Proposed Update to the Oklahoma's Selenium Aquatic Life Criterion and Development of Implementation Rules

Staff Report

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

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Introduction

Water quality standards define the goals for a waterbody and work to safeguard human health and aquatic life by establishing provisions to limit pollution to waterbodies. Standards are comprised of three components 1) a waterbody's beneficial uses, 2) water quality criteria to protect those uses and determine if they are being attained, and 3) antidegradation policies to help protect high quality waters. The Oklahoma Water Resources Board (OWRB) is the state agency responsible for promulgating the Oklahoma Water Quality Standards (OWQS) to ensure water quality protection across the state.

Water quality criteria are set to protect beneficial uses and in accordance with section 304(a) of the Clean Water Act (CWA) the Environmental Protection Agency (EPA) develops nationally recommended numeric water quality criteria for the protection of aquatic life. The 304(a) nationally recommend criteria are based upon the latest scientific information and are available to assist States in adopting water quality criteria that protect beneficial uses in accordance with CWA §303(c)(2). The numeric ambient water quality criteria (AWQC) for aquatic life criteria (ALC) found in Oklahoma's Water Quality Standards, Appendix G are implemented in key water quality programs across the state. For example, these criteria are used in monitoring programs and water quality assessment programs to evaluate trends in water quality and to determine if beneficial uses are attained or not attained. These criteria also provide the regulatory basis for establishing water quality-based effluent limits in Oklahoma Pollutant Discharge Elimination System (OPDES) permits. Water quality criteria provide the baseline value to determine success in improving or maintaining water quality.

Many of Oklahoma's existing aquatic life numeric criteria were adopted as part of Oklahoma's 1988 triennial review of water quality standards (OWRB, 1988). Periodically, updated toxicological information has resulted in revisions to several of these criteria, including a comprehensive update in 2012. During this triennial review of WQS, OWRB staff recommend to update the chronic ALC for selenium (OWRB, 2012).

Selenium General Information

Selenium is a naturally occurring element that is present in both sedimentary rocks and soils and is naturally occurring in freshwaters as methyl derivatives of selenium. It naturally enters the surface water environment through both weathering of geologic strata and discharge of groundwater to surface water. Selenium may also enter the environment through a variety of anthropogenic activities, including surface mining, irrigated agriculture, some industrial processes, and both industrial and municipal point source discharges.

Selenium is an essential nutrient in small amounts and is necessary for cellular functions in many plants and animals. However, selenium bioaccumulates through the food chain and is toxic in higher concentrations. In freshwater environments, chronic exposure to selenium causes reproductive impairments, adversely affects growth and causes deformities, and may lead to juvenile mortality (Figure 1).

Figure 1. Reproductive impairments and adverse effects on growth in embryonic and juvenile fish caused by chronic exposure to selenium.

Background

In 1988, Oklahoma adopted a chronic aquatic life criterion of 5 µg/L for selenium, which was based upon the 1987 EPA recommended criterion. Accompanied by an acute criterion of 20 µg/L, the 1987 iteration of selenium is still in the OWQS. Prior to 1987, the EPA recommended criterion was based on water-only exposure and lacked consideration for bioaccumulation through the food chain. Based upon field-studies that included both exposure routes (water column and dietary uptake), the EPA promulgated the current recommended chronic criterion of 5 µg/L in 1987. The criterion is based on total recoverable selenium in water.

In the late 1990's, the EPA began to consider contemporary science for selenium. This science suggested that chronic toxicity was more directly related to food-chain bioaccumulation than exposure through the water column. Through the 2000's, continued research and development centered on a fish-tissue approach for chronic toxicity, and culminated in the 2009 Pellston scientific workshop that specifically assessed ecological risk. Several key findings from the workshop were published (Chapman, et al., 2009, 2010). First, diet is the primary exposure pathway for selenium in aquatic organisms. Second, selenium fate and transport is highly dependent on site-specific factors, such as food web structure and hydrology (EPA, 2016a). And, third, "Selenium toxicity is primarily manifested as reproductive impairment due to maternal transfer, resulting in embryo toxicity and teratogenicity in egg-laying vertebrates" (EPA, 2016a).

A conceptual model for selenium partitioning and bioaccumulation is provided in Figure 2 (EPA, 2016a). The largest bioaccumulation of dissolved selenium from the water column occurs at the base of the food web. As movement occurs through primary producers up through trophic level 3 organisms (e.g., fish and birds), the primary pathway for accumulation is dietary. Primary producers along with bound selenium create the particulate fraction of selenium in the water column and become the primary source for entrance of selenium to the aquatic food web. Therefore, use of water column concentration to predict selenium tissue concentrations is inadequate.

