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WATER QUALITY
CONTROL COMMISSION

STATE OF NEW MEXICO
WATER QUALITY CONTROL COMMISSION

IN THE MATTER OF THE TRIENNIAL REVIEW
OF STANDARDS FOR INTERSTATE AND
INTRASTATE SURFACE WATERS, 20.6.4 NMAC

WQCC No. 14-05(R)

CHEVRON MINING INC.'S
NOTICE OF INTENT TO PRESENT TECHNICAL TESTIMONY

Chevron Mining Inc. ("CMI"), pursuant to the Procedural Order issued July 10, 2014, submits this Notice of Intent to Present Technical Testimony.

1. **Identify the person for whom the witness(es) will testify**

Chevron Mining Inc.

2. **Identify each technical witness the person intends to present and state the qualifications of that witness including a description of their educational and work background**

CMI expects to offer the following technical witness at the hearing:

Robert W. Gensemer, Ph.D.
Vice President and Senior Ecotoxicologist
GEI Consultants, Inc

Dr. Gensemer's qualifications and background are described in detail in Exhibit 1 to his direct testimony.

3. **Attach the full direct testimony of each technical witness**

A copy of Dr. Gensemer's direct testimony is attached to this notice.

4. **State the anticipated duration of the direct testimony of each technical witness**

CMI anticipates that the duration of Dr. Gensemer's direct testimony will be approximately 30 minutes.

5. <u>Include the text of any recommended modification to the proposed regulatory change</u>

CMI does not propose any modification to the proposed changes to the Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC) for the 2013 Triennial Review.

6. <u>Identify and attach all exhibits to be offered by the person at the hearing</u>

Exhibits to be offered by Robert W. Gensemer, Ph.D.

Exhibit 1 – Curriculum Vitae

Exhibit 2 – Exhibit 2 of 2009 Pre-filed Direct Testimony of Robert W. Gensemer, Ph.D.

Exhibit 3 – 2009 Pre-filed Rebuttal Testimony of Robert W. Gensemer, Ph.D.

Exhibit 4 – Exhibit A of 2009 Pre-filed Direct Testimony of Steven P. Canton

Exhibit 5 – 2009 Pre-filed Rebuttal Testimony of Steven P. Canton

Exhibit 6 – 1985 USEPA Guidelines for Deriving Numerical National Water Quality Criteria for Protection of Aquatic Organisms and Their Uses

Exhibit 7 – 2011 Letter to Pamela Homer, NMED: GEI Responses to EPA Region 6 Record of Decision on New Mexico's Triennial Review Water Quality Standards Amendments

7. <u>Position on other proposed changes to the standards</u>

CMI takes the following positions on changes to the standards proposed by other parties:

A. Peabody Energy

Peabody Energy has proposed (1) a change to the numeric criteria for Selenium in 20.6.4.900.J NMAC for the wildlife habitat use; and (2) changes to 20.6.4.900.D and 20.6.4.900.E NMAC, criteria for primary contact, to clarify that man-made ponds and/or man-made wetlands that are used or intended to be used for livestock watering or wildlife habitat purposes are not subject to primary or secondary human contact standards.

CMI supports the proposed changes.

(1) *Changes to 20.6.4.900.J NMAC.* The current selenium water quality standard for the protection of wildlife habitat is 5.0 µg/L (total recoverable), which is identical to and duplicative of the chronic aquatic life water quality standard. The 5.0 µg/L concentration is based on the current national recommended EPA ambient water quality criteria for selenium based on the protection of fish, which were determined to be more sensitive than other aquatic life species (e.g. macroinvertebrates). While aquatic life such as fish and macroinvertebrates spend their entire lives or sensitive life stages in the water, as stated in the NMAC definition, wildlife use water only for drinking or through incidental consumption during feeding. Thus, different standards are appropriate for terrestrial wildlife than for aquatic life. CMI agrees with Peabody's proposal to revise the current selenium water quality standard for protection of wildlife habitat of 5 µg/L to 50 µg/L, which is equivalent to the current selenium water quality standard for protection of livestock.

(2) *Changes to 20.6.4.900.D and 20.6.4.900.E NMAC.* Application of the primary or secondary human contact standards, which are more stringent than the livestock or wildlife standards otherwise applicable to these water bodies, is inconsistent with the purpose of these man-made water bodies and creates a disincentive to creating these structures. CMI believes that the creation of these structures is beneficial and consistent with good public policy in the arid Southwest. The current standards, without the clarification, could be an impediment to creating and maintaining these structures after operation ceases.

