DRAFT

Preliminary Implementation Considerations for Application of BLM-derived Copper Criteria in the Los Angeles Region

Los Angeles Regional Water Quality Control Board

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1. Introduction

Copper is a naturally occurring trace element found in the earth's crust and in surface waters. It is a micronutrient at low concentrations - essential to plants and animals (including fish and shellfish) for carbohydrate metabolism and the functioning of certain enzymes. At higher concentrations copper can become toxic to aquatic life. For example, high concentrations of copper cause gill damage in aquatic invertebrates and interferes with osmoregulation in fishes. Elevated concentrations of copper interfere with oxygen transport and energy metabolism (Eisler, 1998). Other adverse effects include reduced growth and survival rates and reproductive effects in aquatic organisms as a result of chronic exposure to high copper concentrations.

Over the past four decades, the United States Environmental Protection Agency (EPA) has provided guidance pertaining to aquatic life criteria recommendations for copper – with occasional revisions as new scientific information becomes available. The Los Angeles Regional Water Board's (Regional Water Board's) current water quality objectives for copper are based on EPA's 1984 hardness-based criteria which include acute (1-hr) and chronic (4-day) concentrations of dissolved copper to which aquatic life can be exposed without harmful effect. These criteria are expressed as a function of hardness which serves as a surrogate for a number of water quality characteristics that affect the toxicity of copper. Increasing hardness generally has the effect of decreasing the toxicity of copper.

The 1984 hardness-based water quality criteria were included in EPA's promulgation of water quality criteria for priority pollutants in California in 2000 through the California Toxics Rule (CTR). The CTR metals criteria (and thus the Regional Water Board's objectives) include a water effect ratio (WER) to account for other site-specific water quality characteristics that affect the toxicity of metals to aquatic life. A WER has a default value of 1 unless a study is conducted to empirically derive a site-specific value. In the Los Angeles Region, there are a few instances where the copper water quality objectives have been modified by the application of Site-specific WER values.

In 2007, based on new data on the toxicity of copper to aquatic organisms in fresh and salt waters, EPA revised its copper criteria from a hardness-based approach to a water-quality dependent approach that uses a predictive model – the Biotic Ligand Model (BLM). The BLM-derived criteria include those individual water quality parameters for which hardness served as a surrogate in the 1984 criteria. EPA believes that the revised criteria will provide improved guidance on the concentrations of copper that will be protective of aquatic life.

While a number of states have adopted the revised criteria in some fashion as part of their water quality regulations, the State of California has not yet taken such action. However, in 2018, the Los Angeles Regional Water Board prioritized consideration of EPA's new and revised Clean Water Act Section 304(a) recommended criteria for adoption during the 2017-2019 triennial review period[1]. Considering the incorporation of EPA's 2007 copper criteria into the Los Angeles Region's Basin Plan is part of this effort.

The purpose of this document is to provide information and guidance to assist with the adoption of BLM-derived freshwater aquatic life water quality objectives for copper in the Los Angeles

[1] In October 2015, revisions to the federal Water Quality Standards (WQS) regulations at 40 C.F.R. Part 131 went into effect. The final rule addressed certain key WQS program areas including triennial reviews pursuant to CWA section 303(c)(1). Per the final rule, during their next triennial review, states and authorized tribes are to consider, for adoption as WQS, new or updated CWA section 304(a) water quality criteria recommendations published by the U.S. EPA since May 30, 2000.

Region. It provides an overview of the BLM and its input parameters and discusses implementation considerations for the development of BLM-derived objectives, including data requirements, objective derivation, and options for applying these objectives in the Los Angeles Region. This document is not a policy or regulation of the Regional Water Board and is intended solely as a foundational resource for both Regional Water Board staff and stakeholders as discussions occur regarding a possible basin plan amendment(s) to incorporate BLM-based water quality objectives for copper. It is intended to ensure consistency in the application of EPA's 2007 freshwater aquatic life criteria for copper in the region.

2. Copper Impairment in the Los Angeles Region

The extent of known copper impairment in the Los Angeles Region is shown in Figure 2.1, which is based on data/information from the State Water Board's 2014/2016 California Integrated Report (Clean Water Act Section 303(d)List/305(b) Report). The bulk of the identified copper impairments occur in Los Angeles County, particularly in the Los Angeles River Watershed. The only identified copper impairment in Ventura County occurs in the Calleguas Creek Watershed.

FIGURE 2.1: MAP OF COPPER IMPAIRED WATERBODIES IN THE LOS ANGELES REGION

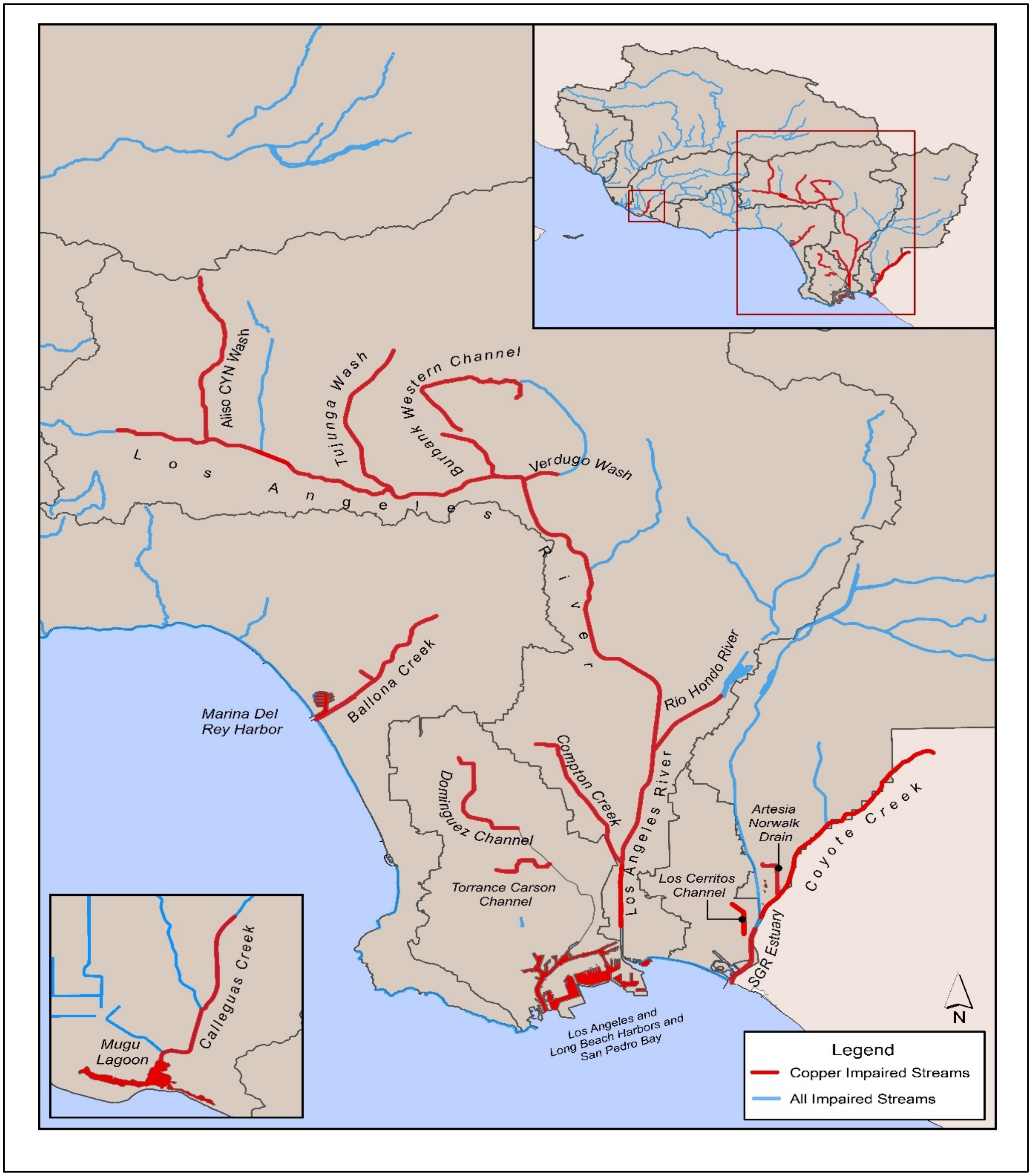


TABLE 2.1A: WATERBODY REACHES AND THEIR EXTENT IDENTIFIED ON THE CWA SECTION 303(D) LIST AS IMPAIRED DUE TO COPPER

Impaired Stream Reach	Length (Miles)
Aliso Canyon Wash	6.45
Artesia-Norwalk Drain	2.40
Ballona Creek & Estuary	8.73
Burbank Western Channel	6.24
Calleguas Creek Reach 2	4.69
Compton Creek	8.50
Dominguez Channel	6.77
Los Angeles River Estuary	1.01
Los Angeles River Reaches 1-6	48.16
Los Cerritos Channel	3.25
Rio Hondo Reach 1	4.52
San Gabriel River Estuary	4.44
Torrance Carson Channel	5.00
Tujunga Wash	9.86
Verdugo Wash Reach 1	3.47
Total	**123.49**