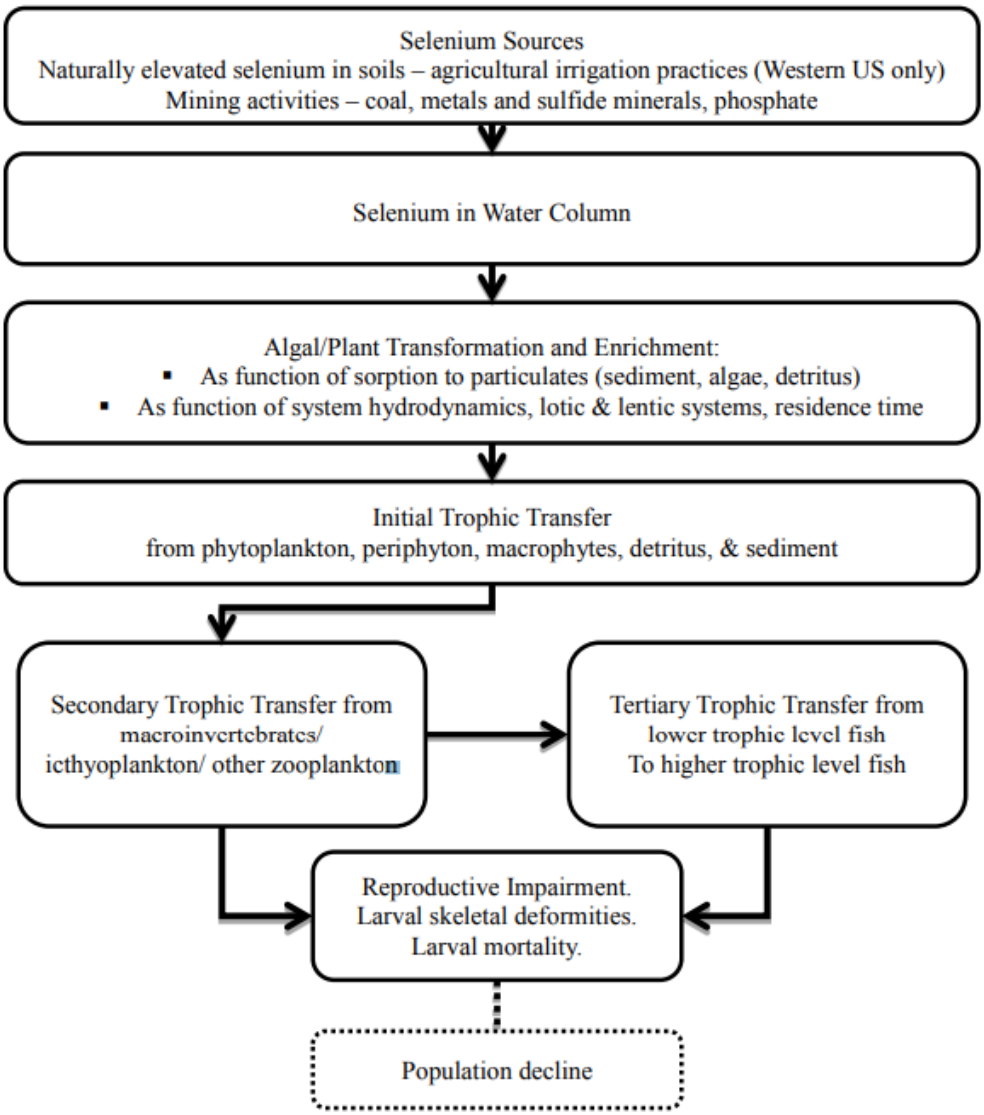

Figure 2. Diagram of Selenium Partitioning, Bioaccumulation, and Effects in the Aquatic Environment. (As shown in EPA, 2016a)

Finally, aquatic life feeding habits have an effect on accumulation. Some benthic and filter-feeders, such as mussels, clams, and some benthic insects have higher rates of bioaccumulation than planktonic insects. These organisms not only ingest higher particulate matter at higher rate but may also eliminate selenium at a lower rate. Some higher trophic level fish, such as molluscivores and benthic insectivores, may have higher rates of bioaccumulation because of feeding preferences.

New Criterion

Nationally Recommended 304(a) Criterion

In 2016, EPA published an updated chronic ALC for selenium using the latest scientific knowledge on selenium fate and transport and toxicity (EPA, 2016a). The new criterion is expressed as four elements in two media, with both fish tissue and water column based elements. Fish tissue elements are expressed as steady-state. Water column values are based on dissolved total selenium and were derived through bioaccumulation models based on fish tissue values. Thus, the tissue and water elements of the criterion are linked. The nationally recommended criterion is presented below.

1. Eggs and ovaries shall not exceed 15.1 mg/kg dry weight, as an instantaneous measurement not to be exceeded.

2. Whole body of fish shall not exceed 8.5 mg/kg dry weight, or muscle tissue of fish shall not exceed 11.3 mg/kg dry weight, as an instantaneous measurement not to be exceeded.

3. The 30-day average in lotic (flowing) and lentic (standing; e.g., reservoirs) waters shall not exceed 3.1 µg/L and 1.5 µg/L, respectively, not more than once in three years on average.

4. A calculated intermittent concentration for waters with new discharges of selenium.

For purposes of implementation, EPA created a hierarchy within the criterion elements; the fish tissue elements take precedence over the water column elements, with water column elements applicable in the absence of steady-state fish tissue data. The four recommended criterion elements are listed above in order of precedence.

