DRAFT Implementation Guidance for the Idaho Copper Criteria for Aquatic Life

Using the Biotic Ligand Model

State of Idaho
Department of Environmental Quality

June 2017

Printed on recycled paper, DEQ Month Year, PID #, CA code. Costs associated with this publication are available from the State of Idaho Department of Environmental Quality in accordance with Section 60-202, Idaho Code.

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June 2017

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1 Introduction

The toxicity of metals to aquatic life is highly variable and depends on physical and chemical factors within a water body. Hardness has long been acknowledged as one such factor and is reflected in DEQ's current hardness dependent criteria, whereby the acute and chronic criteria are determined based on the total hardness of the receiving water body.

Hardness dependent copper criteria do not take into account the effects of other physicochemical properties that affect toxicity, leading to hardness dependent copper criteria being either over- or under-protective of aquatic life. The Biotic ligand model (BLM) based criteria outlined in the EPA's revised national recommended freshwater aquatic life criterion for copper takes into consideration copper toxicity influenced by a wide variety of water characteristics. Therefore, DEQ has updated the copper criteria for aquatic life to the US Environmental Protection Agency (EPA) 2007 recommended 304(a) criteria (EPA 2007a).

This action was identified in both the National Marine Fisheries Service (NMFS) and US Fish and Wildlife Service's (FWS) biological opinions on Idaho's criteria for toxic substances to support aquatic life (NMFS 2014; FWS 2015). These biological opinions concluded that the hardness dependent copper criteria (as well as other toxics criteria) were under-protective of aquatic life support and would result in adverse effects to species listed under the Endangered Species Act (ESA). Their recommendation was to use EPA's 2007 copper criteria which uses the biotic ligand model (BLM) to predict water-body specific criteria by taking into account other physicochemical properties of the water (e.g., pH, dissolved organic carbon, etc.).

This guidance will provide background on copper toxicity and the BLM, and will detail how DEQ will implement the copper criteria for aquatic life. It will discuss data requirements, spatial and temporal representation, and how to reconcile multiple time variable criteria from a single location. It will discuss procedures for estimating criteria when data are limited, and outline how to derive criteria for permitting and assessment purposes.

1.1 Purpose

The purpose of this document is to detail how DEQ will implement the copper criteria for aquatic life using the BLM.

This guidance will address the following issues associated with implementation of the BLM:

- How to use site-specific water chemistry data to derive BLM copper criteria
- Data requirements for using the BLM and for ensuring spatial and temporal variability is accounted for, including monitoring locations
- How to estimate protective criteria when required BLM input data are not available
- How to produce predictable and repeatable NPDES permit limits from multiple instantaneous water quality criteria

- How to identify impairments for the integrated report based on multiple instantaneous water quality criteria

This guidance will ensure that DEQ implements the copper criteria for aquatic life consistently and in a manner that will be protective of aquatic life. This guidance will also provide clarity and transparency for dischargers and other stakeholders interested in understanding how DEQ intends to implement the copper criteria.

1.2 Sources of Copper in the Environment

Copper is a natural element that occurs in the earth's crust at low levels. Natural processes, such as air deposition and erosion of parent material containing copper contribute to the presence of copper in surface waters. In addition, human activities (e.g., mining operations, agriculture, and industrial solid waste) may lead to increased erosion or sediment transport, which could result in higher copper concentrations than would occur from natural weathering alone (ATSDR 2004).

Other anthropogenic activities can lead to elevated levels of copper in the aquatic environment. Anthropogenic sources of copper in surface waters include domestic waste water, urban storm water runoff, active milling and mining, abandoned mine runoff, electroplating operations, corrosion of copper in plumbing and construction materials, effluents from power plants that use copper alloys in the heat exchangers of their cooling systems, leachate from municipal landfills and direct addition of copper sulfate to surface waters as a algaecide (ATSDR 2004).

1.3 Effects of Copper on Aquatic Life

Copper is an essential micronutrient for plants, animals, and humans. However, at concentrations above the recommended levels, copper can become acutely toxic, especially to aquatic organisms (Scannell 2009, Eisler 1998).

Chronic effects of copper include inhibition of photosynthesis, metabolism, and growth in aquatic plants and algae; reduced feeding, growth, and reproduction, as well as gill damage in aquatic invertebrates; and significant effects on behavior, growth, migration, changes in metabolism and organ or cellular damage, and changes in olfactory responses in freshwater fish species (Eisler 1998, Sommer et al. 2016).

1.3.1 Effects of Physical and Chemical Properties on the Toxicity of Copper

Copper toxicity in aquatic environments depends on the ability of copper to bind to a biological receptor or a cell surface of an organism (e.g., the gill surface of a fish). This receptor is known as biotic ligand and is the location where interactions with metals occur. Copper that is free to bind to the receptor is considered bioavailable copper.

Bioavailability of copper in freshwater is related to the following:

- Chemical species of copper (the chemical forms of copper, such as Cu^{2+})

- Complexation of copper with organic ligands[1]
- Complexation of copper with inorganic ligands

Several physicochemical properties can affect copper speciation and the availability of ligands for complexation with copper. The most important of these factors are the concentration of dissolved organic carbon (DOC), which complexes with copper, and pH, which controls copper speciation.

In addition, other cations compete with copper for complexation at the biotic ligand. The most common major cations present in surface waters are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and hydrogen (H^{+}). Therefore, to reliably estimate concentrations of copper that would be toxic at any given sampling location, it is necessary to account for these factors.

Figure 1 presents a conceptual framework for how these processes affect the ability for a free copper to bind to a biotic ligand such as the gill surface.

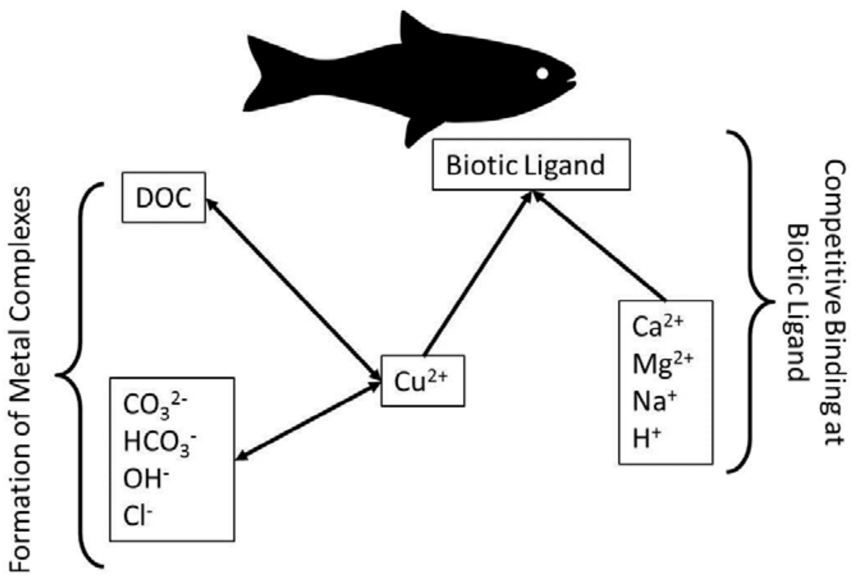

Figure 1. Conceptual model of how chemical speciation, metal complexation, and competition of other cations with copper for binding at biotic ligands affect metal bioavailability. Free metal ion (Me^{z+}) complexes with dissolved organic carbon (DOC) and inorganic ligands. In addition, cations such as Ca^{2+} and Mg^{2+} compete with the remaining free metal to bind to the biotic ligand, limiting the effects of the metal on the organism. (Figure adapted from Windward Environmental, LLC (http://www.windwardenv.com/biotic-ligand-model/)).