TABLE 2.1B: COASTAL WATERBODIES AND THEIR EXTENT IDENTIFIED ON THE CWA SECTION 303(D) LIST AS IMPAIRED DUE TO COPPER

Impaired Waterbody	Surface Area (Square Miles)
Los Angeles/Long Beach Harbors/ San Pedro Bay	4.98
Marina del Rey Harbor	0.61
Mugu Lagoon	0.54
Total	**6.13**

The Regional Water Board has adopted a number of Total Maximum Daily Loads (TMDLs) that address the copper impairment of waterbodies/watersheds including the Los Angeles River Watershed, Ballona Creek, Calleguas Creek Watershed, Los Cerritos Channel, Lower San Gabriel River, Marina del Rey Harbor, and the Los Angeles and Long Beach Harbors. The waste load allocations prescribed in these TMDLs are based on the Regional Water Board's current freshwater and saltwater aquatic life objectives for copper, which are set forth in the California Toxics Rule (CTR).[2] In two instances – the Calleguas Creek and the Los Angeles River watersheds – the criteria have been modified for increased site specificity using Water-Effect Ratios (WERs).

3. Background on Aquatic Life Freshwater Quality Objectives for Copper

As mentioned earlier, the Regional Water Board's current objectives for copper are hardness-based. EPA's 2007 *Aquatic Life Ambient Freshwater Quality Criteria – Copper* lays out the

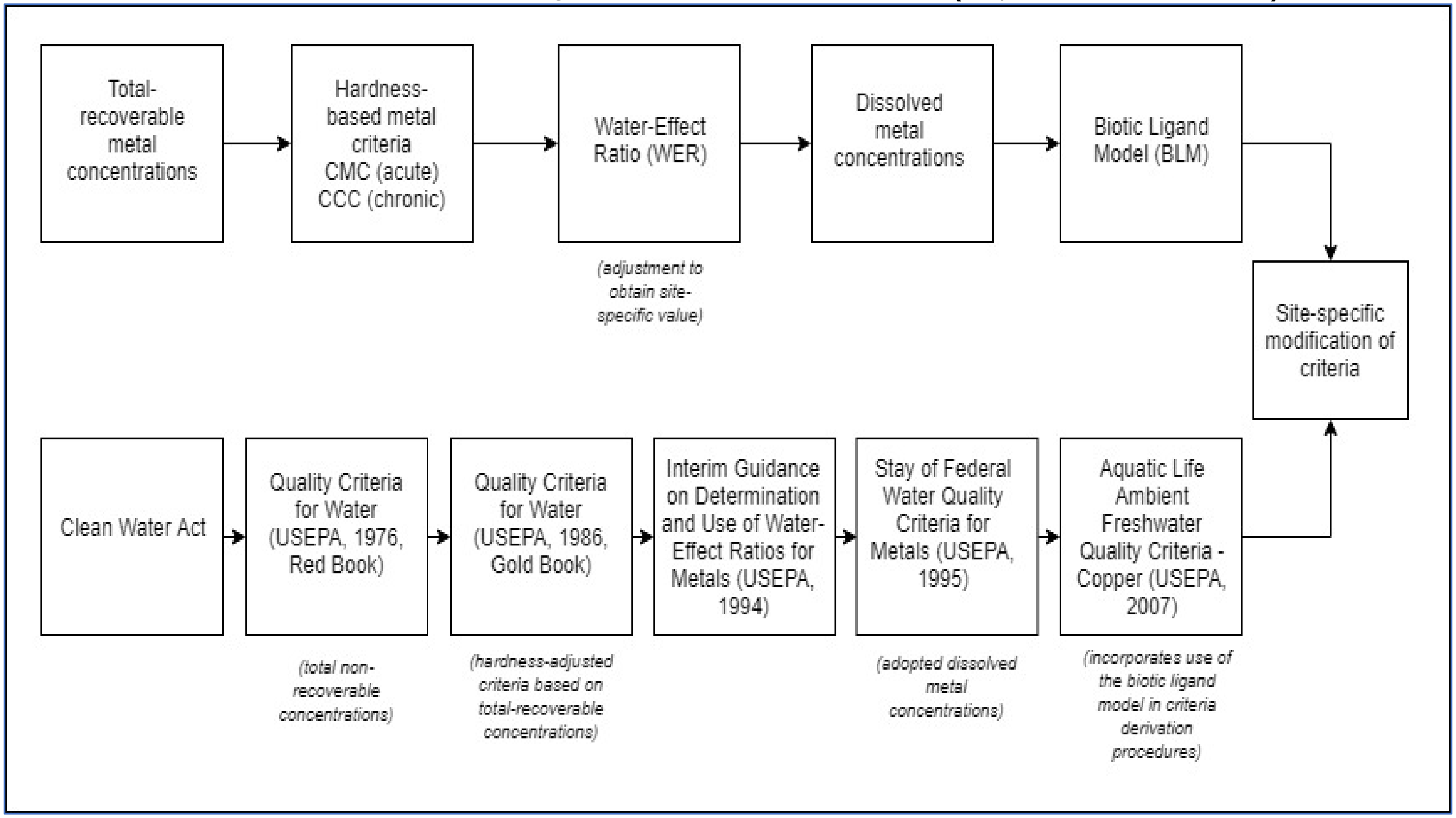
[2] 40 CFR §131.38

functions and limitations of hardness-based copper criteria, along with justification for revision of this criteria, as follows:

- EPA 1984 aquatic life criteria for metals address the reported effects of hardness on metal toxicity using empirical regressions of toxic concentrations versus hardness for available toxicity data across a wide range of hardness. Such regressions provided the relative amount by which the criteria change with hardness but have certain limitations.
- The regressions also covered other factors that were correlated with hardness in the toxicity data set used for the regressions, particularly pH and alkalinity. While these regressions address more bioavailability issues than hardness alone, they best apply to waters in which the correlations among hardness, pH, and alkalinity are similar to the data used in the regressions. The separate effects of these factors are not addressed for exposure conditions in which these correlations are different. In addition, some physicochemical factors affecting metal toxicity, such as organic carbon, are not addressed at all.
- Existing EPA metals criteria also address bioavailability by using dissolved metal as a better approximation for metal bioavailability than total metal (per U.S. EPA, 1993). Although this approach accounts for the low bioavailability of metals on suspended particles, it does not address the major effects of metal speciation on bioavailability.
- To address the modifying effects of site water quality conditions beyond hardness considerations, EPA issued guidance in the early 1980s on the water-effect ratio (WER) method (Carlson et al., 1984; U.S. EPA, 1983, 1992, 1994). The WER is "a biological method to compare bioavailability and toxicity in receiving waters versus laboratory test waters" (U.S. EPA, 1992).
- However, because a WER is empirically derived, it only accounts for the interactions of water quality parameters and their effects on metal toxicity to the species tested and in the water sample collected at a specified location and time. There is also significant cost to generate a single WER.
- Because of the limitations of these past approaches for addressing bioavailability in metals criteria, EPA determined a need for an approach that
    - (1) explicitly and quantitatively accounts for the effect of individual water quality parameters that modify metal toxicity, and
    - (2) can be applied more cost-effectively and easily, and hence more frequently across spatial and temporal scales.

A schematic of the evolution of EPA's numeric aquatic life criteria for metals, including copper is shown in Figure 3.1.

