UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TX 75202-2733

JAN 09 2012

Steve Drown
Manager, Water Division
Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, AR 72118-5317

RE: Site-specific Water Quality Standards Revisions Associated with UMETCO, in Garland County, Arkansas

Dear Mr. Drown:

Thank you for your recent letter, dated October 12, 2011, requesting review and approval of site-specific water quality standards revisions to Regulation No. 2, *Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas* for Wilson Creek in the Ouachita Mountains ecoregion of Arkansas. This stream is also the receiving waterbody for a discharge from a reclaimed mining facility operated by UMETCO, in Garland County, Arkansas. Your letter included a request for U.S. Environmental Protection Agency (EPA) approval of the removal of site-specific criteria for chloride, sulfate, and total dissolved solids (TDS) in the above mentioned stream.

We have completed our review of your request for approval of these site-specific water quality standards revisions. Based upon the supporting documentation, the site-specific criteria have been demonstrated as appropriate to protect the designated uses in Wilson Creek as well as the designated uses downstream in Lake Catherine. The approval of the site-specific criteria revisions are subject to the results of consultation under section 7(a)(2) of the Endangered Species Act (ESA). By approving the site-specific criteria "subject to the results of consultation under section 7(a)(2) of the Endangered Species Act," EPA retains the full range of options available under section 303(c) for ensuring that water quality standards are environmentally protective. EPA retains the discretion to revise its approval decision of these criteria if the consultation identifies deficiencies in the water quality standards that require remedial action

A detailed explanation as well as the rationale for EPA's approval decision is provided in the enclosed record of decision. I would like to acknowledge the efforts of the Pollution Control and Ecology Commission, and particularly ADEQ, in the development of these revised standards. We look forward to working with you on future efforts. If you have any questions or concerns, please contact me at (214) 665-7101, or have your staff contact Matt Hubner at (214) 665-9736.

Sincerely yours,

WK Honker

William K. Honker
Acting Director
Water Quality Protection Division

Enclosure

cc: Sarah Clem, Branch Manager, Water Division, ADEQ
Mary Barnett, Ecologist, Water Division, ADEQ

TECHNICAL SUPPORT DOCUMENT:
EPA APPROVAL OF SITE-SPECIFIC REVISIONS TO THE ARKANSAS WATER QUALITY STANDARDS

Site-specific Minerals Criteria for
Wilson Creek
Garland County, Arkansas

U.S. Environmental Protection Agency – Region 6

December 2011

TECHNICAL SUPPORT DOCUMENT: EPA APPROVAL OF SITE-SPECIFIC REVISIONS TO THE ARKANSAS WATER QUALITY STANDARDS

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I. INTRODUCTION

Background

As described in §303(c) of the Clean Water Act (CWA) and in the standards regulation within the Code of Federal Regulations (CFR) at 40 CFR §131.20, states and authorized tribes have primary responsibility to develop and adopt water quality standards to protect their waters. State and tribal water quality standards consist of three primary components: beneficial uses, criteria to support those uses, and an antidegradation policy. In addition, CWA §303(c)(1) and 40 CFR §131.20 require states to hold public hearings at least once every three years to review and, as appropriate, modify and adopt standards. Under 40 CFR §131.21, EPA reviews new and revised surface water quality standards that have been adopted by states and authorized tribes. Authority to approve or disapprove new and/or revised standards submitted to EPA for review has been delegated to the Water Quality Protection Division Director in Region 6. Tribal or state water quality standards are not considered effective under the CWA until approved by EPA.[1]

The purpose of this technical support document is to provide the basis for the Environmental Protection Agency's (EPA) approval of water quality standards revisions to Regulation No. 2: *Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas* adopted by the Arkansas Pollution Control and Ecology Commission (APC&EC) in Minute Order 10-12 and further described in the subsection below titled "Summary of Revised Provisions."

Chronology of Events

June 14, 2010	A third party, UMETCO, filed a petition with the APC&EC to amend Regulation No. 2.
June 25, 2010	The APC&EC initiated the rulemaking proceeding via Minute Order No. 10-23.

[1] "Alaska rule" [*Federal Register*: April 27, 2000 (Volume 65, Number 82)]

June 30, 2010 & July 1, 2010	Public notice of the proposed rule-making was published.
August 16, 2010	Public hearing on the proposed rule-making was held in Hot Springs, Arkansas.
August 26, 2010	Due to the volume of public comments at the hearing, public notice extending the comment period was published
September 20, 2010	Public comment period ended on the proposed changes to Regulation No. 2.
August 26, 2011	Teresa Marks, Director, Arkansas Department of Environmental Quality (ADEQ), signed Minute Order 11-24 adopting changes to Regulation No. 2.
October 14, 2011	Miguel I. Flores, Director, Water Quality Protection Division, EPA Region 6, received letter from Steve Drown, Water Division Chief, ADEQ, requesting EPA approval of the adopted revisions and transmitting the water quality standards submission package.

Summary of Revised Provisions

By letter dated October 12, 2011, from Steve Drown, ADEQ, to Miguel Flores, EPA Region 6, ADEQ requested EPA approval of site-specific water quality standards revisions to Regulation No. 2, *Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas* for Wilson Creek in the Ouachita Mountains ecoregion of Arkansas. Wilson Creek is the receiving waterbody for discharges from a reclaimed vanadium mining operation owned by UMETCO in Garland County, Arkansas.

The letter included a request for EPA approval of site-specific criteria for chloride, sulfate, and total dissolved solids (TDS) for the three waterbodies. A request for domestic water supply use removal was not included as proposed values are at or below the drinking water criteria. This record of decision applies to the site-specific water quality criteria revisions for the waterbodies identified above, and are further outlined in Table 1 below.