In general, in waters with low DOC, low pH, and low hardness, the fraction of copper that is bioavailable is greatest. As DOC, pH, and hardness increase, the bioavailability of copper decreases.

[1] A "ligand" is a complexing chemical (ion, molecule, or molecular group) that interacts with a metal like copper to form a larger complex (EPA 2007).

1.4 Impaired waters and TMDLs

Currently, there are very few waters in Idaho where copper has been identified as impairing aquatic life. The 2012 Integrated Report (IR) identified 43 stream and river miles where copper was impairing aquatic life (DEQ 2014). This represents less than 0.05% of the 95,119 stream and river miles that DEQ reported on in the 2012 IR.

Of the 43 miles of impaired stream and rivers, 22 are covered under an approved subbasin assessment and total maximum daily load (TMDL) (DEQ 2007). According to the subbasin assessment and TMDL, the source of the copper impairment is from historic and current activities associated with mining in the upstream reaches of the Clark Fork River in Montana. Thus, Montana DEQ is responsible for reductions of copper to meet the criteria at the Idaho border (DEQ 2014).

In addition, 15 miles of impaired streams and rivers are in areas that are impacted by the Blackbird Mine and are under active remediation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (DEQ 2014).

The remaining 6 miles are a single impaired reach of Prichard Creek, a tributary to the Coeur d’Alene River.

Figure 2 shows the scope and location of waters that have been identified as impaired for aquatic life by copper.

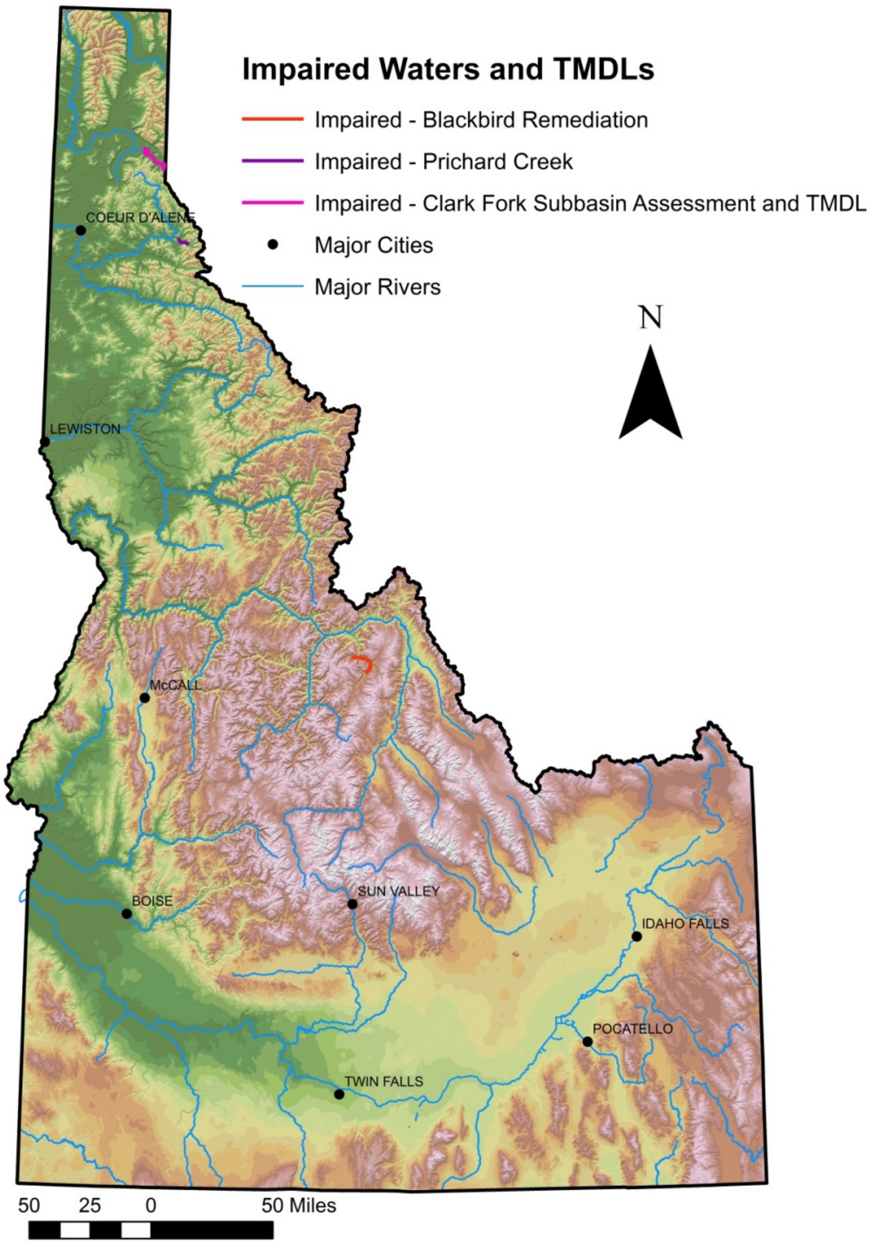

Figure 2. Map of Idaho showing the limited scope of waters where aquatic life is impaired by copper.

1.5 NPDES Permits in Idaho

There are relatively few point source dischargers in Idaho that have copper effluent limits. As of the date of this guidance, there are approximately 390 municipal, industrial, commercial, and aquaculture dischargers with NPDES permits in Idaho; 20 dischargers have copper effluent limits. Of these permittees, 8 are mines, 10 are municipal waste water treatment plants, and 2 are fish hatcheries (Figure 3).

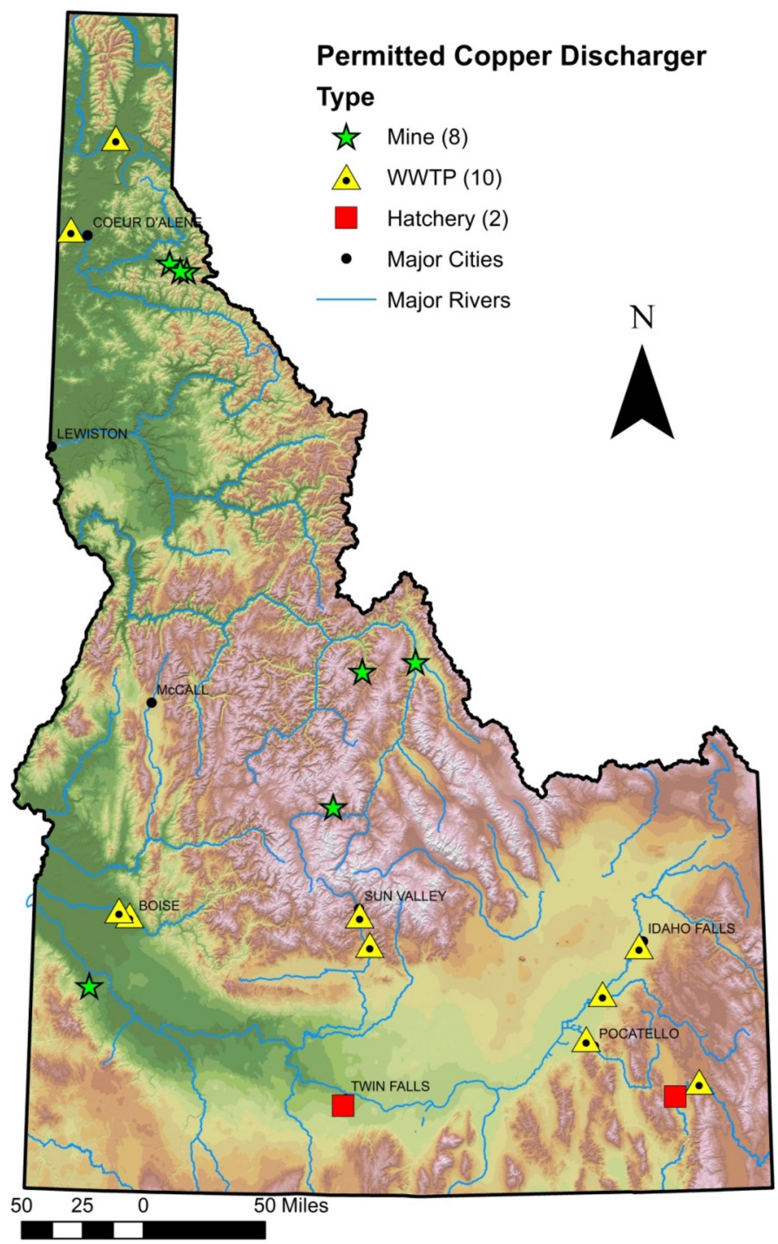

Figure 3. Map of Idaho showing the location and type of dischargers with copper effluent limits.