Proposed Oklahoma Criterion

For Oklahoma, staff are recommending the adoption of only the chronic fish tissue criteria, expressed as whole body or muscle tissue, and the 30-day average chronic criterion for lotic (flowing) waters (Table 1). The current chronic criterion of 5 µg/L will remain in effect for lentic waters (reservoirs and other standing waters). Moreover, at this time the egg/ovary criterion element will not be considered as part of the statewide

criterion; however egg/ovary concentrations may be used in the development of site-specific criteria. Likewise, an intermittent expression of the criterion is not being proposed, but will be further investigated and may be proposed at a later date. Finally, because current selenium science clearly demonstrates the chronic nature of selenium toxicity staff are recommending that the current acute selenium aquatic life criterion of 20 µg/L be removed from OWQS.

Table 1. Recommended chronic selenium criterion[1]

Media	Criterion Element	Magnitude	Duration	Frequency
Fish Tissue	Whole Body	8.5 mg/kg dry weight	Instantaneous	Not to exceed
	Muscle	11.3 mg/kg dry weight		
Water	Lotic waters	3.1 µg/L	30 day average	Not to exceed more than once in 3 years
	Lentic waters	5.0 µg/L [2]	4 day average	
	Excluded Waterbodies [3]	5.0 µg/L [2]		

[1] Fish whole-body or muscle tissue supersedes the water column element when both fish tissue and water concentrations are measured.

[2] Current chronic criterion for selenium (OWRB, 2017)

[3] The excluded waterbodies include: a) Cimarron River, b) Beaver River from the confluence of Palo Duro Creek downstream to the confluence of Kiowa Creek, c) Salt Fork of the Arkansas River, d) Washita River above the confluence with Cavalry Creek, e) Canadian River above the confluence with Deer Creek, f) Red River above Lake Texoma, g) North Fork of the Red River, h) Salt Fork of the Red River, and i) Elm Fork of the Red River. This criterion may also be applied to tributaries within the watersheds of the waterbodies listed above upon scientifically defensible demonstration that measurements of specific conductance greater than a mean of 2,500 µS/cm are due only to natural sources.

Rationale for Excluded Waterbodies

As a result of naturally occurring salt deposition and native geology (e.g., gypsum deposits), certain areas of western Oklahoma have naturally elevated levels of salinity. The Oklahoma Geological Survey (OGS) notes that “thick salt deposits are widespread in the subsurface in the west” of Oklahoma, that “gypsum and salt are widespread in western Oklahoma”, and that “natural salt plains and saline rivers are present in the west” (OGS, 2008). The OGS notes that “natural salt plains occur along some rivers where natural brines seep to the surface” (OGS, 2008). This salinity is often measured as conductivity in many water quality programs, including the Beneficial Use Monitoring Program (OWRB, 2018), which has collected data throughout Oklahoma since 1998.

As data from the BUMP shows (Table 2), elevated conductivity values can be seen in watersheds across western and central Oklahoma, including the upper Red River, the Salt Fork of the Arkansas River, the Cimarron River, and the Canadian River (OWRB, 2018).

Table 2. Conductivity values for some western Oklahoma lotic waterbodies (OWRB, 2018).

Waterbody	Mean Conductivity (µS/cm)	Max Conductivity (µS/cm)	N Samples
Elm Fork of the Red River	33560	169119	194
Cimarron River	10369	63954	332
Sandy Creek	8780	11175	51
Beaver Middle	8039	15500	68
North Fork of the Red River	5798	16235	154
Red River (above Texoma)	4407	21375	272
Beaver River	3961	15500	152
Salt Fork of the Red River	3836	7648	96
Salt Fork of the Arkansas	2386	6338	92
Canadian River (Upper)	2217	4187	43
Washita River (Upper)	2176	3641	93
Washita River	1816	3237	306
Elk Creek	1651	2865	104
Sweetwater Creek	1643	5513	12
Skeleton Creek	1556	2904	49
Beaver River Lower	1495	3482	81
Little River (below Thunderbird)	1251	4335	49
Canadian River	1245	4187	275
North Canadian River	1229	3250	254
Arkansas River	1222	3115	240
Chikaskia River	1163	6238	49
West Cache Creek	1081	3604	46
Wolf Creek	989	1500	52
Black Bear Creek	866	1865	48
Mud Creek	799	1972	51
Deep Fork River	746	1577	95
East Cache Creek	708	1450	50

Knowing that much of western Oklahoma naturally drains salt surface and subsurface areas, staff investigated the suitability of the new criterion for certain Oklahoma waters. A literature review revealed studies that demonstrate a relationship between salinity, expressed as conductivity, and dissolved selenium. Several studies by the United States Geological Survey (USGS) have demonstrated a positive relationship between salinity (expressed as conductivity) and selenium (Butler and Leib, 2002; Linard and Schaffrath, 2014). Additionally, a report by the Kansas Department of Health and Environment (KDHE) for the development of a selenium total maximum daily load (TMDL) in the Arkansas River associated increased conductivity with selenium (KDHE, 2007).