FIGURE 3.1: EVOLUTION OF EPA'S AQUATIC LIFE CRITERIA FOR METALS (Adapted from: Smith et al., 2015**)**



The progression of EPA's recommended aquatic life water quality criteria for copper (such as transitioning from total recoverable concentrations to dissolved concentrations, and refinements of site-specific adjustments) has occurred in response to the availability of new information on metal toxicity to aquatic life.

The BLM incorporates site-specific water chemistry parameters that have a major influence on metal bioavailability. This allows BLM-based criteria to be customized to the particular water body under consideration (EPA, 2016).

3.1 The Copper Biotic Ligand Model (BLM)

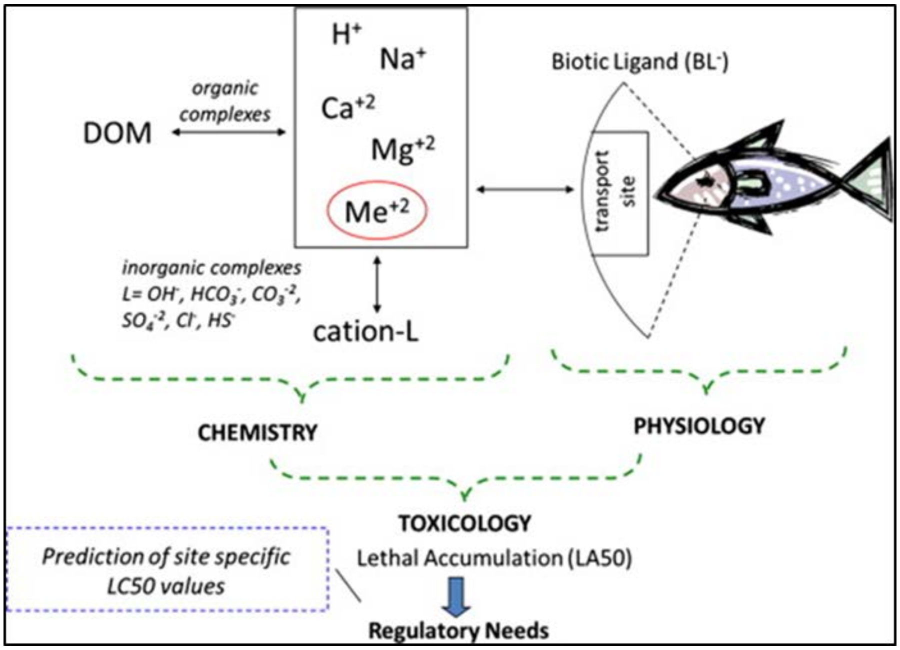
The BLM calculates metal toxicity to aquatic organisms as a function of concentrations of certain chemical constituents of water, including, for example, ions that can either complex with copper and limit biological availability (bioavailability), or compete with copper for binding sites at the point of entry (ion exchange tissues) on aquatic organisms (e.g., at the fish gill) (Carleton, 2008; EPA, 2012). Metal toxicity is also affected by the presence of dissolved organic carbon (DOC), which binds with metals and reduces their bioavailability. Therefore, BLM predictions of metal criteria concentrations, such as copper in freshwater, vary according to changes in the associated water quality parameters.

A "ligand" is an ion, molecule, or molecular group that binds to a metal like copper to form a larger complex. A "biotic ligand" is a ligand except that the ion receptor (binding site) is on an organism, such as a fish gill (Oregon DEQ, 2016; EPA, 2017).The toxicity of metals to organisms is assumed to occur as the result of metal reacting with binding sites on an aquatic organism, resulting in the formation of a metal-biotic ligand complex (EPA, 2003).

The BLM is a model that predicts the accumulation of copper at a biotic ligand at or above a critical threshold that leads to acute toxicity (Oregon DEQ, 2016), and accounts for how this toxicity varies with changing water conditions. In the BLM, metal ions or complexes may bind to the biotic ligand in competition with other cations (e.g., $Ca^{2}+$, Na+, and H+). As a result, the presence of these cations in solution can mitigate toxicity, with the degree of mitigation depending on their concentrations and on their strength of binding to the biotic ligand (EPA, 2003).

Through the use of chemical equilibrium modelling, the BLM addresses this competition between the free metal ion and other cations for complexation with a biotic ligand, which is assumed to be the site of toxic action. This is typically the gill structures of fish and invertebrates and algal cell surfaces. The relationships between the various solution components are shown in Figure 3.2, with the free metal ion represented by $Me^{2}+$, the competing cations by Na+, H+, $Mg^{2}+$, and $Ca^{2}+$, and the abiotic ligands by DOC (dissolved organic carbon), and CO_3^{2-}. The site of toxic action is represented by the fish gill (WFD-UKTAG, 2012).

FIGURE 3.2: SIMPLIFIED SCHEMATIC OF THE BIOTIC LIGAND MODEL (SMITH ET AL., 2015)
(Me²+ is the free metal ion, DOM is dissolved organic matter)



The BLM has three primary components:

- Thermodynamic calculations that partition dissolved elements among their free and complexed forms;
- Relationships between the physiology of organisms, uptake of metal by biological receptors, and metal toxicity; and
- Prediction of site-specific LC50 values.

The BLM output (Instantaneous Water Quality Criteria or “IWQCs”) shows the effect of variations in water chemistry over time and space on copper bioavailability at a given site. As detailed in EPA’s 2007 Freshwater Copper Criteria, use of the BLM in deriving freshwater copper criteria is consistent with EPA’s 1985 “Guidelines for Deriving Numerical Water Quality Criteria for the Protection of Aquatic Life and Their Uses.”

4. Implementing the Copper Biotic Ligand Model

This section of the document discusses the implementation considerations necessary to develop BLM-derived criteria in the Los Angeles Region. For each element, a summary of available information, including EPA suggestions and examples of applications by other states, is provided. Additionally, based on an evaluation of EPA suggestions and other states' approaches, this section presents the initial conclusions of Regional Water Board staff regarding the recommendations it intends to make regarding future basin plan amendment(s).

4.1 BLM Input Parameters

Since the BLM predicts metal toxicity for a particular site based on the ambient water quality, a number of site-specific water quality parameters are required to be monitored to provide the necessary input data. These parameters include temperature, pH, dissolved organic carbon, major geochemical cations (calcium, magnesium, sodium, and potassium), dissolved inorganic carbon or alkalinity,[3] and other major geochemical anions (chloride, sulfate) (EPA, 2007). The model generally applies default values for humic acid fraction and sulfide.

TABLE 4.1: BLM MODEL INPUT PARAMETERS

Input Data	Constants
Temperature pH DOC (dissolved organic carbon) Calcium (Ca) Magnesium (Mg) Sodium (Na) Potassium (K) Sulfate (SO_4) Chloride (Cl) Alkalinity	Humic acid Sulfide

Copper BLM predictions are most sensitive to DOC, pH, and calcium, magnesium, and sodium concentrations (taken together) – as these parameters affect the bioavailability of copper to aquatic organisms. Specifically, estimates are most sensitive to DOC and vary in direct proportion to a change in value (i.e., they are 100% sensitive to DOC). Estimates are 50% sensitive to a change in pH, and 20% sensitive to the combined concentrations of calcium, magnesium, and sodium (EPA, 2006).

Per EPA (2007), other metals such as iron and aluminum can have an effect on copper toxicity to aquatic organisms, which might be due to interactions of these metals with the biotic ligand, effects of these metals on organic carbon complexation of copper, or adsorption of copper to iron and aluminum colloids which are present in filtrates used to measure dissolved copper. While these metals are not currently included in routine BLM inputs, EPA encourages users to measure dissolved iron and aluminum as part of monitoring efforts to support possible future criteria applications (EPA, 2007).

[3] Values for dissolved inorganic carbon (DIC) can be entered directly if known, or the model allows users to enter alkalinity.

4.1.1. EPA's Missing Parameter Document

Recognizing that some of the required input parameters for the copper BLM are not always collected in states' routine monitoring efforts, EPA developed default values for potential missing input parameters, which it provided in a technical support document (EPA, 2016). This technical support document (TSD) presents approaches to develop default estimates for

(i) Geochemical ions (GIs) – which is the term used in the TSD to classify calcium, magnesium, sodium, potassium, chloride, sulfate, and alkalinity, and
(ii) Dissolved Organic Carbon (DOC).