2 DRAFT Idaho Aquatic Life Criteria for Copper

Idaho's numeric copper criteria for aquatic life are found in IDAPA 58.01.02.210. Derivation of the Idaho aquatic life criteria for copper requires the use of the Biotic Ligand Model, or BLM, version 3.1.2.37 (Windward 2015) to calculate acute and chronic criteria.

An excerpt of the relevant table and footnotes are presented in Figure 4.

A		B Aquatic life	
(Number) Compound	a CAS Number	b CMC (µg/L) B1	b CCC (µg/L) B2
6 Copper	7440508	19.4 r	12.0 r

Table Footnotes

r. Aquatic life criteria for copper are derived from the Biotic Ligand Model, Version 3.1.2.37 (October 2015), US EPA WQC Calculation for Copper *available at* www.deq.idaho.gov. For comparative purposes only, the example values displayed in this table correspond to the model output based on the following inputs: temperature = 15.2°C, pH = 7.9, dissolved organic carbon = 1.9 mg/L, humic acid fraction = 10%, Calcium = 68.9 mg/L, Magnesium = 44.2 mg/L, Sodium = 65.5 mg/L, Potassium = 1.9 mg/L, Sulfate = 72.6 mg/L, Chlorine = 54.5 mg/L, and alkalinity = 280 mg/L $CaCO_3$.

Table Footnote r. Effective on the date EPA issues written notification that the revisions adopted under Rule Docket No. 58-0102-1502 have been approved. See Subsection 210.01.d.iii.

Figure 4. Excerpt from Idaho Water Quality Standards denoting relevant table and footnotes referencing the use of the biotic ligand model to derive copper criteria for aquatic life.

It is important for users to note that the example values found in the criteria table at IDAPA 58.01.02.210 are not intended to represent default criteria values.

3 General Implementation for Aquatic Life Criteria

The following general implementation requirements for aquatic life criteria, found in Idaho Water Quality Standards (IDAPA 58.01.02.210.03) shall be applicable when implementing the copper criteria for aquatic life:

- When a mixing zone is authorized, the BLM derived copper criteria will apply at the boundary of the mixing zone (Section 210.03.a).
- Water quality based effluent limits (WQBEL) shall be based on criteria exceedances only occurring during low flow conditions that meet the following criteria: the lowest one-day flow with a ten year occurrence (1Q10) for acute copper criteria, or based on an allowable exceedance occurring no more than once every three years (1B3). For chronic criteria, these are the lowest seven-day average low flow with a ten year recurrence

(7Q10) or based on an exceedance for four consecutive days occurring no more than once every three years (4B3) (Section 210.03.b).

- The copper criteria for aquatic life will be expressed as concentration of dissolved copper (Section 210.03.c.iii).
- Acute criteria are criteria not to be exceeded for a one-hour average more than once in three years. Chronic criteria are not to be exceeded for a four-day average more than once in three years (Section 210.03.d.i).

In addition, the following implementation tools shall be available when implementing the Idaho copper criteria for aquatic life:

- Flow Tiered NPDES Permit limitations may be provided for dischargers with copper limits in accordance with Section 400.05.
- Intake Credits for Water Quality-Based Effluent Limitations may be allowed in accordance with Section 400.06.

All other water quality standards or Idaho Pollutant Discharge Elimination rules and regulations shall apply when implementing the Idaho copper criteria for aquatic life.

4 The Biotic Ligand Model

The Biotic Ligand Model (BLM) is a model that predicts toxicity of metals by estimating the bioavailability of the metal to bind to the biological receptor, or biotic ligand, such as the gill surface.

In contrast to hardness based criteria, which only account for competitive binding at biotic ligand sites by cations, the BLM also accounts for the metal speciation and complexation with DOC and other inorganic ligands (Figure 1). EPA's 2007 recommended aquatic life criteria for copper replaces the previously recommended hardness based equation with the BLM.

4.1 Overview of BLM Version 3.1.2.37

The BLM Version 3.1.2.37 and associated Users Guide can be downloaded from http://www.windwardenv.com/biotic-ligand-model/ or from DEQ's website (www.deq.idaho.gov). More information can be found in the BLM User's Guide (Windward 2015).

Users must be able to ensure they are using the BLM to return results consistent with EPA's 2007 nationally recommended criteria. In version 3.1.2.37, users must select the "US EPA WQC" radio button and select "Cu" from the dropdown from the "Metal/Organism Selection" shortcut menu (Figure 5 and Figure 6).

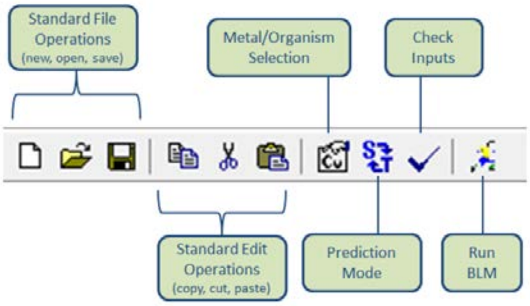

Figure 5. Shortcut toolbar key for BLM Version 3.1.2.37, indicating location of the Metal/Organism Selection shortcut. Taken from Figure 6-11 of the BLM User's Guide (Windward 2015).

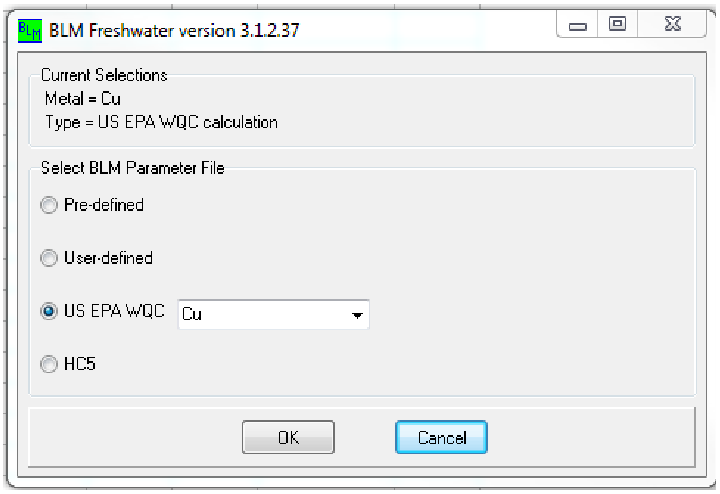

Figure 6. Select US EPA WQC and Cu in order to return results consistent with EPA's 2007 Criteria.

Users must also use the complete site chemistry; simplified site chemistry is not sufficient for calculating criteria under this guidance.

The BLM estimates copper concentrations that would result in acute and chronic effects to aquatic life in a water body based on the following site-specific physical and chemical parameters:

- Temperature
- pH
- DOC
- Calcium
- Magnesium
- Sodium
- Potassium

- Sulfate
- Chloride
- Alkalinity
- Sulfide
- Humic acid

Each parameter will be discussed in more detail in Section 5.1.