II. REVISED PROVISIONS EPA IS APPROVING

In accordance with the requirements found in Regulation No. 2.306 of the Arkansas water quality standards, UMETCO contracted with FTN Associates, Ltd., to complete a use attainability analysis (UAA) of Wilson Creek and associated waterbodies. The purpose of the UAA was to provide scientific justification to support revised site-specific water quality criteria for chloride, sulfate, and TDS for these waterbodies.

Table 1. Site-specific water quality criteria revisions for Wilson Creek submitted by ADEQ to EPA for review and approval (Concentrations in mg/L).

Reach Description	Current Criteria			Proposed Criteria		
	Chloride	Sulfate	TDS	Chloride	Sulfate	TDS
Wilson Creek	15	20	142	56	250*	500*

*Proposed values at drinking water use threshold

Domestic Water Supply Use Removal

As noted above, following ADEQ's recommendation, the proposed removal of the domestic water supply designated use was struck from the final rulemaking. This designated use is associated with chloride, sulfate, and total dissolved solids (TDS) criteria of 250 mg/L, 250 mg/L, and 500 mg/L, respectively. The proposed criteria values for the Wilson Creek, as seen in Table 1, are numbered at or below the use thresholds.

Site-specific Water Quality Criteria for Chloride, Sulfate, and TDS

Criteria Derivation

Revised water quality criteria for chloride, sulfate, and TDS were adopted in the Wilson Creek watershed by the APC&EC on August 26, 2011. The derivation of these site-specific criteria is summarized below.

UMETCO is not planning to increase loadings of minerals in effluent from outfall *001*. Proposed criteria for chloride, sulfate and TDS resulting from this study were originally derived by calculating the 95th percentile of instream data collected from the Wilson Creek outfall *001* and two downstream sites monitored from 2007 to 2009. Following concerns raised during the 2010 open comment period, ADEQ requested that the proposed criteria be modified to protect the drinking water use of downstream Lake Catherine. Therefore, sulfate was reduced to 250 mg/L and TDS to 500 mg/L to meet the drinking water use in Wilson Creek. Chloride remained at 56 mg/L, well below the drinking water use maximum threshold of 250 mg/L.

The reports justified the protection of downstream Lake Catherine by pointing out that current loading of minerals from outfall *001* will remain unchanged. Lake Catherine is currently not listed as impaired for minerals.

Use Support Justification

The designated use most sensitive to minerals is the Ouachita Mountains ecoregion aquatic life use for Wilson Creek. According to the Arkansas water quality standards, the fisheries use "provides for the protection and propagation of fish, shellfish and other forms of aquatic life."

The UAA study for Wilson Creek utilizes site-specific information and a weight-of-evidence approach to provide the necessary scientific justification that the site-specific water quality criteria for chloride, sulfate, and TDS will support the designated aquatic life use for Wilson Creek and Lake Catherine at the confluence with Wilson Creek. Specifically, the 2004 UAA study report[2] and subsequent 2009[3] and 2011[4] addenda provide four primary lines of evidence to support the revised criteria for chloride, sulfate, and TDS.

First, the report provides instream sampling for physical parameters as outlined by the 2000 Arkansas Continuing Planning Process (CPP). Data collected since 2004 at the sampling sites in Wilson Creek shows the present levels of minerals as a result of UMETCO's reclamation activities, upstream and downstream of the outfall *001*. As mentioned above, sampling data was utilized to initially derive the proposed concentrations for the rulemaking; however, following concerns raised by the public and downstream water districts, ADEQ suggested that more conservative numbers be adopted to protect the drinking water use for Wilson Creek, ensuring protection of downstream drinking water uses. Adopting more stringent criteria will also better ensure protection of aquatic life.

Second, in 2011, FTN, on behalf of UMETCO, submitted a detailed evaluation of the ionic makeup of UMETCO's effluent in response to specific concerns raised by EPA during the 2010 open comment period (FTN 2011). Though this data comprises only a single snapshot of the discharge at one point in time, it does provide greater insight into the mineral constituents in UMETCO's discharge. As discussed in Appendix A of this document, the specific ratios of ions can indicate the potential toxicity that such a solution would have on sensitive species. The presented information and analysis indicate that UMETCO's discharge would not likely affect sensitive aquatic species in Wilson Creek.

Third, toxicity testing is beneficial to determine if the assumptions made by analyzing the ionic composition, as discussed above, are correct. Initially, the 2004 study did not focus on toxicity. In the subsequent 2009 addendum, the study provided a brief analysis of

[2] Waste Engineering, Inc. 2004. Wilson Creek Minerals Water Quality Standards Evaluation.
[3] FTN, Inc. 2009. Addendum to the December 2004 Wilson Creek Minerals Water Quality Standards Evaluation. UMETCO Minerals Corporation Former Mine Site Garland County, Arkansas
[4] FTN, Inc. 2011. Letter Submitting Additional Information in Response to EPA Comments