EPA recommended that temperature and pH be measured directly in the field (EPA, 2016).

Estimating default values for GI water quality parameters

Water quality data for BLM GI water quality parameters were retrieved from the United States Geological Survey (USGS) National Water Information System (NWIS), which is comprised of data collected from rivers and streams between 1984 and 2009. These data included measurements for BLM water quality input parameters for copper criteria, including pH, DOC, alkalinity, calcium, magnesium, sodium, potassium, sulfate, and chloride. Using the 10th percentile[4] daily average concentrations at each sampling location from the NWIS data, geostatistical analysis was used to create predictions for unmeasured locations throughout the continental U.S. The geostatistical predictions of BLM water quality parameters were spatially averaged according to the Level III ecoregions[5] of the continental U.S. Ecoregion delineations are based on common patterns of geology, physiography, vegetation, climate, soils, land use, wildlife, water quality, and hydrology (Figure 4.1). The predicted values were further refined through categorization by stream order for low, medium, and high order streams, respectively.[6]

The recommended GI values are presented by ecoregion and stream order in EPA's TSD, and are expected to yield appropriately protective criteria values when applied in the BLM model. EPA determined that the geostatistical and regression-based approaches used to estimate GI input parameters for the BLM did not produce accurate site-specific estimates for DOC.

Estimating default values for Dissolved Organic Carbon

Water quality data for dissolved organic carbon (DOC) were obtained from the National Organic Carbon Dataset (NOCD), which in turn was derived from both EPA's Storage and Retrieval Data Warehouse (STORET)[7] and the United States Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) (the predecessor of the National Waters Information System (NWIS)). Data on particulate organic carbon (POC), dissolved organic carbon (DOC), or total

[4] EPA selected the 10th percentile of the site parameter distributions as a statistic that is a practical compromise between a lower-bound concentration and a percentile that can be reliably determined from small sample sizes. Initial testing with the BLM suggested that protective water quality criteria (WQC) for copper generally corresponded to approximately the 2.5th percentile of the distribution of instantaneous water quality criteria (IWQC) predicted by the BLM. Thus, EPA reasons that BLM predictions made for a site using the corresponding low percentiles of the water quality parameter distributions should (logically) also be a conservative approximation of a protective criterion. As a more reliably determined statistic, the 10th percentile of water quality parameters will also derive reasonably protective criteria, especially for small sample sizes where there may be greater uncertainty at lower percentile estimates.

[5] Ecoregions provide a sound basis for spatial averaging of the water quality predictions. They are designed to serve as a spatial framework for environmental resource management and denote areas within which ecosystems (and the type, quality, and quantity of environmental resources) are generally similar. Ecoregions can be distinguished by landscape-level characteristics that cause ecosystem components to reflect different patterns in different regions.

[6] Stream orders 1 through 3 (low order, headwater streams), 4 through 6 (medium order, mid-reaches), and 7 through 9 (high order, rivers).

[7] Recently renamed the STORET Legacy Data Center (LDC).

organic carbon (TOC) were obtained for the period from 1980 through 1999. The TSD noted the following limitations of the data considered:

i. The data did not reflect a random sampling of U.S. surface waters. The datasets had a diversity of sampling designs and, thus, a potential bias towards locations and waterbodies with known water quality impairments.
ii. The data reflected spatial bias due to unequal sampling efforts in different areas. For example, about half of the DOC and POC values in the databases were from samples collected in Maryland, New York, Ohio, Florida, and Delaware. Therefore, some states were disproportionally represented, even when considering the relative surface water area likely to be contained within each state.
iii. The data generally contained more data from sampling sites in larger river and stream systems, and areas subjected to proportionately greater human influence compared with random statistical sampling.

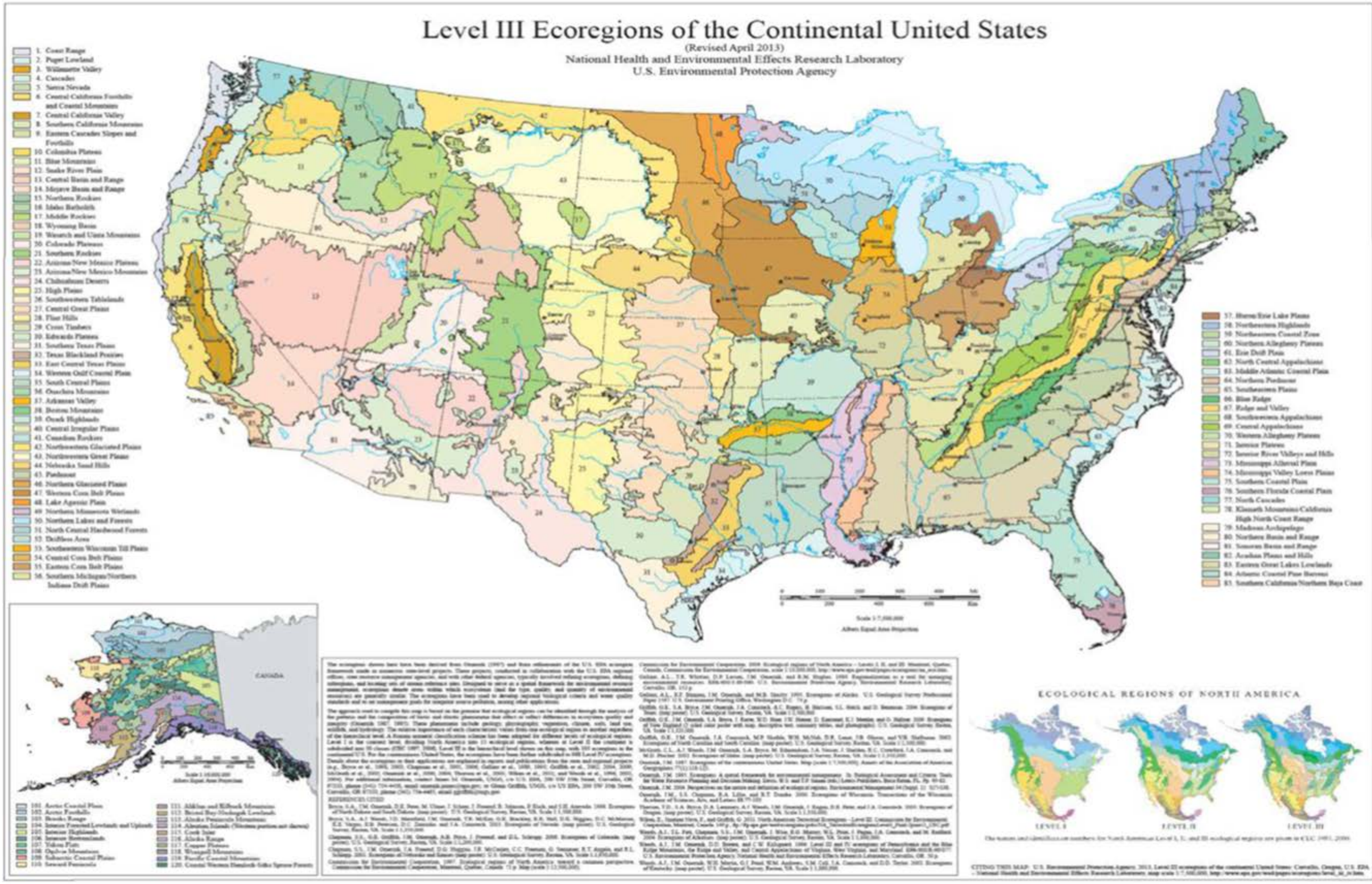
The approach for estimating DOC values is summarized below as follows:

- Lower percentile (1st, 5th, 10th, and 25th percentiles) DOC concentrations were calculated from all data for rivers and streams in each Level III ecoregion.
- An evaluation of bias in the NOCD was conducted using independent data from EPA's Wadeable Streams Assessment (WSA), which included DOC measurements from a statistically based random sample of perennial 1st through 5th order streams.
- Finally, results were compared based on the NOCD and data from the WSA and the National River and Stream Assessment (NRSA) databases.
- Comparison of the WSA data to the ecoregion-specific DOC concentration percentiles calculated from the NOCD indicated that DOC concentrations from the NOCD (i.e. the 10^{th} percentile) were reasonably protective estimates of DOC for use as input parameters for the BLM for some ecoregions.
- For other ecoregions, EPA recommended using estimates based on the WSA/NRSA database.
- Recommended 10th percentile DOC estimated values for 83 of the 84 ecoregions are provided in the TSD. In the remaining ecoregion (76; Southern Florida Coastal Plain), there were insufficient data in either dataset (NOC database or WSA/NRSA) to calculate DOC concentration percentiles.
- There was insufficient data to refine the DOC estimates by stream order.