The model calculates both acute and chronic criteria based on these inputs. The criteria calculated from a single set of inputs are referred to as instantaneous water quality criteria (IWQC). The IWQC represents the criteria that would be protective of aquatic life at the instant that the data were collected. However, the input data are variable over time, so any single IWQC will not necessarily be protective of aquatic life at any given site; if site chemistry changes, individual IWQCs will change.

4.2 Comparison to Hardness Based Criteria

Because the BLM incorporates copper speciation and complexation in addition to competitive binding at biotic ligand sites by cations, it better predicts the toxic effects of copper in the aquatic environment than the hardness based equation.

The BLM produces fairly accurate predictions of toxic effects from copper in a variety of natural waters (e.g., Figure 7). By contrast, the hardness based equation produces highly variable and often inaccurate predictions of actual toxicity (Figure 8) (NMFS 2014).

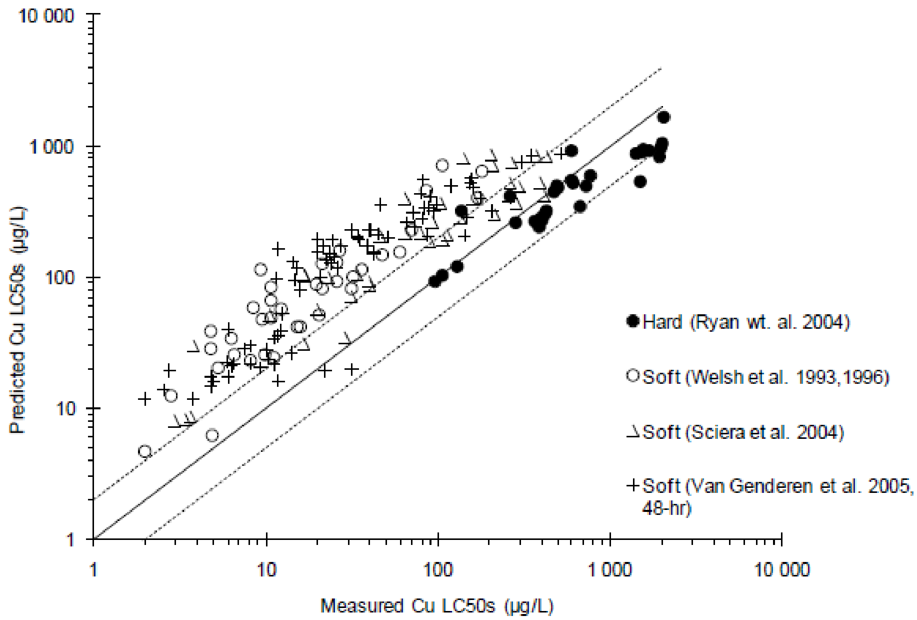

Figure 7. BLM predicted and measured copper LC50s for Fathead Minnows in soft and hard waters (from Appendix C of NMFS 2014).

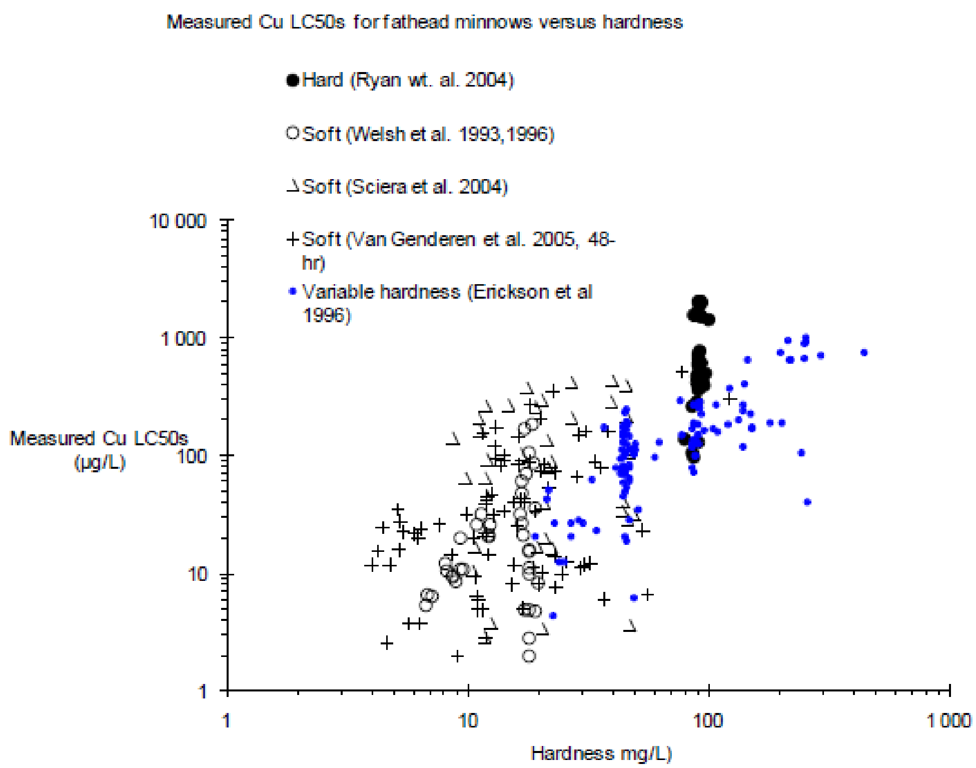

Figure 8. Hardness predicted and measured copper LC50s for Fathead Minnows in soft and hard waters (from Appendix C of NMFS 2014).