sodium chloride toxicity to the water flea (*Ceriodaphnia dubia*). The results indicated that proposed chloride concentrations were not likely detrimental to aquatic life at levels presently observed in Wilson Creek. The addendum also included a toxicity analysis of the nearby low pH seeps. The analysis of the seep samples showed acute toxicity to test organisms; however, it was determined that the toxicity is not likely a result of minerals, and the seeps do not directly discharge to Wilson Creek. In the open comment period, EPA voiced concern that the results in the addendum did not clearly separate minerals from the observed toxicity in the seeps, and that the sodium chloride toxicity testing alone did not evaluate the potential effects of ion interaction that would be present in the effluent. As a result, UMETCO submitted a final addendum (FTN 2011) that provided biomonitoring whole effluent toxicity (WET) testing results for outfall *001* in addition to spiked laboratory tests conducted at two independent laboratories. The routine monitoring WET results indicated no acute toxicity; however, some sublethal reproductive failures were noted noted. Because WET testing evaluates the effluent as a whole, it is difficult to determine if one set of contaminants are responsible for any observed failures. Therefore, laboratory testing was conducted to specifically evaluate the effects of minerals concentrations in their real-world ratios on test organisms. Testing was conducted at two independent laboratories to provide comparative results. The tests concluded that minerals concentrations far greater than those currently in the UMETCO discharge would be necessary to cause toxicity to the most sensitive test organism (*C. dubia*). These results corroborate many of the conclusions made in the 2009 and 2011 addenda.

Fourth, a comparison of the site-specific water quality monitoring data in combination with fish and benthic macroinvertebrate monitoring data indicate that existing ambient chloride, sulfate, and TDS concentrations do not limit the benthic communities in these waterbodies. Comparisons between the upstream reference and downstream sites in both macroinvertebrate and fish investigations indicate that there are differences in diversity at some of the downstream stations in the vicinity of the reclaimed mine. However, when the data is coupled with the habitat profiles, it is apparent that the disparity in habitat quality is the likely reason for such differences. It is also likely that past mining activities have resulted in limited habitat in the vicinity of the mine, and EPA cannot rule out possible contaminant influences resulting from the low pH seeps from the information presented in these studies. Despite these issues, both macroinvertebrate and fish studies support the existence of functioning aquatic communities downstream of the discharge. Key ecoregion species were identified at the reference site upstream and downstream of outfall *001* sample locations.

Based upon the above supporting site-specific documentation and the summary of available toxicity information for acute and chronic lethality effects of chloride, sulfate, and TDS provided in Appendix A of this record of decision, EPA approves the site-specific chloride, sulfate, and TDS criteria identified in Table 1 for Wilson Creek.

Additional Concerns

EPA recognizes the numerous and invaluable comments brought forth during the open comment period. We have noted that a majority of the concerns discussed in the public comment period surround issues larger in scope than increased minerals in Wilson Creek. Though we approve the site-specific minerals criteria presented in this rulemaking, we remain concerned and vigilant regarding the complaints brought forth by the citizens of Arkansas. The following are especially of concern:

- The unidentified acute toxicity observed in the low pH seeps as discussed in the 2009 addendum points to a possible source for some of the reproduction failures observed in routine WET testing. The 2009 report indicates metals as a possible candidate.
- The possibility of an unpermitted discharge to Indian Spring Creek.
- Non-point source runoff from reclamation activities.

We strongly encourage that the State and UMETCO continue work towards addressing these concerns in addition to continuing efforts to increase communication with the surrounding communities on such efforts. Resolution of the issues above will ensure compliance with the goals of the Clean Water Act.

APPENDIX A:
SUMMARY OF AVAILABLE TOXICITY INFORMATION FOR ACUTE AND CHRONIC LETHALITY EFFECTS OF CHLORIDE, SULFATE, AND TOTAL DISSOLVED SOLIDS (TDS)

BACKGROUND

EPA has published CWA §304(a) recommendations for chloride,[1] but has not developed aquatic life criteria for sulfate and TDS. The recommended chloride criteria for protection of aquatic life are 860 mg/L for acute toxicity and 230 mg/L for chronic toxicity. These values were derived following the Agency's procedures.[2] In total, EPA's criteria document for chloride includes acute data for twelve freshwater species. Data from numerous invertebrates were included in the calculation of EPA's recommended criteria including the following organisms: cladocerans, snail, isopod, midges, caddisfly, and mosquito larva. The most sensitive organism, based on species mean acute values, was *Daphnia magna*. The LC_{50} concentration (lethal concentration for 50% of the test organisms in a set period of time) associated with this ranking was 1470 mg/L of sodium chloride. EPA's criteria document also includes three chronic tests, in which *D. magna* was the most sensitive organism with a chronic LC_{50} of 372 mg/l for tests with sodium chloride.

For the purposes of this summary, EPA also considered available toxicity information for chloride, sulfate and TDS. As discussed above, the Agency has published an aquatic life criteria document for chloride, which includes some toxicity data. A study funded by the Gas Research Institute (GRI) evaluated toxicity of saline waters to freshwater organisms.[3] This study evaluated toxicity of four major cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and three major anions (HCO_3^-, SO_4^- and Cl^-) to the fathead minnow (*Pimphales promelas*) and two invertebrates (*Ceriodaphnia dubia* and *D. magna*). The relative toxicity to the fathead minnow and *C. dubia*, in order of decreasing toxicity was:

$$K^{+} > HCO_3^{-} > Mg^{++} > Cl^{-} > SO_4^{-}$$

The toxicity to *D. magna* followed a similar pattern, with bicarbonate and magnesium reversed. Sodium and calcium were not found to be toxic to the test species at the concentrations tested (range of 14 mg/L to 3960 mg/L).