B. Amigos Bravos

Aquatic Life Criteria for Aluminum. For the reasons outlined in Dr. Gensemer's testimony, CMI opposes the proposed change, which would return the Aluminum criteria to pre-2009 Triennial Review levels.

Respectfully submitted,

MONTGOMERY & ANDREWS, P.A.

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CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing ***Chevron Mining Inc.'s Notice of Intent to Present Technical Testimony*** was sent via U.S. mail, and/or hand-delivered on December 12, 2014, to the following:

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STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

IN THE MATTER OF THE TRIENNIAL REVIEW OF STANDARDS FOR INTERSTATE AND INTRASTATE SURFACE WATERS, 20.6.4 NMAC	**WQCC No. 14-05(R)**

DIRECT TESTIMONY OF ROBERT W. GENSEMER, Ph.D.
GEI CONSLUTANTS, INC.

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I. INTRODUCTION

I have prepared the following direct testimony in opposition to *Amigos Bravos' Proposal Regarding Criteria Applicable to Existing, Designated or Attainable Uses Unless Otherwise Specified in 206.4.97 through 20.6.4.899 NMAC*. *See* Amigos Bravos Proposed Changes and Statement of Basis ("Amigos Bravos Proposal"), 8-9 (filed Sept. 30, 2014). Amigos Bravos proposes to withdraw the current hardness-based criteria for aluminum (Al) that were adopted by the New Mexico Water Quality Control Commission ("WQCC") in the 2009 Triennial Review of Surface Water Quality Standards ("2009 Triennial Review"), and subsequently approved by the U.S. Environmental Protection Agency ("USEPA"), and revert back to the aquatic life criteria that were in place prior to the 2009 Triennial Review.

The former criteria for Al, which had not been updated for over 20 years prior to the 2009 Triennial Review, were not adjusted for water hardness, and consisted of a Criterion Continuous Concentration ("chronic criterion") of 87 µg Al/L, and a Criterion Maximum Concentration of 750 µg Al/L ("acute criterion"), both measured on the basis of dissolved Al concentrations. The current, updated criteria recognize that the toxicity of Al to aquatic life is hardness-dependent – i.e., Al toxicity is greater in softer waters and decreases as water hardness increases – and were derived on the basis of USEPA guidance (USEPA 1985). As discussed in this testimony, I have reviewed the scientific literature, the 2009 Triennial Review and the USEPA review of the revised criteria and have concluded that the current criteria are supported and appropriate, and that it would be inappropriate to reinstate the former criteria.

II. QUALIFICATIONS

I am a Vice President and Senior Ecotoxicologist at GEI Consultants, Inc. with 30 years of experience as an aquatic ecologist and ecotoxicologist in both the academic and consulting sectors. My project experience includes the conduct and oversight of ecological risk assessments for both aquatic and terrestrial habitats, general aquatic plant toxicology, and the development and modification of ambient water quality criteria for protection of aquatic life. My technical approach focuses on providing high quality, unbiased scientific support based on a thorough understanding of appropriate regulatory guidance and the current scientific literature.

My primary areas of scientific expertise include the toxicology of metals to aquatic organisms, and the development and modification of ambient water quality criteria (AWQC) for protection of aquatic life and their uses. With respect to metals toxicology, I have extensive experience conducting and/or reviewing primary laboratory research that evaluates the influence of water quality characteristics (e.g., hardness, alkalinity, and dissolved organic carbon) on the bioavailability and toxicity of metals and inorganics, primarily for aluminum (Gensemer 1989, 1990, 1991a, 1991b, Gensemer et al. 1994, Gensemer and Playle 1999, Gensemer et al. 1999), copper (Playle et al. 1992, Gensemer et al. 2002, Paquin et al. 2002, Naddy et al. 2003, Van Genderen et al. 2007, Gensemer 2008), and cyanide (Clark et al. 2006, Gensemer et al. 2006, Gensemer et al. 2007). Much of this research has been in support of the development and modification of the Biotic Ligand Model, which is increasingly forming the technical basis of many regulatory metals standards worldwide, including copper for freshwaters in the U.S. (USEPA 2007).