The relationship between selenium concentrations and conductivity was explored with broad-based regression analysis to compare grouped measures of distribution for both dissolved selenium and conductivity at a variety of sites throughout state. A comparison of dissolved selenium and conductivity means for sites throughout the state are shown in Figure 3. A relationship between the two measures is evident with an R^2 of 91.0. However, at the lower end of the curve, it is apparent that a great deal of variation occurs around a conductivity of 2,000 µS/cm.

To explore this variation, the data set was bisected into two groups at conductivities greater and less than 2,000 µS/cm (Figures 4 and 5). In Figure 4, it is evident that a strong relationship exists between dissolved selenium and conductivity when mean conductivity exceeds 2,000 µS/cm. However, the relationship becomes much weaker when mean conductivity is less than 2,000 µS/cm (Figure 5). The data in Figure 5 was further bisected to determine if a relationship exists between conductivities of 1,000 and 2,000 µS/cm (Figure 6). Both visually and statistically ($R^2 < 6.0$), no relationship exists with dissolved selenium within that conductivity range.

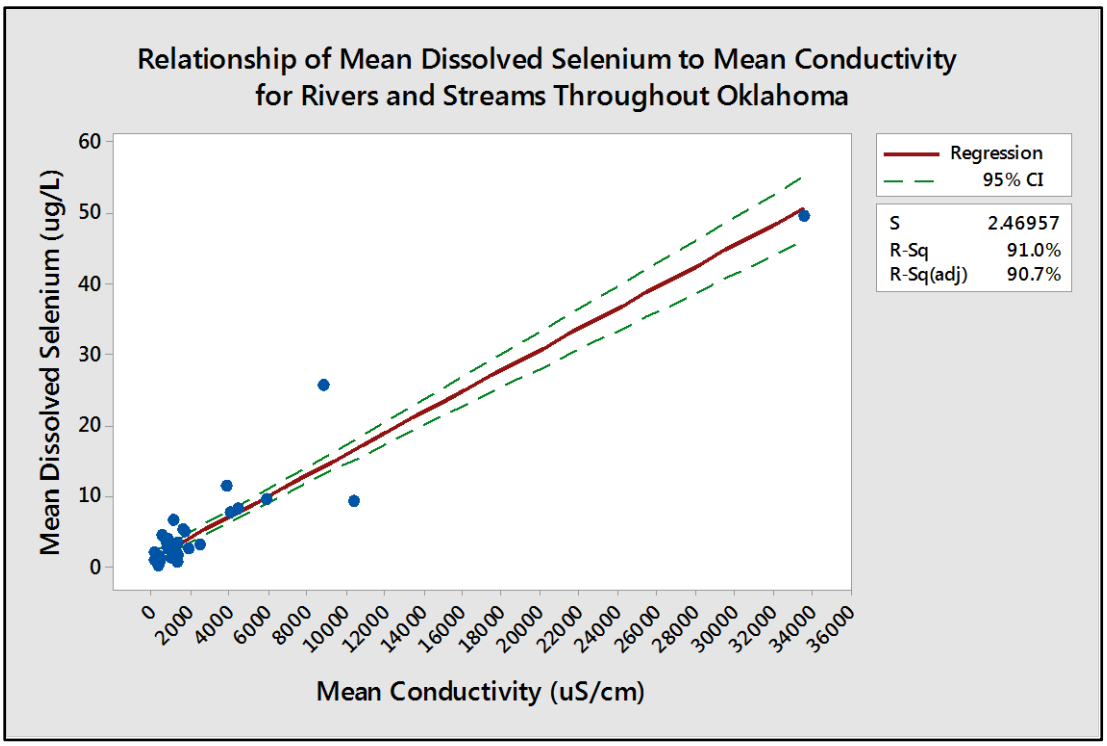

Figure 3. Relationship of Mean Dissolved Selenium to Mean Conductivity for Rivers and Streams throughout Oklahoma.

