0.25		0.61	0.41		4	23.4	69				

Site No.	Group	Description (data source)	Sample hard-ness	Mean hard-ness	Sample Cd	Median Cd	Cd 95%-tile	CMC	Cd/ CMC	95%-tile/ CMC	N	Trout density (No./100 m2)	% Cottids	SFI	Total invert taxa	Mayfly taxa	Total metal sensitive invert density
NROK-8	M	Prichard Creek at Prichard (near mouth) (1)	12	17	< 1.0	0.43	0.67	0.24	1.77	2.8	6	1.1	85	89	30	6	977
1996SCDAB032	M	Prichard Creek at Prichard (near mouth) (2,5)		16		0.43	0.67	0.32	1.32	2.1	7	0.3	99	84	15	4	
NROK-7	M	Prichard Creek near Murray, ID (1)	10	16	< 1.0	0.59	1.34	0.20	2.95	6.7	11	19	0	73	24	9	2288
1996SCDAB030	M	Prichard Creek near Murray, ID (2)		16		0.59	1.34	0.32	1.83	4.2	11	3.6	0	32	16	5	
sfcdamorn	M	SF Coeur d'Alene R above Canyon Cr near Morning District (4,5)		55		1.27	2.76	1.13	1.13	2.4		5.7	81				
US4	R	SF Coeur d'Alene R above Mullan near Highway Department using SF10 chemistry (3)		30		0.10	1.15	0.61	0.16	2.02	34	36.8	89				
IDFG92	M	SF Coeur d'Alene R above Canyon Cr		57		1.00	1.61	1.17	0.85	1.4	34	17.7	0				
SF_8	M	SF Coeur d'Alene R above Canyon Cr (4,5)		57		1.00	1.61	1.17	0.85	1.4	34	11	0				
1998SCDA020	M	SF Coeur d'Alene R below Canyon Cr (2)		57		8.3	13.0	1.17	7.1	11.1	34	6.0	0	58	18	2	
sfcdacomp	M	SF Coeur d'Alene R above Canyon Cr near Compressor District, 1996 (2)	76	57	0.8	1.20	2.76	1.17	0.68	2.1	24	8	0				
SF_228,NRT94	M	SF Coeur d'Alene R above Canyon Cr near Golconda, 1994 (2)		64	0.90	1.20	2.76	1.13	1.06	2.4	24	17.2	0				
SF_228_NRT95	M	SF Coeur d'Alene R above Canyon Cr near Golconda, 1995 (4,5)		64	1.00	1.20	2.76	1.32	0.91	2.1	24	12	0				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT94 (4)		30		0.10	1.15	0.61	0.16	2.02	33	8.8	69				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT95 (2)		30		0.10	1.15	0.61	0.16	2.02	34	8.1	93				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT96 (2)	21	30	0.7	0.10	1.15	0.42	1.65	2.02	33	3.4	89				
SF-2	M	SF Coeur d'Alene R at Elizabeth Park (3)		65		6.6	11.0	1.34	4.93	8.2	62	1.5	0				
US3	M	SF Coeur d'Alene R below Mullan, using SF-9 chemistry (3)		46		0.25	1.15	0.61	0.41	1.9	34	18.5	69				
NROK-11	R	SF Coeur d'Alene River above Mullan (1)	28	30	< 1.0	0.10	1.15	0.57	0.18	2.0	33	13	87	100	36	7	1483