I also have over 15 years of experience applying my knowledge of aquatic toxicology to the development and modification of AWQC for aquatic life according to USEPA guidance (USEPA 1984, 1985, 1994, 2001). Key examples of past AWQC-related projects include preparation of draft AWQC for methyl tertiary-butyl ether (MTBE), proposed updates to the AWQC for cyanide (Gensemer et al. 2007), and several projects conducted under the Arid West Water Quality Research Project (AWWQRP; funded in part by USEPA Region 9, and administered by Pima County, AZ). These AWWQRP projects focused on the evaluation and modification of ambient water quality criteria in effluent-dependent and ephemeral water courses in the arid western U.S., including Colorado, New Mexico, Arizona, Nevada, and California. Most recently, I have been leading several projects related to implementation of USEPA's Biotic Ligand Model-based AWQC for copper, and the oversight of new toxicity testing to support the registration and classification of Al under Europe's Registration, Evaluation, Authorisation, and Restriction of Chemicals program (REACH).

For additional detail, my full *curriculum vitae* is attached as Exhibit 1 to this Direct Testimony.

III. BACKGROUND

The current hardness-based Al criteria are based on changes proposed by Chevron Mining Inc. (CMI) and Los Alamos National Security ("LANS") during the 2009 Triennial Review. I testified in support of changes to the heavy metals standard, including Al, on behalf of LANS in that proceeding. Additional expert testimony in support of the new Al criteria was provided by Steve Canton on behalf of CMI. My and Mr. Canton's pre-filed testimony from the 2009 Triennial Review are attached hereto as Exhibit 2 (Gensemer 2009 Direct Testimony); Exhibit 3 (Gensemer 2009 Rebuttal Testimony); Exhibit 4 (Canton 2009 Direct Testimony); and Exhibit 5 (Canton 2009 Rebuttal Testimony).

As we explained in our testimonies at the 2009 Triennial Review, between the time when USEPA released the existing nationally-recommended ambient water quality criteria ("1988 AWQC") for Al in 1988 and the 2009 Triennial Review, several acute and chronic Al toxicity studies were published in the scientific literature that suggested the national criteria needed to be updated (Exhibits 2 and 4). Many of these toxicity studies met USEPA guidelines for AWQC development, and resulted in additional data for deriving an acute-to-chronic ratio ("ACR") for Al. These studies also demonstrated that the toxicity of Al to aquatic life is hardness-dependent – i.e., Al toxicity is greater in softer waters and decreases as water hardness increases.

While Al toxicity was known to be dependent on water pH at the time of the 2009 Triennial Review, studies available at that time did not support mathematical adjustment of Al criteria on the basis of pH over the range used in the 1988 AWQC and as initially proposed by both CMI and LANS (i.e., pH 6.5 – 9.0). Therefore, CMI and LANS modified their proposals to include the following hardness-based aquatic life criteria for Al derived according to USEPA guidance, which were adopted by the WQCC as part of 20.6.4.900 NMAC, and which were ultimately approved by USEPA for waters with a pH between 6.5 – 9.0:

$$\text{Acute Criterion} = e^{(1.3695[\ln(\text{hardness})]+1.8308)}$$

$$\text{Chronic Criterion} = e^{(1.3695[\ln(\text{hardness})]+0.9161)}$$

Amigos Bravos now claims that these criteria should not have been adopted for two primary reasons: (1) because USEPA has not updated their nationally-recommended criteria (USEPA 1988); and (2) because adequate studies were not available to update these criteria on the basis of hardness. Amigos Bravos has also raised concerns regarding the effects of pH on Al toxicity when pH values exceed 7.5.

While CMI recognizes that USEPA has not yet updated their nationally-recommended AWQC for Al, adequate and acceptable studies did exist to update the Al criteria at the time of the 2009 Triennial. The proposals filed by CMI and LANS during the 2009 Triennial Review upon which the current criteria are based provided a thorough and rigorous analysis of appropriate hardness-based criteria derived on the basis of USEPA guidance; and, indeed, those criteria ultimately secured USEPA's approval.

This direct testimony presents CMI's support for the existing hardness-based Al criteria and its opposition to Amigos Bravos's proposed return to the pre-2009 criteria. In my testimony, I summarize 1) the process that CMI and LANS followed in preparation of their 2009 criteria update proposals, and 2) the review and approval of these proposals by NMED and USEPA, and

3) address Amigos Bravos's concerns with application of these criteria as a function of pH. I conclude that returning to the 1988 AWQC Al as the basis of New Mexico's water quality standards for Al would represent a retreat to an outdated scientific approach that does not address the important influence of hardness on Al toxicity in freshwater. Therefore, I recommend that the WQCC reject Amigos Bravos's proposal to repeal the hardness-based Al criteria and return to the outdated pre-2009 criteria.