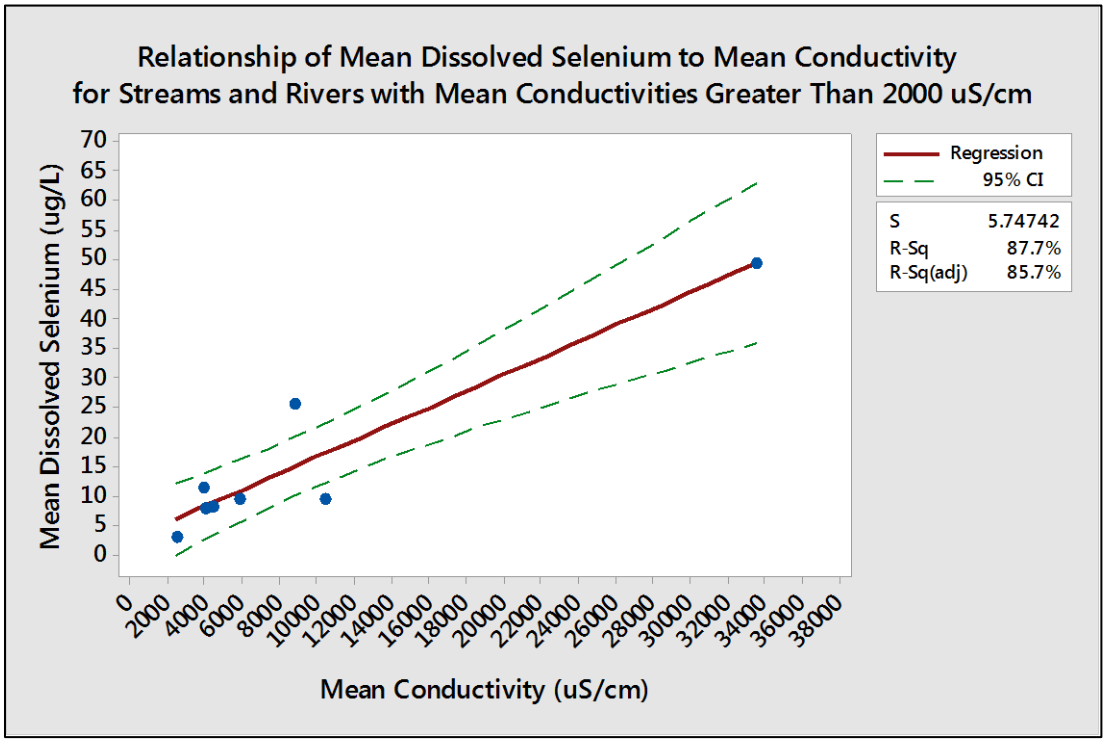

Figure 4. Relationship of Mean Dissolved Selenium to Mean Conductivity for Rivers and Streams with Mean Conductivities Greater Than 2000 µS/cm.

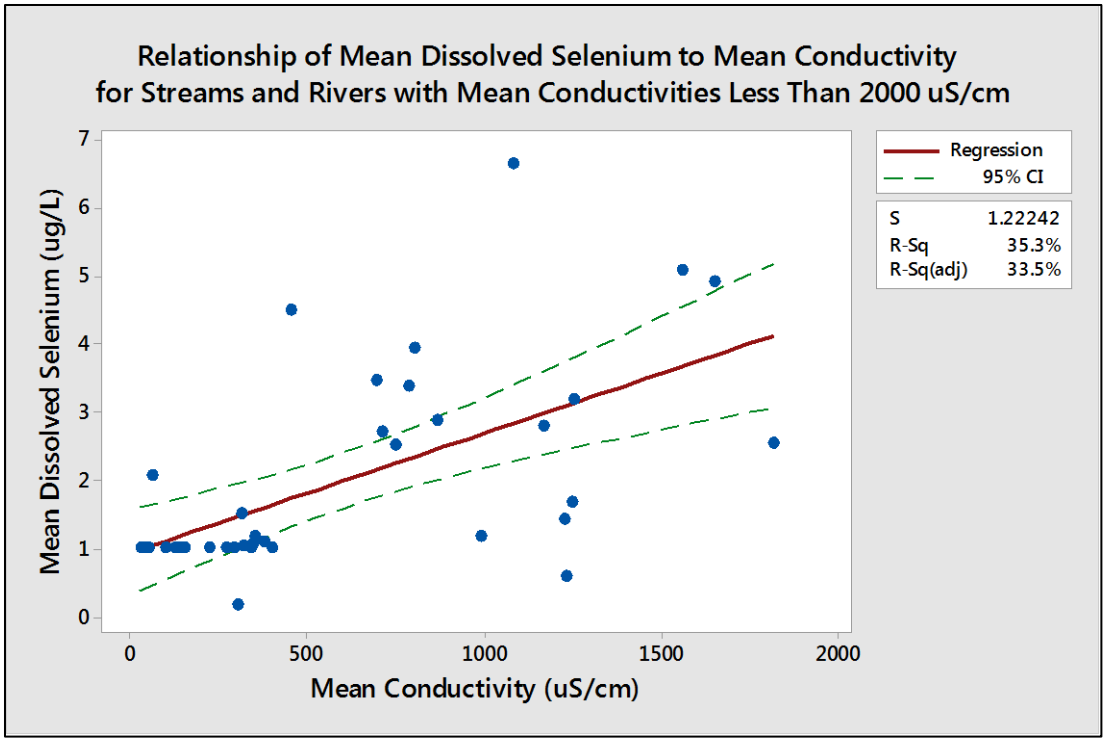

Figure 5. Relationship of Mean Dissolved Selenium to Mean Conductivity for Rivers and Streams with Mean Conductivities Less Than 2000 µS/cm.