Due to limitations in the DOC database and the importance of this parameter in criteria calculation, EPA encourages site-specific sampling for DOC, wherever possible, as a basis for determining BLM input rather than using default parameters.

The approaches described in the TSD can be used to provide reasonable default values for input parameters in the BLM to derive protective freshwater aquatic life criteria for copper when data are lacking. However, EPA notes that site-specific data are always preferable for developing criteria based on the BLM and should be used when possible. EPA also encourages users of the BLM to sample their waterbody of interest, and to analyze the samples for the constituent (parameter) concentrations as a basis for determining BLM inputs where possible (EPA, 2016).

FIGURE 4.1: MAP OF LEVEL III ECOREGIONS IN THE U.S.



Source: Map of EPA's Level III Ecoregions

4.1.2. States' Actions with respect to Default Values for BLM Input Parameters

The State of Oregon's Department of Environmental Quality (DEQ) conducted an independent analysis to develop its own database and default values for the Copper BLM parameters using data from 823 United States Geological Survey (USGS) and Oregon DEQ water quality monitoring sites across the state. Similar to EPA's approach in its TSD, estimates were spatially averaged according to geographical location. In this instance, Level 4 Hydrologic Unit Codes were used to distinguish the geographical regions. The analysis compared results from this exercise to those from EPA's recommended default values for Oregon's Level III Ecoregions and determined that the similarity between EPA's recommended 10th percentile data and DEQ's estimated 10th percentile data indicated that the DEQ could reliably derive estimates for parameters from its own database (Oregon DEQ, 2016a). The DEQ eventually proposed using default input values equal to the 20th percentile of the distribution of geochemical ions and DOC data for most regions, and the 15th percentile for the eastern region (Oregon DEQ, 2016b).

In a similar effort to derive its own default values, the State of Idaho's Department of Environmental Quality conducted surface water monitoring at 200 surface water locations throughout Idaho in the fall of 2016. Eleven of these sites were revisited in the spring of 2017. BLM input parameters and derived criteria were grouped according to five different regional classifications – (i) Idaho's administrative basins, (ii) Level III ecoregions, (iii) stream order, (iv) waterbody assessment guidance site classes, and (v) site classes combined with stream size. It was concluded that conservative criteria could be estimated for a site by applying the lowest of the 10^{th} percentile criteria calculated from the five regional classifications.

4.1.3. Default Parameters for the Los Angeles Region

The Los Angeles Region is covered by two EPA Level III Ecoregions: 8 – Southern California Mountains, and 85 - Southern California Northern Baja Coast. The EPA Missing Parameter Document provides default parameters for geochemical ions and dissolved organic carbon for Ecoregion 8 as shown in Tables 4.2A and 4.2B, respectively. However, similar default values are not provided for Ecoregion 85, which leaves a significant portion of the Los Angeles Region without default values. To illustrate this point, Figure 5 shows the coverage of both Level III ecoregions and Table 3 presents the extent of stream length coverage, per ecoregion, in the Los Angeles Region's watersheds.

TABLE 4.2A: PREDICTED 10TH PERCENTILE CONCENTRATIONS FOR BLM GI WATER QUALITY PARAMETERS AND HARDNESS (MG/L) IN LEVEL III ECOREGION 8

(Source: Tables 4, 8, 9 and 10 of EPA's 2016 Missing Parameters Document)

Categories	Ca	Mg	Na	K	Alkalinity	Cl	SO_4	Hardness
Per Level III Ecoregion	63	25	63	3.8	150	54	171	260
Per stream order 1 through 3	29	4.3	10	1.5	70	2.6	0.4	90.13
Per stream order 4 through 6	9.0	1.5	8.4	1.0	17	3.2	6.0	28.65
Per stream order 7 through 9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

n.a. not available

TABLE 4.2B: RECOMMENDED ECOREGIONAL DOC CONCENTRATIONS (MG/L) BASED UPON COMBINED DATA FROM THE NOCD AND WSA/NRSA DATA IN LEVEL III ECOREGION 8

(Source: Table 10 of EPA's 2016 Missing Parameters Document)