IV. THE HARDNESS-BASED Al CRITERIA WERE APPROPRIATELY DERIVED USING USEPA GUIDANCE

The expert testimony submitted by CMI and LANS in the 2009 Triennial Review provided a full review of the scientific literature available at that time, and used USEPA (1985) guidelines to derive the new hardness-based Al criteria. These guidelines were summarized in Exhibit 2 to my 2009 Direct Testimony, and are appended as Exhibit 6 to this direct testimony:

> To understand how AWQC are developed, it is useful to review the guidelines and terminology provided in USEPA (1985), but the general approach is briefly summarized below. The first step is to compile acute and chronic toxicity data that meet the USEPA (1985) guidelines for the relevance and reliability of each study. A minimum database of acceptable studies representing at least 8 specific taxonomic families of aquatic organisms is also required. For each species with acceptable acute toxicity data, the species mean acute value (SMAV) is calculated as the geometric mean of available 48 to 96-hr median lethal concentrations (LC50s) or median effect concentrations (EC50s) for each species. The genus mean acute value (GMAV) is then calculated as the geometric mean of available SMAVs for each genus. The lowest 5th percentile of the distribution of available GMAVs is identified as the final acute value (FAV), which is divided by two to determine the criterion maximum concentration (CMC) which is more commonly termed the "acute criterion." The FAV is divided by two because USEPA determined setting the CMC equal to the FAV (i.e., without dividing by two) was not sufficiently protective since it could induce up to 50% mortality to sensitive species. It is important to note that the 5th percentile is calculated based solely on the four most sensitive GMAVs and the total number of GMAVs (USEPA 1985).

See Exhibit 2, at Exhibit 2, p. 2.

Prior to deriving the new Al criteria, the available toxicity literature was extensively reviewed to ensure adherence to USEPA (1985; *See* Exhibit 6) study quality and minimum database requirements, again as summarized in Exhibit 2 to my 2009 Direct Testimony:

> The USEPA (1985) guidelines for AWQC development specify minimum study requirements for consideration in the development of acute and chronic criteria for protection of aquatic life. For example, acute toxicity studies must have an exposure duration of 96 hours (although 48 hours is acceptable for more short-lived species, such as cladocerans and midges), organisms must not be fed during the study, and the endpoint must be mortality, immobilization or a combination of the two. Chronic toxicity studies must be conducted using exposure durations that encompass the full life cycle or, for fish, early life stage and partial life cycle studies are acceptable. In addition, toxicant concentrations in the exposure solutions must be analytically verified in chronic studies. Finally, under the USEPA (1985) guidelines, toxicity studies that do not meet the specific study requirements may still be retained as "other data" if the study was otherwise scientifically valid. Such "other data" are not used in the calculation of the CMC and FCV, but may be used to justify lowering the acute or chronic criteria for a toxicant if the species and endpoint tested are considered to be "biologically or recreationally important," and if the CMC or FCV were determined to be inadequately protective of these species or endpoints.

*Id.*at Exhibit 2, p. 3-4.

USEPA (1985; *See* Exhibit 6) also provides methods to derive AWQC on the basis of water quality parameters that can be scientifically shown to vary in a consistent manner with toxicity. The direct testimony at the 2009 Triennial focused in particular on relationships between Al toxicity and water quality parameters such as hardness and pH. While statistically valid relationships could be derived for hardness, this could not be accomplished for pH using the acceptable[1] data available at the time. As summarized in Exhibit A to Mr. Canton's 2009 Direct Testimony:

> Attempts to develop such an equation were hindered by limited studies conducted for any species at an acceptable range of pH values (6.5-9.0). In fact, the greatest pH value in the database is 8.29, at which no increased toxicity was apparent. Available data points at lower pH values approximately 6.5 for some taxa indicate

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[1] The word "acceptable" in this sense refers to studies that meet minimum data quality requirements for AWQC derivation according to USEPA (1985; *See* Exhibit 6).

> that increased toxicity occurs at the lower end of the USEPA recommended range. This trend provided qualitative evidence of a water quality toxicity relationship in some organisms. However, this relationship is not significant within, or consistent between, an acceptable sample of organisms in the updated database.