The GRI study developed equations to predict the survival of the test organisms at concentrations of the major ions. The results of these equations indicate that mortality for the fathead minnow and the two invertebrate species does not occur until chloride concentrations are over 1000

[1] U.S. Environmental Protection Agency. 1988. *Ambient Water Quality Criteria for Chloride.* Office of Water Regulations and Standards, Washington D.C.
[2] U.S. Environmental Protection Agency. 1985b. *Guidelines for Deriving National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses.* Office of Water Regulations and Standards, Washington, DC. 45 F.R. 79341, November 28, 1980, as amended at 50 F.R. 30784, July 29, 1985.
[3] Gas Research Institute. 1992. *Development of a Salinity/Toxicity Relationship to Predict Acute Toxicity of Saline Waters to Freshwater Organisms.* Prepared by David R. Mount, ENSR Consulting and Engineering and David D. Gully, University of Wyoming.

mg/L. Tests used in the GRI study indicate that sulfate is less toxic than chloride and that mortality does not occur until concentrations are over 2000 mg/L.

CHLORIDE

In addition to the above information, a search of EPA's ECOTOX database[4] was conducted for toxicity of sodium chloride and calcium chloride to fish species. The ECOTOX database included 153 freshwater acute (test duration less than or equal to 96 hours) LC_{50} results and two freshwater chronic (test duration greater than 96 hours) LC_{50} results for sodium chloride and calcium chloride for the following eleven freshwater species: American eel, goldfish, Crucian carp, western mosquitofish, eastern mosquitofish, bluegill, striped bass, rainbow trout, medaka-high eyes, fathead minnow, and sailfin mollies (see Tables 1 and 2 below). Sodium chloride and calcium chloride acute LC_{50} results for these freshwater fish species ranged from 1000 mg/L to 21,450 mg/L. The two chronic LC_{50} concentrations were for the goldfish and blue gill and were equal to 4324 mg/L and 10,650 mg/L, respectively.

EPA also conducted a search of EPA's ECOTOX database for effects of sodium chloride and calcium chloride to invertebrate species. The ECOTOX database included 111 freshwater acute (test duration less than or equal to 96 hours) LC_{50} results and 27 freshwater chronic (test duration greater than 96 hours) LC_{50} results for sodium chloride and calcium chloride for several species included within the following general groups: insects, crustaceans, worms, and molluscs (see Tables 3 and 4 below). Sodium chloride and calcium chloride acute LC_{50} results ranged from 649 mg/L to 44,425 mg/L. With the exception of two sodium chloride chronic LC_{50} concentrations for *C. dubia* of 280 mg/L and 330 mg/L, chronic LC_{50} concentrations for sodium chloride ranged from 910 mg/L to 7500 mg/L. While the two chronic LC_{50} concentrations for *C. dubia* were relatively low, fourteen additional sodium chloride chronic LC_{50} concentrations for *C. dubia* ranged from 910 mg/L to 2000 mg/L.

Table 1. Acute freshwater LC_{50} values for sodium chloride and calcium chloride for fish species from EPA's ECOTOX database.

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Anguilla rostrata*	American eel	17880	593
Sodium chloride (NaCl)	*Anguilla rostrata*	American eel	21450	592
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	6170	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	6180	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	6800	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	6800	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	6800	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	6950	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	6950	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7000	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7000	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7050	2145

[4] U.S. Environmental Protection Agency. 2002. ECOTOX User Guide: ECOTOXicology Database System. Version 2.0. Available: http:/www.epa.gov/ecotox/.

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7050	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7150	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7200	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7200	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7200	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7300	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7341	5230
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7350	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7388	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7400	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7400	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7550	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7600	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7650	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7850	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7900	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7900	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7900	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7950	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7950	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	7950	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	8050	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	8200	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	8350	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	8400	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	8500	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	8530	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	8800	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	8800	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	9270	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	9600	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	9750	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	9800	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	9850	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	9900	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	9950	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	9980	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	10000	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	10100	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	10200	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	10270	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	10400	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	10450	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	11050	2145
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	11050	2145
Sodium chloride (NaCl)	*Carassius carassius*	Crucian carp	13750	915
Sodium chloride (NaCl)	*Gambusia affinis*	Western mosquitofish	17550	508
Sodium chloride (NaCl)	*Gambusia affinis*	Western mosquitofish	18100	508
Sodium chloride (NaCl)	*Gambusia affinis*	Western mosquitofish	18100	508