Number of Observations	DOC (mg/l) - 10%	Data Source
43	0.7	WSA/NRSA

WSA: Wadeable Streams Assessment, NRSA: National River and Stream Assessment

FIGURE 4.2: MAP OF EPA'S LEVEL III ECOREGIONS' COVERAGE OF THE LOS ANGELES REGION

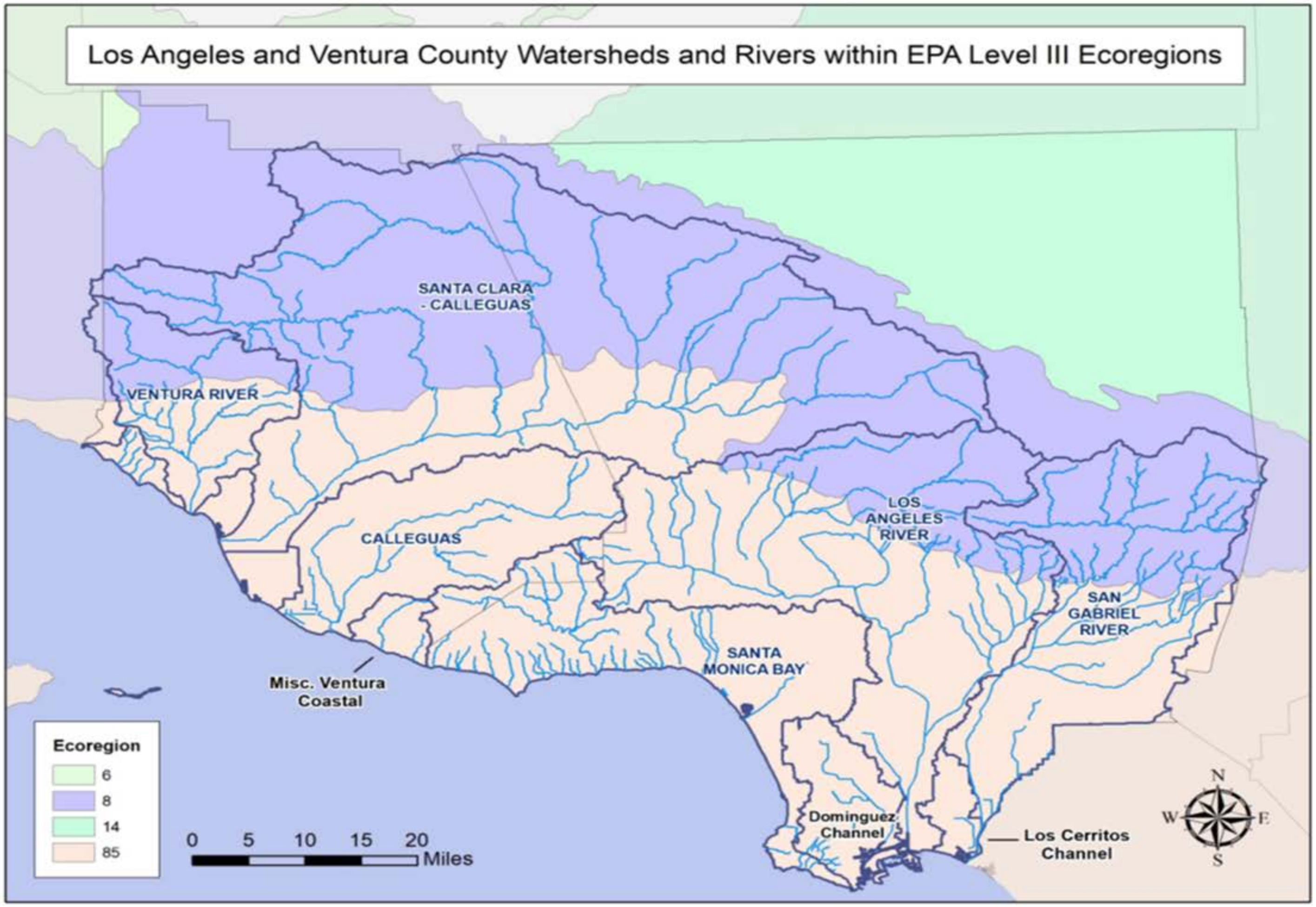


TABLE 4.3: EPA'S LEVEL III ECOREGION COVERAGE OF THE LOS ANGELES REGION

Watershed Basin	Watershed Abbreviation	Total Stream* Length (meters)	Stream Length (Ecoregion 85) (meters)	Percent Stream Length (Ecoregion 85)	Stream Length (Ecoregion 8) (meters)	Percent Stream Length (Ecoregion 8)
Calleguas Creek	CC	176,416.89	176,416.89	100%	0	0%
Dominguez Channel	DC	53,392.38	53,392.38	100%	0	0%
Los Angeles River	LAR	630,579.85	524,473.42	83%	106,106.43	17%
Los Cerritos Channel	LCC	7,573.94	7,573.94	100%	0	0%
Misc. Ventura Coastal	MVC	45,597.35	45,597.35	100%	0	0%
San Gabriel River	SGR	478,887.17	268,722.03	56%	210,165.14	44%
Upper Santa Clara River	USCR	341,948.45	85,049.11	25%	256,899.34	75%
Lower Santa Clara River	LSCR	436,527.46	154,141.38	35%	282,386.08	65%
Santa Monica Bay	SMB	298,125.23	298,125.23	100%	0	0%
Ventura River	VR	183,259.80	131,009.75	71%	52,250.06	29%

*Stream lengths calculated for mainstems, and primary and secondary tributaries in each watershed

In the absence of region-specific data for a significant portion of the waterbodies in the Los Angeles Region, it will be necessary to either create a region-specific database, or sample for all ten parameters in all locations wherever the Copper BLM is to be applied. A few stakeholders have initiated data collection to this effect in the Los Cerritos Channel, Lower San Gabriel River, and Lower Los Angeles River watersheds. Additionally, the Regional Water Board is working with the Southern California Coastal Water Research Program (SCCWRP) through a 205(j) grant to compile existing BLM-relevant data into a database in order to assess the Los Angeles Region's data needs going forward.

Board Staff Preliminary Recommended Approach:

- At the onset of this effort, collect data for all 10 BLM-input parameters for every instance where BLM-derived criteria are to be developed, until region-specific default values are developed.

- Continue work on developing and populating a region-specific database of BLM input parameters. Eventually consider establishing default BLM input parameters based on data from the database.

- Where default values are, or eventually become, available, collect site-specific data for those parameters which EPA identified as sensitive (i.e. DOC, pH, and calcium, magnesium, and sodium concentrations) as well as temperature.

4.2 Minimum Number of Samples

The BLM generates an instantaneous water quality criterion for each complete set of input data. This criterion represents the copper concentration that is protective of aquatic life for the specific water body under the water quality conditions defined by the input parameters. EPA does not recommend deriving a criterion based on a single ambient sample. An instantaneous criterion would not account for variations in the BLM input parameters, some of which may vary substantially on a temporal and/or spatial scale. However, EPA does not specify a preferred number of sampling events that should be used with the BLM due to the diversity of waterbodies to which the BLM may be applied. Rather, EPA states that "in developing a site-specific criterion, enough data should be collected to characterize and manage the spatial and temporal variability of the site" (EPA, 2015a).

In its Training Materials provided for its 2015 Workshop on the Biotic Ligand Model, EPA provides some direction on the number of samples required to develop site-specific copper criteria, as follows:

- In developing a site-specific criterion, enough data should be collected to characterize and manage the spatial and temporal variability of the site.

- Because some of the BLM input parameters are known to vary seasonally, EPA suggests a possible starting point of at least one sampling event per season.[8]

- Spatial variability in the BLM input parameters caused by physical factors such as watershed size or the presence or absence of a point source discharge(s) to a waterbody should also be considered when determining how many sampling events should be collected when using the BLM to develop site-specific copper criteria.

- Regardless of the number of sampling events involved, data collection should reflect site-specific characteristics and consider special circumstances that may affect copper toxicity throughout the expected range of receiving water conditions.

- EPA suggests that states develop Quality Assurance Project Plans (QAPPs) for sampling protocols, in order to ensure that representative data are collected.

A few states have developed some form of guidance regarding the minimum number of samples required for BLM criteria development (Table 4.4). Monthly sampling for the period of one to two years appears to be the consensus.

[8] EPA analyzed thirteen river and stream segments and found that BLM-predicted copper criteria in this study were generally higher in the spring and summer and lower in the fall and winter. Note: In the Los Angeles River Watershed, summer was determined to be the critical condition for WER development and resulting criteria were lower for this period.

TABLE 4.4: MINIMUM NUMBER OF SAMPLES FOR BLM CRITERIA DEVELOPMENT

State	Minimum Number of Samples	Source
Colorado	1-year sampling period – (minimum of 24 sampling events)	*EPA, 2015b*
Iowa	2 years of monthly sampling – (minimum of 24 sampling events) • 1 year of monthly sampling (minimum of 12 sampling events) where there is low variability in the IWQC	*Iowa Department of Natural Resources (2016)*
Oregon	2 years of monthly sampling – (minimum of 24 sampling events)	*Oregon Department of Environmental Quality (2016)*
Idaho	1 year of water quality data – (minimum of 12 sampling events) • 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	*Idaho State of Idaho Department of Environmental Quality (2017)*

In a 2018 article outlining a BLM implementation framework to help guide the decision-making process when designing sampling and analysis programs to support use of the BLM to derive water quality criteria, Gondek et al., suggest at least 24 monthly samples be collected over two years at each sampling location, representing multiple seasons and flow conditions.

Board Staff Preliminary Recommended Approach:

- Collect a minimum of two years of monthly data per sampling location (i.e. 24 samples) to ensure that a full range of waterbody conditions have been captured.
- Where it is not possible to capture this range of conditions within a 24-month period (e.g., as a result of extremely wet or dry periods), an extended sampling period may be required.
- Where sample collection is not possible during certain months of the year due to limited streamflow or other limiting conditions, supplemental samples should be collected in the subsequent months.

4.3 BLM Sampling Locations

In its Training Materials provided for its Workshop on the Biotic Ligand Model (EPA 2015a), EPA provides some direction on the number of sampling locations required to develop site-specific copper criteria using the BLM as follows:

- Because BLM input parameters may vary spatially within a water segment or waterbody, multiple sampling locations may be appropriate.
- The unique characteristics of each site should be considered, including variability in BLM input parameters. For example, relatively homogenous systems may require fewer sampling locations as compared with more heterogeneous waterbodies. If necessary, larger water segments could be divided into smaller segments.

As part of the training materials (EPA, 2015b), EPA presents informal guidance from the State of Colorado regarding the use of the BLM, which suggests:

- Samples should be taken above and below wastewater treatment facilities. The downstream sample should be taken where the effluent has fully mixed with the receiving water.
- More than one sampling site is recommended for stream segments longer than five miles.
- Sampling should be taken below each National Pollutant Discharge Elimination System (NPDES) permit discharge for stream segments with more than one NPDES permit.

This informal guidance was meant for site-specific criteria for effluent dominated stream segments. EPA states that Colorado's informal guidance is intended to provide an illustrative example of how one state has used the BLM and should not be construed as EPA's recommendation (EPA, 2015b).

In its *Implementation Procedures for the Site-Specific Application of Copper Biotic Ligand Model (2016)*, the State of Iowa's Department of Natural Resources (DNR) echoes EPA's guidance for determining the number of sampling locations. DNR's Implementation Procedures also specify that:

> *"For sites with more than one NPDES permit, water quality samples are taken below each NPDES permit discharge just above the next discharge and below all discharges at a location where complete mixing occurs."*

For the DNR, the specific number of sampling locations will be provided in the required work plan for each instance of BLM criteria development.