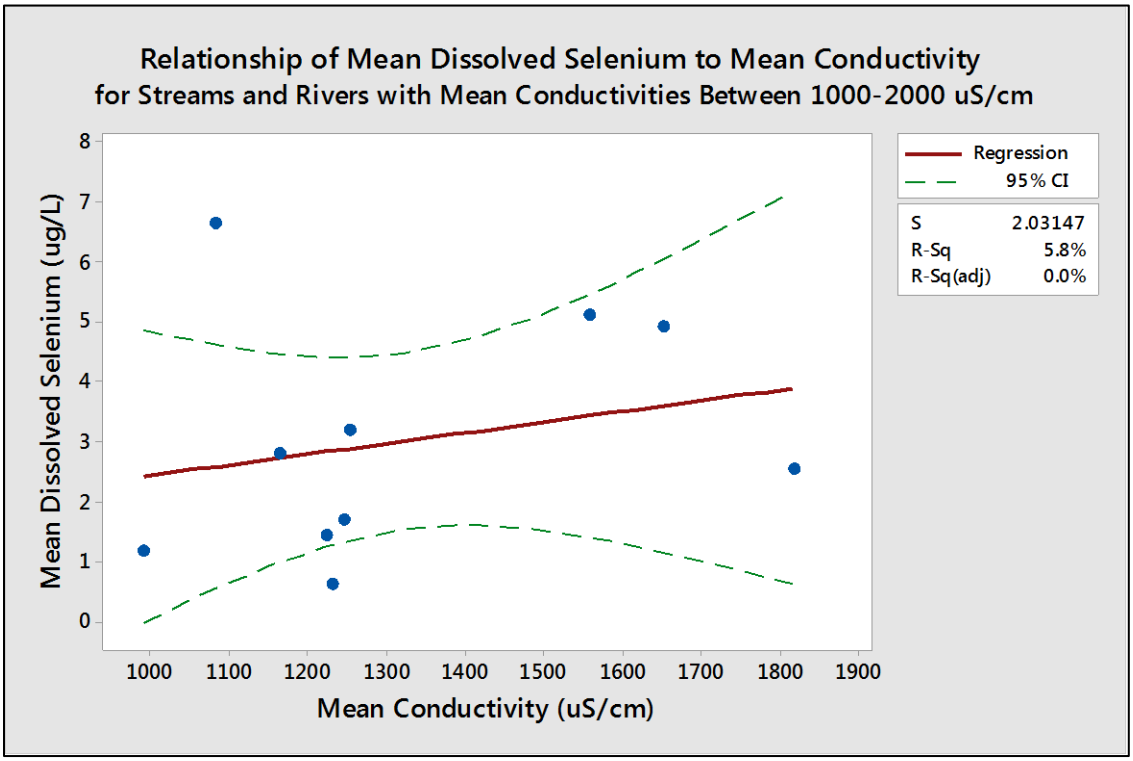

Figure 6. Relationship of Mean Dissolved Selenium to Mean Conductivity for Rivers and Streams with Mean Conductivities Between 1000 and 2000 µS/cm.

Based on this analysis, it was determined that the current chronic selenium criterion of 5 µg/L would remain in effect for certain waterbody segments. These waters are excluded from the current proposed rulemaking (Figure 7). Using a cut-point of 2,000 µS/cm, nine waterbodies (those in blue) are proposed to retain the current chronic selenium criterion of 5 µg/L (Figure 7). Certain waterbodies have only portions excluded, which are notated parenthetically within the graph. The excluded waterbodies include the Cimarron River, the Beaver River from the confluence of Palo Duro Creek downstream to the confluence of Kiowa Creek, the Salt Fork of the Arkansas River, the Washita River above the confluence with Cavalry Creek, the Canadian River above the confluence with Deer Creek, the Red River above Lake Texoma, the North Fork of the Red River, the Salt Fork of the Red River, and the Elm Fork of the Red River. The existing chronic selenium criterion may also be applied to tributaries within the watersheds of the waterbodies listed above upon scientifically defensible demonstration that measurements of specific conductance greater than a mean of 2,500 µS/cm are due to natural sources.

Grounded in both empirical data and certain assumptions about the biological communities in the above listed waters and much of their watersheds, the OWRB believes that the maintenance of a 5 ug/L criterion for selenium is protective of the Fish and Wildlife Propagation beneficial use. Biological collections of both fish and benthic invertebrates from the OWRB (OWRB, 2018) and the Oklahoma Conservation Commission (OCC, 2018) demonstrate that community population dynamics are affected by the occurrence of naturally high salinity in these waters. Generally, both richness and community diversity are adversely affected by higher salinity (OWRB, 2010 and 2013). Food web dynamics are likely disrupted as well. It is the intention of the OWRB to further explore these waterbodies to determine regionally-specific fish tissue and water column criteria for selenium.