Enclosure

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Calcium chloride	*Gambusia affinis*	Western mosquitofish	13400	508
Calcium chloride	*Gambusia affinis*	Western mosquitofish	13400	508
Calcium chloride	*Gambusia affinis*	Western mosquitofish	13400	508
Sodium chloride (NaCl)	*Gambusia holbrooki*	Eastern mosquitofish	11540	6176
Sodium chloride (NaCl)	*Lepomis macrochirus*	Bluegill	1294.6	8037
Sodium chloride (NaCl)	*Lepomis macrochirus*	Bluegill	5840	45826
Sodium chloride (NaCl)	*Lepomis macrochirus*	Bluegill	12946	5683
Sodium chloride (NaCl)	*Lepomis macrochirus*	Bluegill	12946	949
Sodium chloride (NaCl)	*Lepomis macrochirus*	Bluegill	14125	915
Calcium chloride	*Lepomis macrochirus*	Bluegill	8350	915
Calcium chloride	*Lepomis macrochirus*	Bluegill	9500	930
Calcium chloride	*Lepomis macrochirus*	Bluegill	9500	930
Calcium chloride	*Lepomis macrochirus*	Bluegill	10650	8037
Calcium chloride	*Lepomis macrochirus*	Bluegill	10650	5683
Calcium chloride	*Lepomis macrochirus*	Bluegill	11300	930
Sodium chloride (NaCl)	*Morone saxatilis*	Striped bass	1000	2012
Sodium chloride (NaCl)	*Morone saxatilis*	Striped bass	1000	2012
Sodium chloride (NaCl)	*Morone saxatilis*	Striped bass	1500	2012
Sodium chloride (NaCl)	*Morone saxatilis*	Striped bass	3000	2012
Sodium chloride (NaCl)	*Morone saxatilis*	Striped bass	5000	2012
Sodium chloride (NaCl)	*Morone saxatilis*	Striped bass	5000	2012
Sodium chloride (NaCl)	*Morone saxatilis*	Striped bass	5000	2012
Sodium chloride (NaCl)	*Morone saxatilis*	Striped bass	7000	2012
Sodium chloride (NaCl)	*Oncorhynchus mykiss*	Rainbow trout,donaldson trout	6094	56474
Sodium chloride (NaCl)	*Oncorhynchus mykiss*	Rainbow trout,donaldson trout	6094	58703
Sodium chloride (NaCl)	*Oncorhynchus mykiss*	Rainbow trout,donaldson trout	7461	56474
Sodium chloride (NaCl)	*Oncorhynchus mykiss*	Rainbow trout,donaldson trout	7461	58703
Calcium chloride	*Oryzias latipes*	Medaka, high-eyes	1000	12497
Calcium chloride	*Oryzias latipes*	Medaka, high-eyes	1000	12497
Calcium chloride	*Oryzias latipes*	Medaka, high-eyes	1000	12497
Calcium chloride	*Oryzias latipes*	Medaka, high-eyes	1000	12497
Calcium chloride	*Oryzias latipes*	Medaka, high-eyes	1000	12497
Calcium chloride	*Oryzias latipes*	Medaka, high-eyes	1000	12497
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	6390	18272
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	6510	18272
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	6570	45826
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7050	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7050	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7050	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7100	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7100	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7100	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7200	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7200	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7200	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7200	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7300	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7400	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7400	2145

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7400	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7400	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7400	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7450	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7500	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7500	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7500	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7500	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7550	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7600	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7650	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7650	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7650	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7650	5230
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7650	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7650	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7700	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7750	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7750	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7800	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7800	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7950	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	7950	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8100	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8150	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8150	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8200	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8200	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8280	18272
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8300	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8300	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8300	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8300	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8400	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8700	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8800	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	8800	2145
Sodium chloride (NaCl)	*Pimephales promelas*	Fathead minnow	9000	2145
Calcium chloride	*Pimephales promelas*	Fathead minnow	4630	18272
Calcium chloride	*Pimephales promelas*	Fathead minnow	6560	18272
Calcium chloride	*Pimephales promelas*	Fathead minnow	6660	18272
Sodium chloride (NaCl)	*Poecilia latipinna*	Sailfin molly	16595	915
Sodium chloride (NaCl)	*Poecilia latipinna*	Sailfin molly	18735	915

Table 2. Chronic freshwater LC_{50} values for sodium chloride and calcium chloride for fish species from EPA's ECOTOX database.

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Carassius auratus*	Goldfish	4324	10487
Calcium chloride	*Lepomis macrochirus*	Bluegill	10650	949

Table 3. Acute freshwater LC_{50} values for sodium chloride and calcium chloride for invertebrate species from EPA's ECOTOX database.

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Argia sp.*	Damselfly	32000	2050
Sodium chloride (NaCl)	*Argia sp.*	Damselfly	32000	2050
Sodium chloride (NaCl)	*Argia sp.*	Damselfly	26000	2050
Sodium chloride (NaCl)	*Argia sp.*	Damselfly	32000	2050
Sodium chloride (NaCl)	*Argia sp.*	Damselfly	23000	2050
Sodium chloride (NaCl)	*Argia sp.*	Damselfly	24000	2050
Sodium chloride (NaCl)	*Argia sp.*	Damselfly	26000	2050
Sodium chloride (NaCl)	*Argia sp.*	Damselfly	24000	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	5600	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	10000	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	5600	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	10000	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	5100	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	8250	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	5100	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	8250	2050
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	16439	19999
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	17008	19999
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	23817	19999
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	25064	19999
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	25190	19999
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	25786	19999
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	14899	19999
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	22457	19999
Sodium chloride (NaCl)	*Caenorhabditis elegans*	Nematode	24829	19999
Calcium chloride	*Caenorhabditis elegans*	Nematode	44425	18605
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	3380	18272
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1960	18272
Calcium chloride	*Ceriodaphnia dubia*	Water flea	1830	18272
Calcium chloride	*Ceriodaphnia dubia*	Water flea	2260	18272
Sodium chloride (NaCl)	*Cricotopus trifasciatus*	Midge	6221	6244
Sodium chloride (NaCl)	*Culex sp.*	Mosquito	10500	915
Sodium chloride (NaCl)	*Culex sp.*	Mosquito	10200	915
Calcium chloride	*Daphnia hyalina*	Water flea	3000	5339
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	3412	915
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	3412	2465