Board Staff Preliminary Recommended Approach:

- Have a minimum of one sampling location per waterbody reach (as defined in Chapter 2 of the Water Quality Control Plan for the Los Angeles Region – Basin Plan).
- Where waterbody reaches are greater than 5 miles, conduct an analysis of the variability of water quality conditions within the segment to determine the appropriate number of samples to be collected. In the Los Angeles region, most stream segments are less than 10 miles, with about 57% with lengths of 5 miles or less (see table 4.5).

TABLE 4.5: STREAM LENGTHS FOR WATERBODIES IN THE LOS ANGELES REGION

Length of Waterbody Segment/Reach (miles)	Number of Waterbody Segments/Reaches
0 to 5	166
5 to 10	84
10 to 20	24
20 to 50	7
>50	2

- Collect samples upstream and downstream of major NPDES discharges. Specific sampling locations should be detailed in a work plan for each BLM criteria application.

4.4 Methods for Deriving Criteria

For each set of input parameters, the BLM calculates an instantaneous water quality criterion (IWQC). This criterion is a snapshot of what would be protective at the sampling location at the time the monitoring data was collected. A set of samples from any given site will therefore result in a series of instantaneous water quality criteria for the location. A single instantaneous criterion does not take into account variations in the BLM input parameters, some of which may vary substantially on a temporal and/or spatial scale. For this reason, EPA recommends BLM monitoring that sufficiently captures site variability. There are two common approaches to derive single-value copper criteria for a site based on IWQC:

(i) Using a statistic (e.g. percentile or geometric mean) of the IWQC, and;
(ii) Calculating a Fixed Monitoring Benchmark (FMB).

4.4.1 Percentile or Geometric Mean of the IWQC

In its *Training Materials on the Copper BLM: Data Requirements* (2015a), EPA states that a site-specific criterion should protect a waterbody, i.e., its designated use for aquatic life, under a variety of circumstances (e.g., seasonal conditions, high and low flows) and should not be exceeded more than the time allowed by the state standard (e.g., once every three years, on average). In this document, EPA also outlines the following procedure for deriving a single numeric site-specific criterion from multiple BLM-derived IWQC:

- If the water quality parameters and BLM-derived copper criteria are relatively constant over a range of seasonal and flow conditions (i.e., there is little variation in the input parameters and IWQC) then using the geometric mean of all IWQC may be appropriate. A geometric mean is a measure of central tendency and is less likely to be affected by outliers than an arithmetic mean.

- If a water body exhibits significant seasonal variations in the BLM input parameters and BLM-derived IWQC, then it may be best to develop seasonal criteria using seasonal geometric means. In such waterbodies, averaging on an annual basis could result in a criterion value that is potentially underprotective during parts of the year (e.g., fall and winter).

- If the BLM-derived copper criteria vary significantly for reasons that cannot be easily explained (e.g., are not seasonal), then a lower percentile value (e.g., 5th) may be best to ensure that the waterbody is sufficiently protected, and the criterion is not exceeded more than the state standard allows.

- If there are significant spatial differences in the instantaneous BLM-derived criteria for a water segment, then dividing the segment into smaller sections may be appropriate.

In its *Implementation Procedures for the Site-Specific Application of Copper Biotic Ligand Model (2016)*, the State of Iowa's Department of Natural Resources (DNR) adopts this approach to derive its copper criteria and defines significant variation as IWQC having a coefficient of variation greater than or equal to 0.53.[9]

[9] The CV value of 0.53 is derived using regression tree analysis based on the IWQCs derived from ambient monitoring data for the 10 BLM input parameters and the DOC concentrations. At or below the breakpoint CV value of 0.53, the relative change for both the instantaneous criteria and the DOC concentrations reaches the lowest variability (Iowa DNR, 2016).

4.4.2 Fixed Monitoring Benchmark

The Fixed Monitoring Benchmark (FMB) approach is a probability-based method that incorporates time variability in BLM-predicted instantaneous water quality criteria and in-stream copper concentrations. It provides benchmarks that can be used to simplify implementation of time-variable WQC (Iowa, 2016). In effect, it derives a fixed-site criterion from time-variable results. This approach requires collection of copper data in addition to the other ten BLM input parameters.

The FMB does not technically represent a limit above which aquatic effects are expected. Rather, it represents a fixed concentration intended to yield the same level of protection as time-variable IWQC, which rely upon toxic unit (TU) distribution; each TU is calculated for a single sample using the copper (Cu) concentration and IWQC for this sample.

$$TU_i = \frac{Cu_i}{IWQC_i},$$

where TU_i is a single TU value calculated for a single sample collected at time i,
Cu_i is the Cu concentration in this sample, and
$IWQC_i$ is the BLM-based IWQC calculated for this sample.

The calculation of TU_i requires that all the BLM input parameters needed to calculate IWQC and the measured Cu concentration are available for this sample. The distribution of TU values for all of the samples collected at a site is then used to estimate the probability that an in-stream Cu concentration equals or exceeds its associated IWQC, in other words the probability that $TU \geq 1$.

The FMB approach determines a Cu distribution such that the resulting water quality criteria exceedance frequency is consistent with the level of protection that is intended for the applicable water quality standard (WQS) i.e., the derived criteria will not be exceeded more than once in three years on average as required in EPA's 1985 "Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses" (Iowa 2016, and Ryan et al., 2018).

FMBs are currently the method of choice for development of site-specific BLM copper criteria in the State of Colorado. The process of FMB derivation is laid out in detail in EPA's "Calculation of BLM Fixed Monitoring Benchmarks for Copper at Selected Monitoring Sites in Colorado" (USEPA, 2016). This document can be found at the following link: EPA's Fixed Monitoring Benchmark Document.

The State of Idaho Department of Environmental Quality's implementation guidance presents four possible approaches for developing criteria from multiple IWQC (Idaho DEQ, 2017):

- *Minimum of the IWQCs*. This approach is conservative but appropriate, particularly when there are few data points (e.g., fewer than 24 monthly samples, or samples do not represent the annual hydrograph) and, therefore, there is lower confidence that the site's temporal variability has been sufficiently characterized.
- *Percentile of the IWQCs:* When sufficient data are available to fully characterize the seasonal variability of IWQCs (e.g., at least 24 consecutive, monthly samples), then a conservative percentile of all IWQCs should be used. Users must demonstrate that the selected percentile will be protective of aquatic life and will not lead to a frequency of copper exceedance of individual IWQCs at the site more than once in 3 years.

- *Statistical Approach of FMBs*: When sufficient data are available to fully characterize the variability of IWQCs and the relationship of IWQCs to copper concentrations, a fixed monitoring benchmark may be used. In some cases, it may require up to 3 or more years of monthly samples for all BLM input parameters as well as copper to fully characterize the variability of flows and water quality within a waterbody.
- *Seasonal Criteria*: For waters with predictable seasonal variability of IWQCs, seasonal criteria may be developed. For example, in waters with sufficient IWQC data, it may be possible to derive dry season criteria based on the distribution of IWQCs during low-flow conditions, and wet season criteria based on the distribution of IWQCs during high flow. To consider seasonal criteria, sufficient data must be available and demonstrate predictable seasonality. This would generally require at least 36 consecutive monthly samples and may require multiple years of monthly samples to fully capture the variability and flood cycle.

Board Staff Preliminary Recommended Approach:

- Derive BLM-based copper water quality objectives using the percentile approach, which is easily implementable. Use the 5^{th} percentile.
- Consider wet and dry weather objectives where there is significant seasonal variation.

5. Options for Adopting BLM-derived Water Quality Objectives

Based on alternatives provided in EPA's *Training Materials on the Copper BLM: Implementation (2015a),* the 2007 freshwater copper criteria can be incorporated into the Los Angeles Region's Basin Plan as water quality objectives in a number of ways, including by the following:

i. Regionwide adoption of EPA's 2007 copper BLM criteria to replace the current hardness-based criteria. This would involve developing BLM-derived objectives for each of the region's waterbodies. Since BLM input data is not currently available across the region, this approach would have to be implemented incrementally and may require preliminary actions such as incorporating BLM parameters into regionwide monitoring programs. The hardness-based criteria will be retained but will only apply where BLM-derived objectives have not been developed.

ii. Adopting site-specific copper objectives authorization language into the Basin Plan requiring use of the BLM - and applying this in a targeted manner that would provide the flexibility to use the BLM on a limited basis where it will have the most impact. (e.g. in waters where the hardness-based copper objectives may be potentially overprotective, such as waters with high DOC, or potentially under-protective, such as waters with low pH). The current hardness-based copper objectives would still apply to all waters except those where site-specific objectives are derived using the BLM.

iii. Developing BLM-derived site-specific copper objectives authorized by already existing general site-specific objective (SSO) language in Chapter 3 of the Basin Plan. This will require no formal adoption action to incorporate objectives based on EPA's 2007 recommended criteria. However, any SSO developed using the copper BLM would be incorporated through a Basin Plan amendment. The current hardness-based copper objectives would be maintained for all other waters to which such SSOs do not apply.