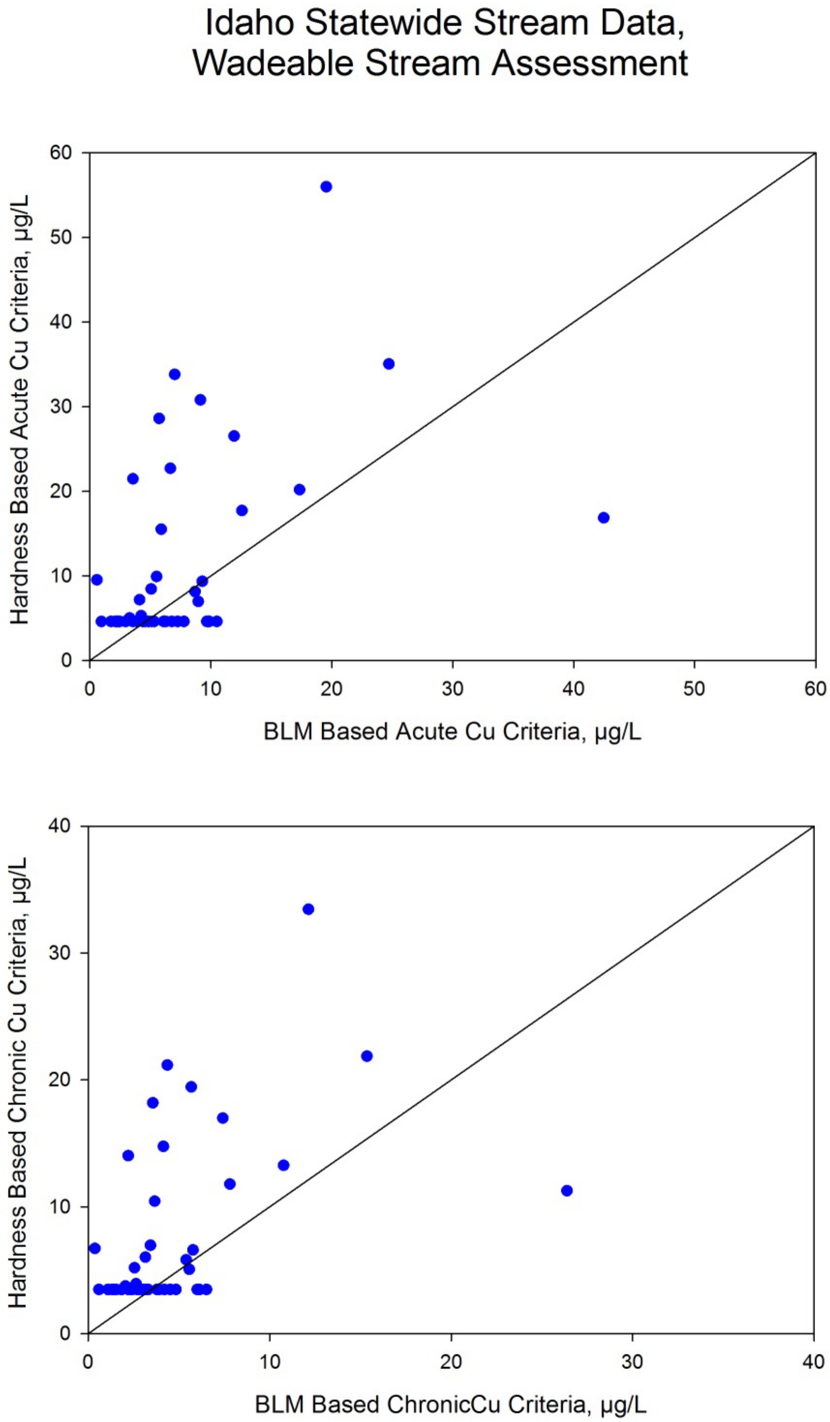

Figure 9. Comparison of BLM derived to hardness based criteria calculated from sites monitored as part of the Wadeable Streams Assessment (EPA 2006) for both acute and chronic criteria. The solid black line is the 1:1 line; sites above the line have BLM criteria that are more stringent than the hardness based criteria, sites below the line have BLM criteria that are less stringent. Idaho's hardness based criteria included a minimum hardness floor of 25 mg/L.

While the BLM does provide more accurate and precise predictions of toxic effects from a given copper concentration, it is important to note that the BLM does not always provide more stringent criteria.

For example, when waters have relatively high DOC concentrations, such as in the case of downstream from a municipal wastewater treatment facility, BLM derived criteria will often be less stringent than those derived from the hardness based equation. Conversely, in areas with very limited organic inputs, or with more acidic conditions (lower pH), BLM derived criteria may be more stringent than criteria derived from the hardness based equation.

Figure 9 shows comparisons of acute and chronic criteria derived from both the hardness based equation and the BLM for 45 stream sites monitored in the summer as part of the Wadeable Stream Assessment (EPA 2006), showing the variable nature of how BLM derived criteria compare to hardness based criteria. Even at a single location, the relative stringency of the BLM and Hardness based criteria can change, with one resulting in more stringent criteria at some times of the year while the other does for different times of the year (Figure 10).

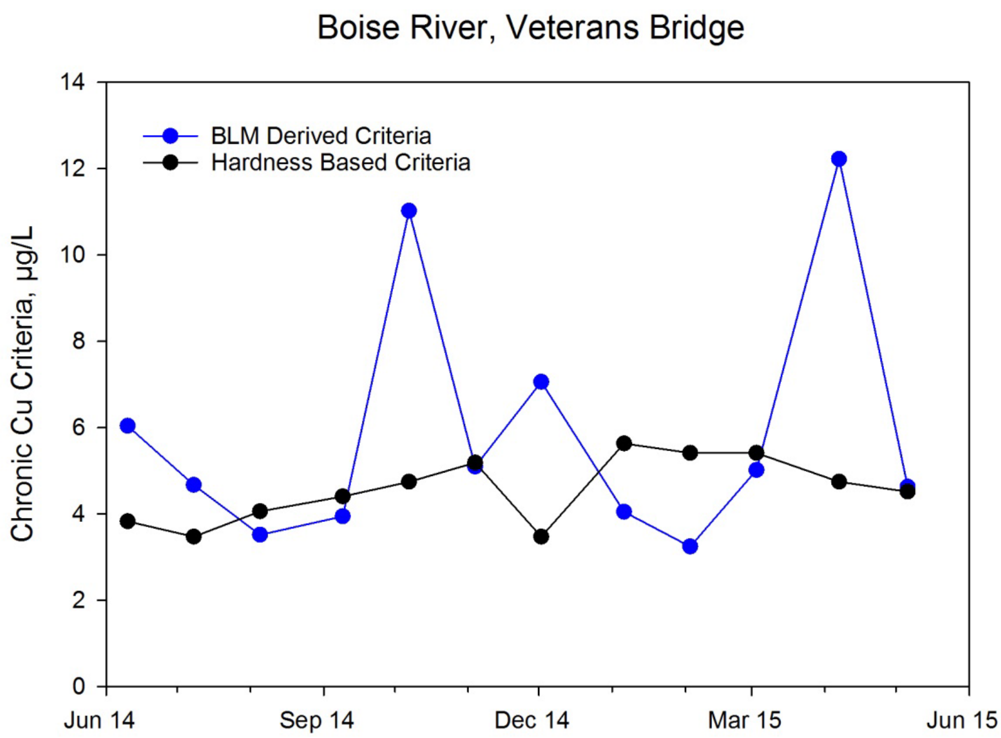

Figure 10. BLM derived and hardness based criteria calculated from a single location on the Boise River from June 2014 to June 2015. For parts of the year the BLM derived criterion is more stringent, while for other times of the year the hardness based criterion is more stringent. Data are from the City of Boise (unpublished data).

This disparateness is related to the seasonality of the BLM inputs and their importance to the BLM criteria. As has been discussed previously, even though the concentration of cations is a factor in the calculation of BLM criteria, the BLM is most sensitive to DOC and pH. However, the lowest concentrations of DOC in a stream usually coincide with the highest concentrations of cations, meaning that when hardness dependent criteria predict that copper is least bioavailable, the BLM derived criteria will predict the greatest copper bioavailability and toxicity (Figure 11).