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	6380	18272
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	6447	915
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	3310	915
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	3318	2465
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	4745	13712
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	4770	18272
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	5020	14713
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	5600	14713
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	5600	14713
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	6027	14713
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	6027	14713
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	5874	915
Sodium chloride (NaCl)	*Daphnia magna*	Water flea	3114	915
Calcium chloride	*Daphnia magna*	Water flea	649	915
Calcium chloride	*Daphnia magna*	Water flea	759	915
Calcium chloride	*Daphnia magna*	Water flea	759	2465
Calcium chloride	*Daphnia magna*	Water flea	759	915
Calcium chloride	*Daphnia magna*	Water flea	1838	915
Calcium chloride	*Daphnia magna*	Water flea	1838	2465
Calcium chloride	*Daphnia magna*	Water flea	2770	18272
Calcium chloride	*Daphnia magna*	Water flea	3005	915
Calcium chloride	*Daphnia magna*	Water flea	3250	18272
Calcium chloride	*Daphnia magna*	Water flea	3526	915
Sodium chloride (NaCl)	*Daphnia pulex*	Water flea	1470	45826
Sodium chloride (NaCl)	*Daphnia pulex*	Water flea	3050	45826
Sodium chloride (NaCl)	*Erpobdella punctata*	Red leech	10000	2050
Sodium chloride (NaCl)	*Erpobdella punctata*	Red leech	7500	2050
Sodium chloride (NaCl)	*Erpobdella punctata*	Red leech	7500	2050
Sodium chloride (NaCl)	*Erpobdella punctata*	Red leech	7500	2050
Sodium chloride (NaCl)	*Gyraulus circumstriatus*	Flatly coiled gyraulus	10000	2050
Sodium chloride (NaCl)	*Gyraulus circumstriatus*	Flatly coiled gyraulus	10000	2050
Sodium chloride (NaCl)	*Gyraulus circumstriatus*	Flatly coiled gyraulus	3700	2050
Sodium chloride (NaCl)	*Gyraulus circumstriatus*	Flatly coiled gyraulus	3200	2050
Sodium chloride (NaCl)	*Helisoma campanulatum*	Ramshorn snail	10000	2050
Sodium chloride (NaCl)	*Helisoma campanulatum*	Ramshorn snail	7500	2050
Sodium chloride (NaCl)	*Helisoma campanulatum*	Ramshorn snail	6150	2050
Sodium chloride (NaCl)	*Helisoma campanulatum*	Ramshorn snail	6150	2050
Sodium chloride (NaCl)	*Hydroptila angusta*	Caddisfly	6621	6244
Sodium chloride (NaCl)	*Limnodrilus hoffmeisteri*	Tubificid worm, Oligochaete	7500	2050
Sodium chloride (NaCl)	*Limnodrilus hoffmeisteri*	Tubificid worm, Oligochaete	6950	2050
Sodium chloride (NaCl)	*Limnodrilus hoffmeisteri*	Tubificid worm, Oligochaete	6800	2050
Sodium chloride (NaCl)	*Limnodrilus hoffmeisteri*	Tubificid worm, Oligochaete	6200	2050
Sodium chloride (NaCl)	*Lirceus fontinalis*	Aquatic sowbug	2970	45826
Sodium chloride (NaCl)	*Lymnaea sp.*	Pond snail	3412	915

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Lymnaea sp.*	Pond snail	3388	915
Calcium chloride	*Lymnaea sp.*	Pond snail	2573	915
Calcium chloride	*Lymnaea sp.*	Pond snail	3094	915
Calcium chloride	*Lymnaea sp.*	Pond snail	3308	915
Calcium chloride	*Lymnaea sp.*	Pond snail	4485	915
Sodium chloride (NaCl)	*Nais variabilis*	Oligochaete	2569	6244
Sodium chloride (NaCl)	*Physa gyrina*	Pouch snail	2540	45826
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	4200	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	4800	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	5600	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	7500	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	3700	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	4250	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	5600	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	6950	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	3500	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	4250	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	5600	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	6200	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	3500	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	4100	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	5100	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	6200	2050
Sodium chloride (NaCl)	*Sphaerium sp.*	Orb cockle, fingernail clam	2250	2050
Sodium chloride (NaCl)	*Sphaerium sp.*	Orb cockle, fingernail clam	2400	2050
Sodium chloride (NaCl)	*Sphaerium sp.*	Orb cockle, fingernail clam	1550	2050
Sodium chloride (NaCl)	*Sphaerium sp.*	Orb cockle, fingernail clam	1950	2050
Sodium chloride (NaCl)	*Sphaerium sp.*	Orb cockle, fingernail clam	1250	2050
Sodium chloride (NaCl)	*Sphaerium sp.*	Orb cockle, fingernail clam	1250	2050
Sodium chloride (NaCl)	*Sphaerium sp.*	Orb cockle, fingernail clam	1100	2050
Sodium chloride (NaCl)	*Sphaerium sp.*	Orb cockle, fingernail clam	1150	2050

Table 4. Chronic freshwater LC_{50} values for sodium chloride for invertebrate species from EPA's ECOTOX database.

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	7200	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	6800	2050
Sodium chloride (NaCl)	*Asellus communis*	Aquatic sowbug	6150	2050
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	280	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	330	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	910	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1170	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1430	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1640	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1710	11152

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1740	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1830	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1830	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1830	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1940	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1940	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1940	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	1940	11152
Sodium chloride (NaCl)	*Ceriodaphnia dubia*	Water flea	2000	45168
Sodium chloride (NaCl)	*Erpobdella punctata*	Red leech	7500	2050
Sodium chloride (NaCl)	*Gyraulus circumstriatus*	Flatly coiled gyraulus	3200	2050
Sodium chloride (NaCl)	*Helisoma campanulatum*	Ramshorn snail	6150	2050
Sodium chloride (NaCl)	*Limnodrilus hoffmeisteri*	Tubificid worm, Oligochaete	6200	2050
Sodium chloride (NaCl)	*Limnodrilus hoffmeisteri*	Tubificid worm, Oligochaete	5800	2050
Sodium chloride (NaCl)	*Limnodrilus hoffmeisteri*	Tubificid worm, Oligochaete	5800	2050
Sodium chloride (NaCl)	*Limnodrilus hoffmeisteri*	Tubificid worm, Oligochaete	5800	2050
Sodium chloride (NaCl)	*Physa heterostropha*	Pond snail, pneumonate snail	5100	2050