SITE NO.	GROUP	DESCRIPTION (DATA SOURCE)	SAMPLE HARD-NESS	MEAN HARD-NESS	SAMPLE CD	MEDIAN CD	CD 95%-TILE	CMC	CD/ CMC	95%-TILE/ CMC	N	TROUT DENSITY (NO./100 M2)	% COTTIDS	SFI	TOTAL INVERT TAXA	MAYFLY TAXA	TOTAL METAL SENSITIVE INVERT DENSITY
NROK-14	M	SF Coeur d'Alene River at Silverton, ID (1)	68		7.0	7.40	11.74	1.40	4.99	8.4	34	2.7	0	58	20	1	48
1998SCDA030	M	SF Coeur d'Alene River at Silverton, ID (2)		68		7.40	11.74	1.40	4.99	8.4	34	0.4	0	18			
SF-5	M	SF Coeur d'Alene River at Silverton, ID (3)		68		7.40	11.74	1.40	4.99	8.4	34	0.9	0				
NROK-17	M	SF Coeur d'Alene River near Pinehurst, ID (1)	120	72	8.7	8.30	16.90	2.50	3.48	6.8	84	0.3	0	52	21	2	290
NROK-18	R	St Joe River at Red Ives Ranger St. (1)	22		< 1.0	0.25		0.45	0.56		1	0.9	90	100	35	6	2070
strrdeer	R	St Regis near Haugen, NRT 8/13/96 (4)	35		0.1			0.71	0.14		1	2.6	7				
strrsalt	R	St Regis near Saltese, NRT 8/12/96 (4)	36		0.1			0.73	0.14		1	1	82				
strrhead	R	St Regis R. near headwaters, NRT 8/8/96 (4)	31		0.1			0.63	0.16		1	2.8	95				
NROK-1	R	St Regis River above Rainy Ck, MT (1)	33		< 1.0	0.10		0.67	0.15		2	3.3	92	100	30	8	3218
NROK-2	R	St Regis River near Haugan, MT (1)	27		< 1.0	0.10		0.55	0.18		2	2.5	91	100	21	5	3275
NROK-3	R	St Regis River near St Regis, MT (1)	12		< 1.0	0.10		0.24	0.42		4	2.7	69	100	37	5	2220
NROK-5	R	WF Eagle Creek below Settlers Grove, (1)	12		< 1.0			0.24			1	13.6	76	99	37	9	2581

Table B-3 Cumulative criteria units (CCU) exceedances, and fish and benthic macroinvertebrate sample metrics

Site No.	Group	Description (data source)	Median CCU ratio	5%-tile CCU ratio	95%-tile CCU ratios	Trout density (no./100 m2)	% Cottids	SFI	Total invertebrate taxa	Mayfly taxa	Total metal sensitive invertebrate density
1996SCDAA060	M	Beaver Creek at Carbon Cr, IDEQ (2,5)	9.16	5.80	12.65	32	2	83	20	4	
BVL	M	Beaver Creek near mouth, NRT 10/3/98 (3)	0.51			19.0	77				
NROK-9	M	Beaver Creek near Mouth (1)	0.14			16.5	48	99	38	8	1850
1996SCDAB039		Beaver Creek near Mouth (2)	0.14			27.3	74	98	25	7	
Big96	R	Big Creek lower, 8/7/96 (2,5)	0.24			10.7	93				
Big97	R	Big Creek lower, IDEQ 10/29/97 (2,5)	0.21			4	80				
NROK-13	M	Canyon Creek at Woodland Park, ID (1)	26.25	14.58	84.86	0	0	0	19	2	59
1996SCDAB038	M	Canyon Creek at Woodland Park, (2)	42.0	14.58	84.86	0	0	0	8	0	3
NROK-12	R	Canyon Creek near Burke, ID (1)	0.09			4.4	87	100	37	9	2059
NROK-6	M	EF Eagle nr mouth (1)	5.65	2.44	15.03	16.8	0	69	28	5	1687
USBM1	R	EF Pine Creek above Constitution mine (6)	0.12			2.9	91				
NROK-15	M	EF Pine Creek above Nabob Creek (1)	8.05			3.4	0	52	22	6	1786
1996SCDAA028	M	EF Pine Creek above Nabob Creek (2)	8.05				0	30	23	7	
USBM3	M	EF Pine Creek below Douglas Cr (6)	5.02			14.5	25				
LNU	R	LNF Coeur d'Alene River, NRT 10/8/98	0.53			5.7	96				
1999SCDAA002	R	LNF SF Coeur d'Alene River (2)	0.58	0.29	0.69	0	100	74	24	7	
NM-1	M	Nine Mile Cr (below RV park) (4,5)	49.09	30.56	78.75	0.0	0	0			
NROK-16	M	Pine Creek below Amy Gulch near Pinehurst, ID (1)	7.66	3.06	16.20	8.6	0	65	20	6	2121
PLL	R	Placer Creek lower, NRT 10/3/98	0.44			23.4	69				
NROK-8	M	Prichard Creek at Prichard (near mouth) (1)	2.27	1.56	3.75	1.1	85	89	30	6	977
1996SCDAB032	M	Prichard Creek at Prichard (near mouth) (2,5)	1.87	1.21	2.88	0.3	99	84	15	4	
NROK-7	M	Prichard Creek near Murray, ID (1)	4.10	2.47	8.92	19	0	73	24	9	2288
1996SCDAB030	M	Prichard Creek near Murray, ID (2)	2.89	1.67	5.78	3.6	0	32	16	5	
sfcdamorn	M	SF Coeur d'Alene R above Canyon Cr near Morning District (4,5)	2.26	1.33	4.44	5.7	81				
IDFG92	M	SF Coeur d'Alene R above Canyon Cr	2.29	1.25	3.45	17.7	0				
SF_8	M	SF Coeur d'Alene R above Canyon Cr (4,5)	2.29	1.25	3.45	11	0				
1998SCDA020	M	SF Coeur d'Alene R below Canyon Cr (2)	16.1	7.0	27.0	6.0	0	58	8	2	