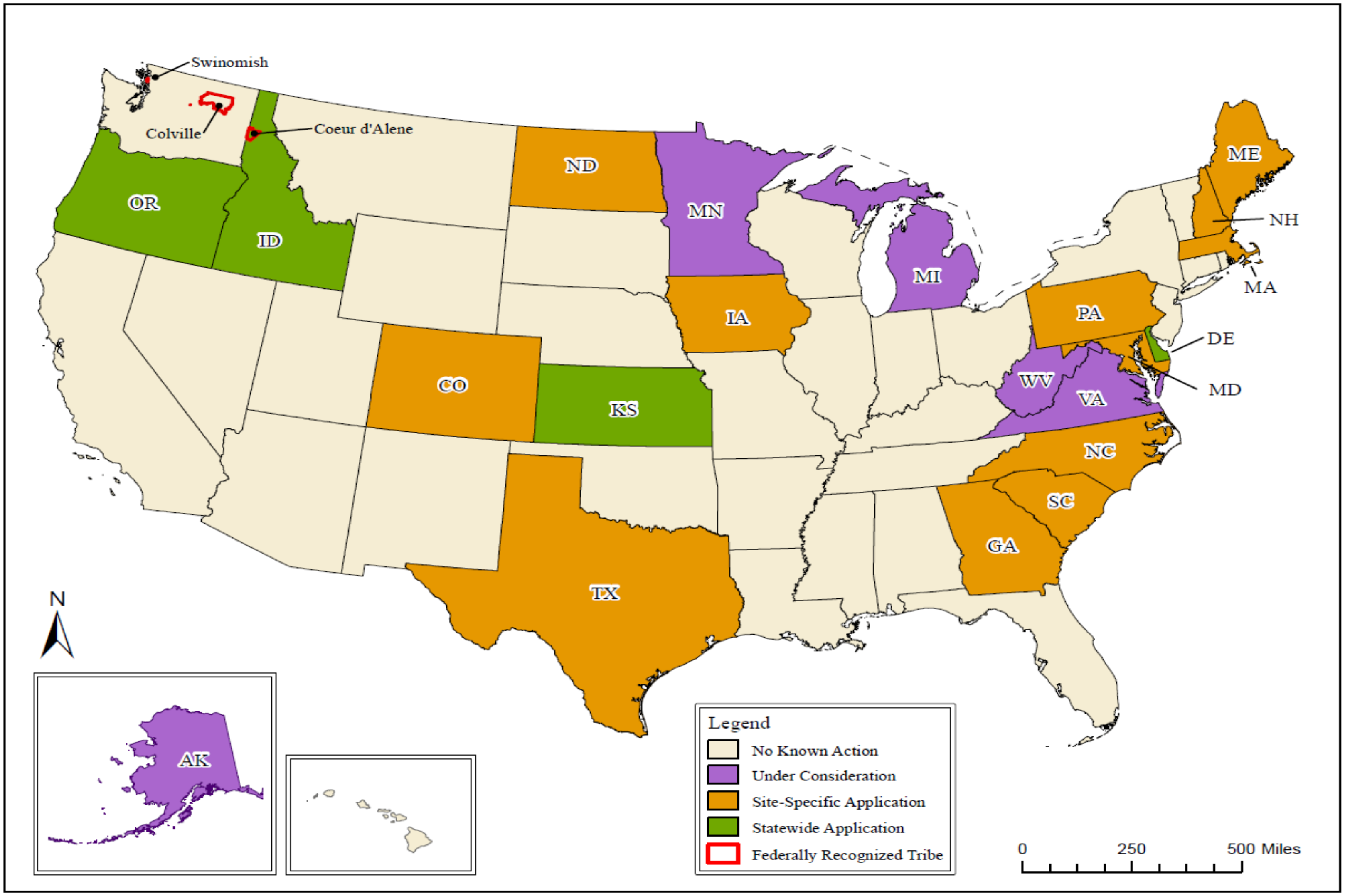
Figure 5.1 shows those states that have adopted EPA's 2007 BLM-derived copper with statewide or site-specific application, as well as those states where the criteria are under consideration.

EPA has taken a few actions that indicate its preference for the use of the BLM as opposed to hardness-based criteria and WERs:

- In 2013, EPA disapproved Oregon Department of Environmental Quality's 2004 adopted hardness-based copper criteria in response to a 2012 National Marine Fisheries Service Biological Opinion, which concluded that the criteria would jeopardize threatened and endangered species, and because at this time EPA's updated national copper criteria recommendations were available.
- In 2015, EPA disapproved a copper WER developed by West Virginia Department of Environmental Protection. In this instance, EPA derived criteria using the BLM (as the best available science) to evaluate the protectiveness of the WER, and determined that, based on the available information, the site-specific criteria resulting from the application of the WER would not be protective of West Virginia's aquatic life beneficial use in the waterbody for which the WER was intended.

In a similar vein, a May 2014 Biological Opinion from the National Oceanic and Atmospheric Administration (NOAA) on the State of Idaho's aquatic life criteria found jeopardy and adverse modification of critical habitat due to several criteria, including acute and chronic hardness-based copper criteria. In this opinion, NOAA identifies EPA's 2007 BLM-derived copper criteria as a reasonable and prudent alternative to avoid jeopardy.

FIGURE 5.1: APPLICATION OF COPPER BLM CRITERIA IN THE U.S



Board Staff Preliminary Recommended Approach:

- Incremental regionwide adoption of BLM-derived copper objectives such that the current hardness-based objectives will gradually be replaced with EPA's 2007 revised copper criteria.

6. Summary of Preliminary Recommendations

This section is a summary of the preliminary approaches recommended by Regional Water Board staff, in Sections 4 and 5 of this document, regarding implementing the biotic ligand model (BLM) and the adoption of BLM-derived water quality objectives in the Los Angeles Region (see Table 6.1).

TABLE 6.1: SUMMARY OF STAFF PRELIMINARY RECOMMENDATIONS

Elements for Consideration	Preliminary Recommendations
BLM Input Parameters	• Collect data for all 10 BLM-input parameters for every instance where BLM-derived criteria are to be developed, until region-specific default values are developed. • Continue work on developing and populating a region-specific database of BLM input parameters. • Where default values are, or eventually become, available, collect site-specific data for those parameters which EPA identified as sensitive (i.e. DOC, pH, and calcium, magnesium, and sodium concentrations) as well as temperature.
Minimum Number of Samples	• Collect a minimum of two years of monthly data per sampling location (i.e. 24 samples) to ensure that a full range of waterbody conditions have been captured. • Where it is not possible to capture this range of conditions within a 24-month period (e.g., as a result of extremely wet or dry periods), an extended sampling period may be required. • Where sample collection is not possible during certain months of the year due to limited streamflow or other limiting conditions, supplemental samples should be collected in the subsequent months.
Sampling Locations	• Have a minimum of one sampling location per waterbody reach. • Where waterbody reaches are greater than 5 miles, conduct an analysis of the variability of water quality conditions within the segment to determine the appropriate number of samples to be collected. • Collect samples upstream and downstream of major NPDES discharges. Specific sampling locations should be detailed in a work plan for each BLM criteria application.
Method for Deriving Criteria	• Derive BLM-based copper water quality objectives using the percentile approach, which is easily implementable. Use the 5th percentile. • Consider wet- and dry-weather objectives where there is significant seasonal variation.
WQO Adoption Approach	• Incremental regionwide adoption of BLM-derived copper objectives such that the current hardness-based objectives will gradually be replaced with EPA's 2007 revised copper criteria.

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