SULFATE

A search of EPA's ECOTOX database was also conducted for toxicity of sodium sulfate and calcium sulfate to fish species. The ECOTOX database included 27 freshwater acute (test duration less than or equal to 96 hours) LC_{50} results and two freshwater chronic (test duration greater than 96 hours) LC_{50} results for sodium sulfate and calcium sulfate for the following four freshwater species: bluegill, fathead minnow, sailfin mollies, and western mosquitofish (see Tables 5 and 6 below). Sodium sulfate and calcium sulfate acute LC_{50} results for these freshwater fish species ranged from 1970 mg/L to 56,000 mg/L. The two chronic LC_{50} concentrations were for the western mosquitofish and were equal to 2200 and 3200 mg/L.

EPA also conducted a search of EPA's ECOTOX database for effects of sodium sulfate and calcium sulfate to invertebrate species. The ECOTOX database included 29 freshwater acute (test duration less than or equal to 96 hours) LC_{50} results and two freshwater EC_{50} results (one acute and one chronic (test duration greater than 96 hours)) for sodium sulfate and calcium sulfate for the following invertebrate species: scud (Amphipoda), water fleas (*C. dubia* and *D. magna*), mosquitos (*Culex sp.*), mayflies (*Tricorythus sp.*), and the pond snail (egg life stage) (*Lymnaea sp.*) (see Tables 7 and 8 below). Sodium sulfate and calcium sulfate acute LC_{50} results for invertebrate species other than the pond snail ranged from 630 mg/L to 13,350 mg/L. For the pond snail (egg life stage), two out of four acute LC_{50} values fell below 480 mg/L, with a range in LC_{50} values from 3.55 mg/L to 5401 mg/L. One of the two EC_{50} concentrations was for the water flea *C. dubia* which had a 48-hour acute EC_{50} value of 3150.21 mg/L. The other EC_{50} concentration was for the water flea *D. magna*, which had a 100.8-hour chronic EC_{50} value of 4547 mg/L.

Table 5. Acute freshwater LC_{50} values for sodium sulfate and calcium sulfate for four fish species from EPA's ECOTOX database.

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
sodium sulfate	*Gambusia affinis*	western mosquitofish	3710	508
sodium sulfate	*Gambusia affinis*	western mosquitofish	3940	508
sodium sulfate	*Gambusia affinis*	western mosquitofish	5350	508
sodium sulfate	*Gambusia affinis*	western mosquitofish	5400	508
sodium sulfate	*Gambusia affinis*	western mosquitofish	5670	508
sodium sulfate	*Gambusia affinis*	western mosquitofish	7800	508
calcium sulfate	*Gambusia affinis*	western mosquitofish	56000	508
calcium sulfate	*Gambusia affinis*	western mosquitofish	56000	508
calcium sulfate	*Gambusia affinis*	western mosquitofish	56000	508
calcium sulfate	*Lepomis macrochirus*	bluegill	2980	5683
calcium sulfate	*Lepomis macrochirus*	bluegill	2980	949
sodium sulfate	*Lepomis macrochirus*	bluegill	3040	8037
sodium sulfate	*Lepomis macrochirus*	bluegill	4380	8037
sodium sulfate	*Lepomis macrochirus*	bluegill	12500	930
sodium sulfate	*Lepomis macrochirus*	bluegill	12750	930
sodium sulfate	*Lepomis macrochirus*	bluegill	13000	930
sodium sulfate	*Lepomis macrochirus*	bluegill	13500	5683
sodium sulfate	*Lepomis macrochirus*	bluegill	13500	949
sodium sulfate	*Lepomis macrochirus*	bluegill	17500	915
calcium sulfate	*Pimephales promelas*	fathead minnow	1970	18272
calcium sulfate	*Pimephales promelas*	fathead minnow	1970	18272
calcium sulfate	*Pimephales promelas*	fathead minnow	1970	18272
sodium sulfate	*Pimephales promelas*	fathead minnow	7960	18272
sodium sulfate	*Pimephales promelas*	fathead minnow	7960	18272
sodium sulfate	*Pimephales promelas*	fathead minnow	8080	18272
sodium sulfate	*Poecilia latipinna*	sailfin molly	15996	915
sodium sulfate	*Poecilia latipinna*	sailfin molly	20040	915

Table 6. Chronic freshwater LC_{50} values for sodium sulfate for the western mosquitofish (*Gambusia affinis*) from EPA's ECOTOX database.

Chemical Name	Scientific Name	Common Name	Cocentration (mg/L)	Ecotox Ref #
sodium sulfate	*Gambusia affinis*	western mosquitofish	2200	508
sodium sulfate	*Gambusia affinis*	western mosquitofish	3200	508

Table 7. Acute freshwater LC_{50} values for sodium sulfate and calcium sulfate for invertebrate species from EPA's ECOTOX database.