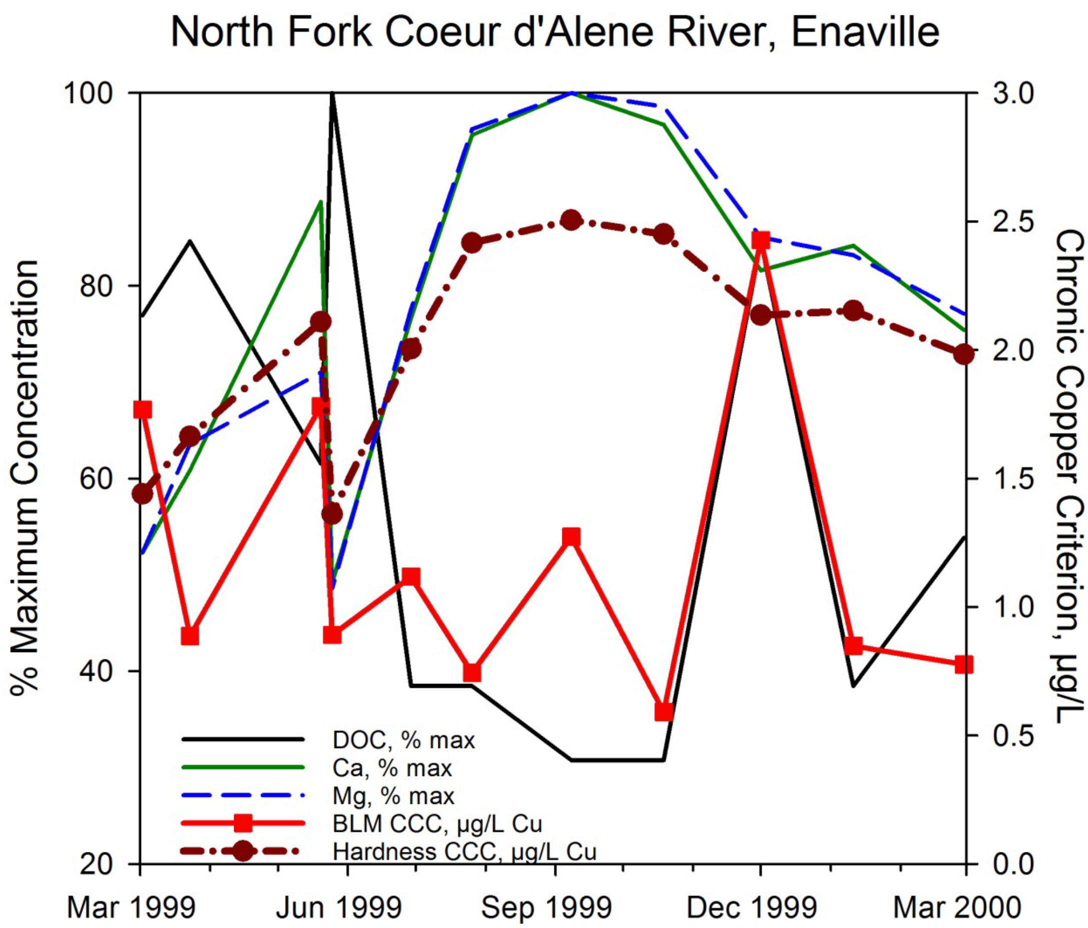

Figure 11. Temporal variability of major cation and DOC inputs to the BLM, BLM derived chronic copper criterion (CCC), and hardness based chronic copper criterion, from the North Fork Coeur d'Alene River, showing that DOC is at its lowest concentration when major cations (and hardness) are at their maximum, and that BLM derived copper criterion closely follows DOC, while hardness based copper criterion closely follows major cations.

5 Data Requirements for Application of the BLM

As described in Section 4.1, the BLM requires users to enter site chemistry in order to generate acute and chronic IWQCs. The following sections will describe the minimum data requirements for generating IWQCs, each parameter and how it is measured, and the BLM's relative sensitivity to the different input parameters.

5.1 General Data Requirements

The following section describes the required input parameters and the required measurement units for each parameter.

Temperature is an important physical characteristic of surface water and affects rates of chemical reactions. Temperature should be measured *in situ* at the time of sample collection. The BLM allows for temperature to be expressed in the following units: °C, °F, or °K.

Chemical speciation is controlled in part by ambient pH. Therefore, the BLM for copper is highly sensitive to changes in pH. Like temperature, pH can be highly variable, and should be measured *in situ* in the field at the time of sample collection.

Dissolved organic carbon mitigates the effects of copper by complexing with free copper. It affects copper speciation and bioavailability. The BLM for copper is highly sensitive to changes in DOC. DOC is entered as a concentration; the BLM allows users to enter DOC concentrations in the following units: mg C/L, mmol C/L.

The major cations (Ca, Mg, Na, and K) compete with copper at the biotic ligand site and affect copper toxicity. Of the major cations used in the BLM, Ca and Na are the most important for copper toxicity. The major cations are entered as a concentration of the dissolved metal and can be entered in the following units: µg/L, mg/L, g/L, µmol/L, mmol/L, and mol/L.

Major anions (SO_4 and Cl) affect ionic strength and charge balance. Concentrations of these ions can be entered in the following units: µg/L, mg/L, g/L, µmol/L, mmol/L, and mol/L.

Alkalinity is a measure of the buffering capacity of a sample. In natural surface waters, carbonate and bicarbonate ions are usually the largest contributor to alkalinity. These ions form complexes with free copper, reducing copper bioavailability. Alkalinity should be entered as mg/L $CaCO_3$.

Sulfide can affect copper bioavailability by affecting speciation. However, sulfide is very uncommon in natural waters, and therefore users should use a default value of near zero (e.g., 1.0×10^{-10}). Similarly, users should enter a default of 10% for humic acid fraction of DOC.

Work by EPA (2012a) and the Oregon Department of Environmental Quality (ODEQ 2016) indicate that the BLM is most sensitive to changes in DOC and pH.

When using the BLM to implement the Idaho copper criteria for aquatic life, a “sample” refers to a complete set of the BLM input parameters as described in Table 1, collected at a single place and time.

Section 6 will detail how to proceed in instances when a sample is incomplete, i.e., when not all required parameters have been measured.

Table 1. BLM parameters required to constitute a complete sample. Included are recommended analytical methods, preservative, holding times, and detection limits.

Parameter	Analytical Method	Preservative	Holding Time	Detection Limit
Temperature and pH	Measured *in situ*, using properly calibrated equipment	N/A	N/A	N/A
Dissolved Ca, Mg, Na, K	EPA 200.7	4 °C. Filter with 0.45 µm filter as soon as practical. Acidify to pH <2 after filtration.	28 days unpreserved. 6 months preserved.	0.1 mg/L
SO_4, Cl	EPA 300.0	4 °C.	28 days.	0.1 mg/L
Alkalinity	SM 2320 B	4 °C.	14 days.	10 mg/L
DOC	SM 5310 B	4 °C. Filter with 0.45 µm filter within 48 hrs. Acidify to pH <2 after filtration.	7 days	0.1 mg/L

5.2 Spatial representation

Physical and chemical parameters can be highly spatially variable. However, when implementing any criteria that are based on site-specific conditions, it is necessary that any single sample location be considered representative of a larger stream segment. How DEQ interprets spatial representation when implementing the copper criteria for aquatic life will depend upon how the data are to be used; whether monitoring results are intended to be used to determine compliance with water quality standards for the Integrated Report (IR) and TMDL development, or for development of effluent limits and determining compliance with NPDES permits.

5.2.1 Ambient Monitoring for the Integrated Report and TMDL development

When monitoring and assessing waters for the Integrated Report or for TMDL development, DEQ applies monitoring results and listing decisions from a single location or relatively short reach to a collection of waters with similar land uses known as an assessment unit, or AU. All waters within an AU can be reasonably expected to have the same ambient water quality and background water chemistry. AUs are numbered systematically, and are based on stratification of water body units identified in Idaho's water quality standards (IDAPA 58.01.02.109) by land use and stream order (Figure 12).