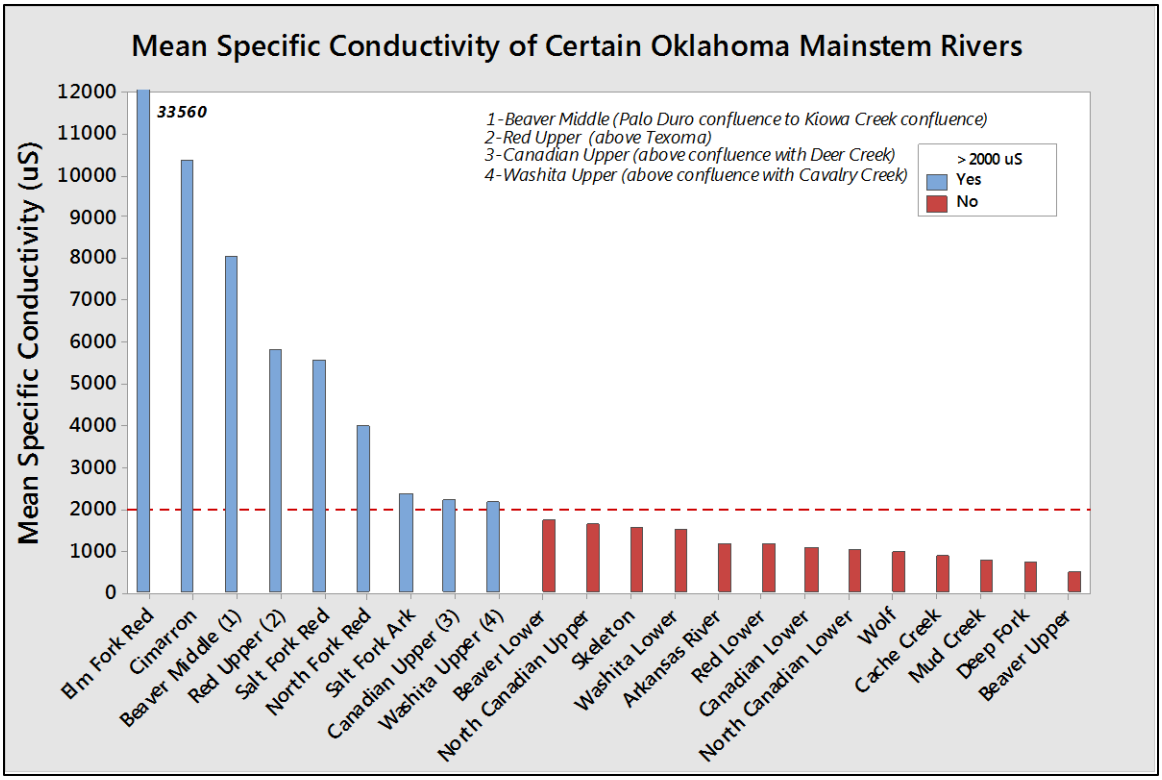

Figure 7. Mean Specific Conductivity of Certain Oklahoma Mainstem Rivers (OWRB, 2018).

Implementation

In order to implement the proposed selenium criterion, revisions are required to OAC 785:46, Oklahoma's WQS Implementation rules (OWRB, 2016). Because the selenium criterion is the first bioaccumulative aquatic life criterion with a fish component, implementation rules need to be developed for both the OPDES permitting process, as well as determination of beneficial use support. Beneficial use support determination is outlined in proposed revisions to Subchapter 15, Oklahoma's Use Support Assessment Protocols (USAP). The new rules provide for the minimum samples required and establishes that if one fish tissue composite sample exceeds the criterion, the Fish and Wildlife Propagation (FWP) beneficial use is not supported. Additionally, rules defining the scope and requirements for fish studies are established. Criteria implementation guidance provided by the USEPA was used to guide staff recommendations (EPA, 2016b and 2016c).

To guide the permitting process, a new section has been added to OAC:785:46-5, which is the subchapter defining implementation of numerical criteria to protect fish and wildlife from toxicity due to conservative substances. The subchapter addresses various implementation requirements for permitting criteria related to the FWP beneficial use, including regulatory flow determination and establishment of reasonable potential. A new section (OAC:785:46-5-10) provides rules for the implementation of multimedia criteria for bioaccumulative pollutants (Appendix A), as they relate the FWP beneficial use. The rule establishes that reasonable potential shall be determined based on the water chemistry criterion element and that a water quality based effluent limit (WQBEL) is also based on water chemistry. However, the fish tissue criterion element may be utilized to confirm the need for a (WQBEL). The rule language also provides for required effluent and fish tissue monitoring if reasonable potential is established or if a WQBEL is required. Monitoring requirements are further established in subsection (b) of OAC:785:46-5-10, including minimum samples within a permitting cycle, as well as reference to OWRB Technical Guidance TRWQ2019-01 and permitting authority rules. Lastly, the rule provides for circumstance under which monitoring requirements may be terminated.

Rules defining the scope and requirements for fish studies are established in a new subchapter, OAC:785:46-14 (Appendix A). The subchapter addresses minimum sampling requirements (section 3), as well as fish study requirements for permits (section 4) and monitoring and assessment (section 5). Minimum requirements provide reference to OWRB Technical Guidance TRWQ2019-01, index period for collections, and characteristics of the composite fish tissue collection, which are in concurrence with nationally and locally recommended methods. An index period of May 15 – October 31 is established to avoid both spawning periods and senescence during over-wintering. During both periods, fat tissue, which stores bioaccumulative pollutants such as selenium, are depleted. Fish tissue studies related to permitting reference technical guidance, as well as minimum reporting and quality assurance requirements. Additionally, the rule establishes the need for a minimum of 3 sample locations below the discharge. Finally, the fish tissue studies related to monitoring and assessment

denote several baselines for assessment. First, only one composite fish tissue sample is required to assess beneficial use support, as the frequency component of the criterion is established as "shall not exceed". The tissue criterion is integrative in nature (over time and space), and the averaging period for exposure is built into the media (i.e., the fish). Second, a beneficial use support decision may be made solely on the application of the water chemistry criterion element, but prior to development of total maximum daily load (TMDL), a fish tissue composite sample must be collected and analyzed to confirm beneficial use impairment.