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
sodium sulfate	Amphipoda	scud order	880	915
sodium sulfate	Amphipoda	scud order	880	915
sodium sulfate	Amphipoda	scud order	1110	915
sodium sulfate	Amphipoda	scud order	2380	915
calcium sulfate	*Ceriodaphnia dubia*	water flea	1910	18272

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
calcium sulfate	*Ceriodaphnia dubia*	water flea	1940	18272
calcium sulfate	*Ceriodaphnia dubia*	water flea	1970	18272
sodium sulfate	*Ceriodaphnia dubia*	water flea	3080	18272
sodium sulfate	*Ceriodaphnia dubia*	water flea	3590	18272
sodium sulfate	*Culex sp.*	mosquito	11430	915
sodium sulfate	*Culex sp.*	mosquito	13350	915
sodium sulfate	*Daphnia magna*	water flea	630	915
sodium sulfate	*Daphnia magna*	water flea	725	915
calcium sulfate	*Daphnia magna*	water flea	1970	18272
sodium sulfate	*Daphnia magna*	water flea	2564	915
sodium sulfate	*Daphnia magna*	water flea	2564	2465
sodium sulfate	*Daphnia magna*	water flea	4547	915
sodium sulfate	*Daphnia magna*	water flea	4580	18272
sodium sulfate	*Daphnia magna*	water flea	6100	915
sodium sulfate	*Daphnia magna*	water flea	6290	18272
sodium sulfate	*Daphnia magna*	water flea	6800	915
sodium sulfate	*Daphnia magna*	water flea	7616	13712
sodium sulfate	*Daphnia magna*	water flea	8384	915
sodium sulfate	*Daphnia magna*	water flea	8384	2465
sodium sulfate	*Lymnaea sp.*	pond snail	3.553	915
sodium sulfate	*Lymnaea sp.*	pond snail	5.4	915
sodium sulfate	*Lymnaea sp.*	pond snail	5400	915
sodium sulfate	*Lymnaea sp.*	pond snail	5401	915
sodium sulfate	*Tricorythus sp.*	mayfly	660	17845

Table 8. Acute and chronic freshwater EC_{50} values for sodium sulfate for water fleas from EPA's ECOTOX database.

Chemical Name	Scientific Name	Common Name	Concentration (mg/L)	Ecotox Ref #
sodium sulfate	*Ceriodaphnia dubia*	water flea	3150.21	20672
sodium sulfate	*Daphnia magna*	water flea	4547	2462

There is a general lack of data available as to the toxicity of dissolved minerals on freshwater mussel species. However, a previous use attainability analysis (UAA) study report associated with site-specific revisions for Ditch No. 27, Ditch No. 6, and the Tyronza River in the delta ecoregion of Arkansas (prepared by FTN & Associates, Ltd.) presented some unpublished data on acute sulfate toxicity for juvenile fatmucket mussels (*Lampsilis siliquoidea*) at various levels of hardness and chloride. This data was obtained from Dr. David Soucek (Illinois Natural History Survey; 607 East Peabody Drive; Champaign, IL 61820) and is summarized in Table 9 below.

Table 9. Acute toxicity (96 h LC_{50}) of sulfate to juvenile fatmucket mussels (*Lampsilis siliquoidea*), at various levels of hardness and chloride.

Hardness (mg/L)	Chloride (mg/L)	96h LC_{50} (Sulfate, mg/L)
100	25	3377
300	25	3525
500	25	3729
100	5	1727
100	33	1822

In addition, another study was conducted by Soucek and Kennedy (2005)[5] which provides acute and chronic sulfate toxicity data for the fingernail clam (*Sphaerium simile*). The study included three rounds of 96-hour toxicity tests (each with three to five *S. simile* juveniles per treatment). A mean acute LC_{50} value of 2078 mg/L was calculated for *S. simile*, as well as a chronic LC_{10} value of 1502 mg/L.

TOTAL DISSOLVED SOLIDS (TDS)

Information on toxicity of TDS to aquatic life is limited. The ECOTOX database does not include tests using TDS. EPA's "Red Book" reports that freshwater fish have survived in waters with TDS concentrations of 10,000 mg/L.[6] TDS levels may have physical toxicity effects by altering the osmotic pressure. The State of Pennsylvania recently incorporated an aquatic life criterion for osmotic pressure in its water quality standards to replace a TDS criterion of 1500 mg/L, on the basis that the two criteria provide the same level of protection to aquatic life. TDS concentrations of less than 1200 mg/L are not likely to affect invertebrate species such as cladocerans.

EPA uses two screening levels equal to 1000 mg/L and 2000 mg/L for evaluation of TDS criteria. The value of 1000 mg/L is based on EPA's Technical Support Document[7] which recommends that freshwater toxicity testing organisms be used when the receiving water salinity is less than 1000 mg/L and that marine organisms be used when salinity equals or exceeds 1000 mg/L. The TDS screening level of 2000 mg/L was obtained from the 1994 EPA Region 6 "Strategy for Evaluating and Addressing Impacts of Total Dissolved Solids in Freshwater Invertebrate Species Toxicity Testing."[8] The strategy states that TDS concentrations greater than 2000 mg/L are needed in order to conclude that TDS is the source of toxicity in a toxicity identification evaluation.

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[5] Soucek, David, and Alan Kennedy. 2005. "Effects of hardness, chloride, and acclimation on the acute toxicity of sulfate to freshwater invertebrates." *Environmental Toxicology and Chemistry.* Volume 24, No. 5, pages 1204-1210.
[6] U.S. Environmental Protection Agency. 1976. Quality Criteria for Water ("Red Book"). U.S. Environmental Protection Agency, Washington, D.C. PB-263 943.
[7] U.S. Environmental Protection Agency. 1991. *Technical Support Document For Water Quality-based Toxics Control.* U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA/505/2-90-001.
[8] Ferguson, Jack. "Strategy for Evaluating and Addressing Impacts of Total Dissolved Solids in Freshwater Invertebrate Species Toxicity Testing." Memo to various internal EPA Region 6 staff and to State water quality contacts. U.S. Environmental Protection Agency, Region 6, Dallas, Texas. 20 Jan. 1994.

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