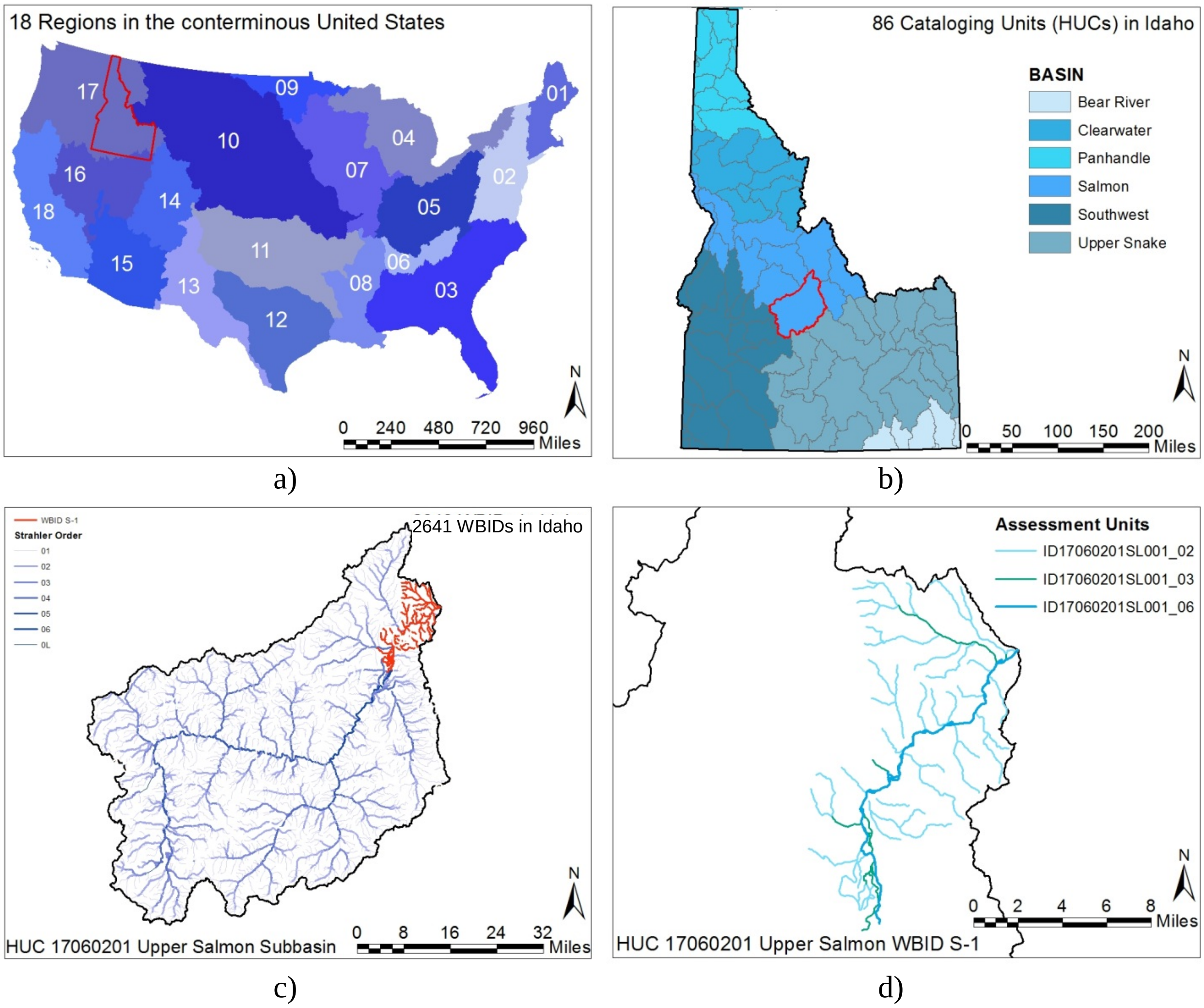

Figure 12. Relationship between hydrologic unit codes (HUCs), water body units, and assessment units (AUs): (a) Level 1 regions in the nation; (b) 86 level 4 HUCs in Idaho (the highlighted HUC is 17060201—Upper Salmon River subbasin in central Idaho); (c) HUC 17060201, Upper Salmon River subbasin, with water body unit S-1 highlighted in red; and (d) water body unit S-1 subdivided into three different AUs (from DEQ 2016).

AUs can be added or deleted as new information becomes available suggesting that a single AU should be split into multiple AUs due to changes in land use or other factors such as mapping errors; or that separate AUs should be grouped into a single AU.

Currently, there are 5,754 AUs in Idaho representing 95,119 miles of rivers and streams (DEQ 2014). More detailed discussions of AUs can be found in the most recent version of the *Integrated Report* (DEQ 2014) as well as the *Water Body Assessment Guidance* (DEQ 2016).

When conducting ambient copper and BLM monitoring for the IR or TMDL development, field crews must collect samples at locations that are considered representative of the entire AU being assessed. If multiple locations within an AU have been monitored, assessors should consider if locations are representative before combining data.

If some or all of the sampling sites are not representative of the water, then DEQ may opt to use none of the data or only use data from those sampling sites that do represent the AU.

5.2.2 Monitoring for Effluent Limit Development

It is necessary to characterize site-specific conditions within the receiving water when developing copper criteria for effluent limit development. Monitoring to determine effluent limits should occur downstream of points of discharge and below any regulatory mixing zones, where fully mixed conditions are expected to occur. Monitoring locations should represent the conditions for the receiving water as affected by the specific discharge being considered. If there are multiple points of discharge within a relatively short distance then a single site below all points of discharge may be necessary for characterizing conditions.

Monitoring results collected for effluent limit development may be used for IR assessment and TMDL development purposes, provided they are determined to be representative of the AU to which they belong.

5.3 Temporal representation

In addition to determining the spatial extent that a sample represents, it is important to properly capture the temporal variability of the physical and chemical parameters that are used as inputs for the BLM. As described in Section 5.1, many of the input parameters can be highly variable, both short term (such as temperature and pH) and seasonally (see Figure 11). This leads to highly variable IWQCs derived from a site (see Figure 10).

5.3.1 Temporal Variability of BLM Parameters

Temperature and pH can have seasonal as well as diel variability. In particular, diel pH variability has been shown to affect concentrations of metals (Brick and Moore 1996). It is important that monitoring programs consider the timing of sampling events in order to address this variability, particularly when evaluating acute effects.

In addition, nearly all of the BLM input parameters exhibit some degree of seasonal variability. The degree of variability, and the relative predictability of seasonal variability, can be site specific.

Generally, 12 monthly IWQCs calculated over the course of a year should be considered appropriate to characterize seasonal variability for any single site. However, users should consider any site specific factors, such as flood or drought conditions, that may require additional sampling in order to fully capture the variability at a site.

5.3.2 Critical Time Period

In many instances, the critical period when copper is expected to have its greatest bioavailability, can be predicted and tied to seasonal variations of DOC. In Idaho, DOC is usually at its lowest concentrations in late fall (NMFS 2014). This is consistent with other observed trends, where BLM-derived IWQCs were usually at their most stringent in fall and winter (EPA 2007b).

5.4 Reconciling multiple IWQCs

When evaluating time-specific results, users can compare a copper concentration to the BLM-derived criteria calculated from the same sample (IWQC). Because IWQCs can be highly variable over time, it is necessary for users to reconcile many different IWQCs in order to apply a single, consistent criterion. The following sections describe approaches that can be used to reconcile multiple IWQCs from a single site.

5.4.1 Minimum of IWQCs

The simplest approach to reconciling multiple IWQCs from a single site is to take the minimum of the IWQCs developed from the site. This approach is the most conservative. However, this approach is likely over protective, and should only be used when there are relatively few data and therefore lower confidence that the temporal variability at a site has been sufficiently characterized.

5.4.2 Distribution of IWQCs

One common approach to reconciling time variable criteria is to select a relatively conservative value from the distribution of criteria. When sufficient data are available to fully characterize the seasonal variability of IWQCs, then the 10^{th} percentile of all IWQCs should be used.

5.4.3 Statistical approaches

Other, more complicated statistical approaches can be used to reconcile multiple IWQCs from a single location. For example, the Fixed Monitoring Benchmark (FMB) can be used to evaluate compliance with time-variable criteria. The FMB uses the relationship of copper and individual IWQCs at a given site to derive a benchmark concentration that would comply with water quality standards. For more information on the FMB, see EPA (2012a). Users may choose to use statistical approaches, such as the FMB, when sufficient data are available to fully characterize the variability of IWQCs and the relationship of IWQCs to copper concentrations. This may require up to three years of monthly samples for all BLM input parameters as well as copper.