SITE NO.	GROUP	DESCRIPTION (DATA SOURCE)	MEDIAN CCU RATIO	5%-TILE CCU RATIO	95%-TILE CCU RATIOS	TROUT DENSITY (NO./100 M2)	% COTTIDS	SFI	TOTAL INVERTEBRATE TAXA	MAYFLY TAXA	TOTAL METAL SENSITIVE INVERTEBRATE DENSITY
sfcdacomp	M	SF Coeur d'Alene R above Canyon Cr near Compressor District, 1996 (2)	1.87	1.47	4.55	8	0				
SF_228,NRT94	M	SF Coeur d'Alene R above Canyon Cr near Golconda, 1994 (2)	2.08	1.51	4.72	17.2	0				
SF_228_NRT95	M	SF Coeur d'Alene R above Canyon Cr near Golconda, 1995 (4,5)	2.16	1.41	4.37	12	0				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT94 (4)	0.68	0.20	2.61	8.8	69				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT95 (2)	0.34	0.20	2.58	8.1	93				
sfcdahead	R	SF Coeur d'Alene R above Mullan near headwaters-NRT96 (2)	1.68	0.20	2.73	3.4	89				
US4	R	SF Coeur d'Alene R above Mullan near Highway Department, (3)	0.58	0.43	2.45	36.8	89				
US3	M	SF Coeur d'Alene R below Mullan, using SF-9 chemistry (3)	2.43	1.26	4.60	18.5	69				
NROK-11	R	SF Coeur d'Alene River above Mullan, ID (1)	0.22	0.20	2.61	13	87	100	36	7	1483
SF-2	M	SF Coeur d'Alene River near Elizabeth Park (3)	11.2	6.0	18.5	1.5	0				
NROK-17	M	SF Coeur d'Alene River near Pinehurst, ID (1)	10.02	3.99	18.29	0.3	0	52	21	2	290
NROK-14	M	SF Coeur d'Alene River near Silverton, ID (1)	11.54	5.72	21.29	2.7	0	58	20	1	48
SF-5	M	SF Coeur d'Alene River near Silverton, ID (1)	11.54	5.72	21.29	0.9	0				
1998SCDA030	M	SF Coeur d'Alene River near Silverton, ID (2)	11.54	5.72	21.29	0.4	0	18			
NROK-18	R	St Joe River at Red Ives Ranger Station, ID (1)	0.57			0.9	90	100	35	6	2070
strrdeer	R	St Regis near Haugen, NRT 8/13/96 (4)	0.16			2.6	7				
strrsalt	R	St Regis near Saltese, NRT 8/12/96 (4)	0.16			1.0	82				
strrhead	R	St Regis R. near headwaters, NRT 8/8/96 (4)	0.18			2.8	95				
NROK-1	R	St Regis River above Rainy Ck, MT (1)	0.28			3.3	92	100	30	8	3218
NROK-2	R	St Regis River near Haugan, MT (1)	0.25			2.5	91	100	21	5	3275
NROK-3	R	St Regis River near St Regis, MT (1)	0.51			2.7	69	100	37	5	2220
NROK-5	R	West Fork Eagle Creek below Settlers Grove, ID (1)	0.06			13.6	76	99	37	9	2581