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Appendix A. Revisions to OAC Title 785, Chapter 46.

785:46-5-10. Implementation of Fish Tissue Criteria for Bioaccumulative Pollutants in Permits

(a) Reasonable Potential

(1) Reasonable potential analysis to determine the need for a water quality based effluent limit shall be based upon the water chemistry criterion element consistent with OAC 785:46-5-3. If the reasonable potential analysis demonstrates the need for a WQBEL, a WQBEL shall be established based upon the water chemistry criterion element. However, the fish tissue criterion element may be utilized to confirm the need for a WQBEL. A fish tissue special study, consistent with OWRB Technical Guidance TRWQ2018-01, shall be required to evaluate the fish tissue criterion element.

(2) To evaluate the fish tissue criterion element a fish tissue special study shall be conducted in accordance with OAC 785:46-14.

(A) If fish tissue data exceed the fish tissue criterion element, a WQBEL shall be required. The WQBEL shall be established based upon the water chemistry criterion element. Effluent and fish tissue monitoring requirements per this subsection shall be included in the permit.

(B) If fish tissue data do not exceed the fish tissue criterion element, a WQBEL is not required; however, effluent and fish tissue monitoring requirements per this subsection shall be included in the permit.

(b) Monitoring Requirements

(1) Fish Tissue Monitoring Requirement

(A) Fish tissue monitoring shall be conducted in accordance with OAC 785:46-14 and OWRB Technical Guidance TRWQ2018-01.

(B) At a minimum, fish tissue monitoring shall be conducted concurrent with permit renewal and at least once within the year 2, 3, or 4 of the permit.

(2) Effluent Monitoring Requirement

(A) At a minimum, effluent monitoring shall be conducted in accordance with permitting authority rules.

(3) Fish tissue and effluent monitoring requirements may be terminated if, for at least 2 permit cycles:

(A) Reasonable potential has not been established per OAC 785:46-5-10(a); and,

(B) No fish tissue collection exceeds the fish tissue criterion.

(C) Discharges shall not cause or contribute to an exceedance of applicable water quality standards or an existing water quality impairment as identified on the 303(d) list contained in the most recently approved Integrated Water Quality Report.

785:46-14. Implementation of Fish Tissue Criteria and Fish Tissue Monitoring to Protect the Fish and Wildlife Propagation Beneficial Use

(a) All fish tissue studies shall be conducted in accordance with OWRB Technical Guidance TRWQ2018-01.

(b) Composite Fish Tissue Samples

(1) Fish collected to implement this sub-section shall be among the preferred fish species in accordance with OWRB Technical Guidance TRWQ2018-01.

(2) Fish collected for a composite fish tissue samples shall be collected from May 15 – October 31, using preferred collection methods in accordance with OWRB Technical Guidance TRWQ2018-01.

(3) Composited fish tissue samples shall be composed individual fish all collected within the same 7 day period.

(4) At a minimum, composite fish tissue samples shall consist of:

(A) Fish all of the same species; and,

(B) At least 3 and no more than 15 individual fish; and,

(C) Individual fish all measuring within 75% of the total length of the largest fish.

(c) Fish tissue special studies for NPDES permits, per OAC 785:46-5-10.

(1) A Monitoring and Reporting Plan shall be developed in accordance with OWRB Technical Guidance TRWQ2018-01, and shall include the following sections:

(A) Title page, introduction, background information, purpose and scope of study

(B) Monitoring section that describes schedule of events, site selection rationale and locations, target species, target contaminants, and field collection methods.

(C) An analysis and reporting section that describes sample preparation methods, laboratory analysis methods, and reporting.

(D) A Quality Assurance Project Plan that meets the most recent requirements for United States Environmental Protection Agency Quality Assurance Project Plans.

(2) Additional Minimum Requirements for Fish Tissue Special Studies Conducted in Accordance with OAC 785:46-5-10, shall include:

(A) Analysis of at least three composite fish tissue samples collected at different locations within receiving waterbody, as designated in OAC 785:45, Appendix A.

(B) All composite fish tissue samples shall be collected downstream of the discharge.

(d) Fish tissue studies for monitoring and assessment.

(1) At a minimum, all studies shall follow procedures and protocols as outlined in OAC 785:46-15.

(2) All studies shall be performed under a Quality Assurance Project Plan that meets the most recent requirements for United States Environmental Protection Agency Quality Assurance Project Plans.

(3) Use of composite fish tissue samples for assessment of beneficial use support for bioaccumulative pollutants with fish tissue criteria.

(A) Only one composite fish tissue sample shall be required to assess beneficial use support.

(B) Fish tissue data shall not be required to determine beneficial use support status for Clean Water Act Section 303(d) reporting.

(C) Prior to development of a Total Maximum Daily Load (TMDL), a fish tissue study must be completed to confirm the beneficial use impairment, in the event that the impairment decision was based solely on water chemistry data.