5.4.4 Seasonal Criteria

For waters with predictable seasonal variability of IWQCs, seasonal or flow tiered criteria may be developed. For example, in waters with sufficient IWQC data, it may be possible to derive dry season criteria based on the 10^{th} percentile of IWQCs during low flow conditions, and wet season criteria based on the 10^{th} percentile of IWQCs during high flow. In order to consider seasonal criteria, sufficient data must be available and must demonstrate predictable seasonality. This would generally require at least 12 monthly samples, and may require up to three consecutive years of monthly samples to fully capture the variability and flood cycle.

6 Estimating Criteria when data are absent

In order to derive criteria the BLM requires complete samples. However, at times, data may be limited, with either incomplete samples with certain parameters missing, or no samples available for a specific waterbody. In these cases, users may choose to estimate criteria based on available data.

This section will detail approaches for estimating criteria when data are absent or incomplete.

6.1 Estimating Input Parameters

Users seeking to estimate copper criteria when data are absent may use statistical methods to estimate major geochemical ions, but should not use estimates of either DOC or pH.

Many of the BLM input parameters are predictable and can be estimated using statistical approaches (e.g., ODEQ 2016, EPA 2016). For example, concentration of major cations can be inferred based on ecoregions (EPA 2013) or specific conductance (ODEQ 2016).

Analysis of state wide data in Oregon showed that estimating geochemical ion concentrations (Calcium, Magnesium, Sodium, Potassium, Sulfate, Chloride, and Alkalinity) based on specific conductance did not significantly affect BLM outputs when compared to measured concentrations (ODEQ 2016).

While it may be possible to estimate conservative concentrations of geochemical ions and DOC based on statistical approaches, (e.g., EPA 2016), this approach may be overly conservative. For example, a minimum BLM chronic criterion of 3.25 µg/L was calculated from monthly samples for the Boise River at Glenwood Bridge. According to Appendix B of this document, the 2.5th percentile of BLM IWQCs is sufficient for protection of aquatic life; the 2.5th percentile of BLM chronic IWQCs at this site was 3.38 µg/L. By contrast, using the recommended 10th percentile of GI and DOC inputs, and a conservative pH of 7, would give a BLM chronic criterion of 1.35 µg/L. This is less than half of the minimum IWQCs calculated at that site (Figure 13).

In addition, using lower percentile values from each of the inputs to the BLM may ignore the natural seasonal variability of these parameters; for example, DOC often is at its lowest concentration during summer-fall low flow conditions. However, at this time, many of the geochemical ions are at their highest concentrations (Figure 11).

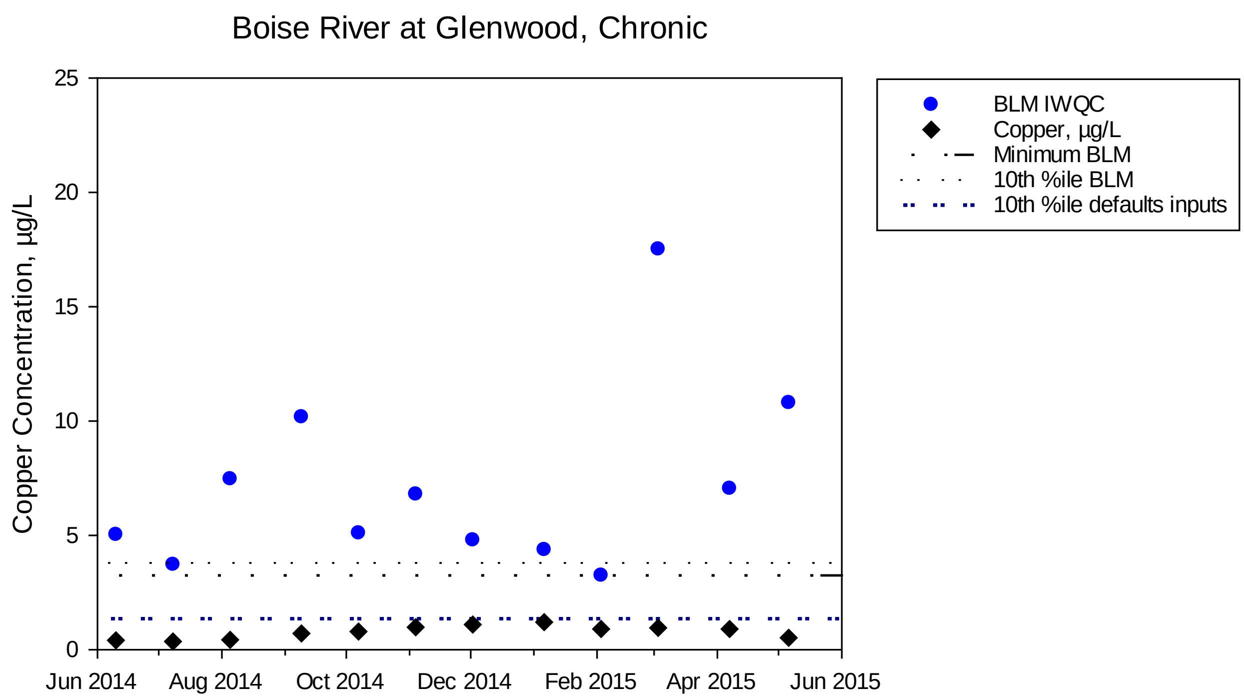

Figure 13. Biotic Ligand Model (BLM) calculated chronic criteria for the Boise River at Glenwood Bridge, June 2014 - 2015. Reference lines demonstrate the criterion that would be calculated from the 10th %ile and minimum of IWQCs calculated from these data, and the criterion calculated using the EPA (2016) recommended default inputs. Data from the City of Boise.

6.2 Estimating Criteria

A better, more realistic approach than using conservative default inputs would be to calculate BLM derived IWQCs for each ecoregion, and then recommend default criteria. This would more accurately reflect water quality at a given site at a given time, and would be easier for states to implement.

It may be possible to estimate conservative criteria based on data collected during the critical time period when IWQCs are expected to be at their minimum.

6.3 Critical Conditions

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7 Determination of Criteria for NPDES Permit Limits

Criteria used for developing NPDES permits should be based on data collected from the receiving water as affected by the specific discharge being considered (see Section 5.2.2). When possible, at least 12 monthly IWQCs, and up to 36 monthly IWQCs, should be available prior to developing the permit in order to properly characterize the water quality in the receiving water (see Section 5.3).

When there are at least 12 monthly IWQCs, the copper criteria used for permit development should be based on the 10th percentile of IWQCs. If data indicate that seasonal or flow tiered criteria are appropriate, then criteria should be based on 10th percentile of IWQCs during low flow conditions and the 10th percentile of IWQCs during high flow conditions (see Section 5.4.4).

If less than 12 monthly IWQCs are available, then the copper criteria used for permit development should be based on the minimum of IWQCs for the site, provided that there is at least one sample from the low flow season.

In cases where there are no data available from the site representing the receiving water, then users should initiate monitoring to generate a minimum of 12 monthly IWQCs.

8 Identifying Impairments for the Integrated Report

All assessment decisions should follow the *Water Body Assessment Guidance* (DEQ 2016).

Data used for developing copper criteria for IR assessment purposes should be representative of the AU being assessed (see Section 5.2.1).

Copper assessments must be based on paired dissolved copper and complete BLM parameter sample results. When copper data are associated with complete BLM parameter results, assessments should be based on direct comparison to the IWQC associated with the dissolved copper sample.

When evaluating copper exceedances, assessors must ensure that the frequency of exceedance requirement is met before listing a waterbody as impaired. This requires at least two exceedances of an acute or chronic criterion within three years. Therefore, a single exceedance of an IWQC is not sufficient for listing. If assessors only have one paired copper and IWQC sample, they must make an effort to collect at least one additional sample to confirm the IWQC exceedance prior to listing the water as impaired.

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