See. Exhibit 4, at Exhibit A, p. 14-15.

In the Record of Decision Addendum that accompanied USEPA's approval of the hardness-based criteria, USEPA acknowledged that "…GEI generally followed methods outlined in EPA's criteria derivation and recalculation procedures…", and further that "EPA has determined that the hardness-based equations would be protective for waters within the pH range of 6.5 to 9.0…" (USEPA 2012). Therefore, even though the 2009 criteria proposals by CMI and LANS were not intended to represent updates to the USEPA nationally-recommended AWQC, they were derived using methods and data requirements as close as possible to USEPA guidance for doing so. Thus, these hardness-based criteria are fully protective of aquatic life in New Mexico (within the intended pH range of 6.5 – 9.0) at the same levels of protection set forth under the Clean Water Act (USEPA 1985; *See* Exhibit 6).

V. THE HARDNESS-BASED Al CRITERIA WERE REVIEWED AND APPROVED BY USEPA

The administrative record from the 2009 Triennial Review indicates that the hardness-based Al criteria proposed by CMI and LANS underwent significant technical review prior to USEPA's approval in their Record of Decision (ROD) Addendum (USEPA 2012). Key steps in the technical review and approval process were as follows:

1. Pre-filed direct testimony submitted by CMI's and LANS' experts was subject to thorough technical review by both the New Mexico Environment Department ("NMED") and USEPA, prompting a series of technical questions for which responses were prepared in the form of pre-filed rebuttal testimony by both proponents. *See* Exhibits 3 and 5.

2. Both Mr. Canton and I presented oral testimony during the Triennial Review hearing December 8-11, 2009. This testimony, and related cross-examination by NMED, addressed many of the same technical comments raised and discussed in pre-filed rebuttal testimony (*See* Hearing Officer's Report; WQCC 2010a).

3. The WQCC issued its Order and Statement of Reasons for Amendment of Standards, concluding that: "The Commission adopts the proposal by Chevron Mining and Los Alamos National Laboratory/Department of Energy (CMI and LANS/DOE) to replace the current acute and chronic aquatic life criteria for aluminum in section 900.J with hardness-based criteria and to show total aluminum in this subsection to reflect findings of new toxicological studies." (*See* Order and Statement of Reasons; WQCC 2010b; paragraph 511)

4. In its initial ROD for the 2009 Triennial Review, USEPA did not act on the hardness-based aluminum criteria, primarily due to concerns pertaining to application of these criteria outside the pH range of 6.5 – 9.0, suggesting that "additional review of the GEI document is warranted" (USEPA 2011, pages 117-118). Responses addressing USEPA's concerns as expressed in the initial ROD were provided jointly by both myself and Mr. Canton and submitted to NMED in 2011 (*See* Exhibit 7).

5. USEPA issued its ROD Addendum approving the hardness-based aluminum criteria for waters of pH between 6.5 – 9.0, but disapproving these criteria for waters below 6.5, stating in the transmittal letter:

> Based on an extensive review of the supporting documentation, we are approving the application of the hardness-dependent equation for aluminum to those waters of the State at a pH of 6.5 to 9.0 because it will yield criteria that are protective of applicable uses in waters within that pH range.

See USEPA (2012)

VI. APPROPRIATENESS OF Al CRITERIA AS A FUNCTION OF pH

As mentioned above, many of the technical concerns raised in particular by USEPA during review of the hardness-based Al criteria related to application of these criteria *outside* the pH range of 6.5 – 9.0, and not within this pH range. It is important to note that the hardness-based Al criteria, as proposed by CMI and LANS, and as adopted by the WQCC, were never intended to apply to waters outside this pH range, nor was any scientific information presented or available at the time for doing so. While these concerns led to USEPA's disapproval of the hardness-based Al criteria below pH 6.5, the hardness-based Al criteria *within this range* ultimately were approved, and are protective of aquatic life and their uses in New Mexico.

In its Proposal, Amigos Bravos claims that "New Mexico's hardness-based standard fails to address important pH effects where the pH is >7.5, a condition prevalent in many New Mexico streams." *See* Amigos Bravos Proposal at page 9. To support this assertion, Amigos Bravos cites a single study that exposed rainbow trout (*Oncorhynchus mykiss*) to Al under circumneutral and weakly alkaline conditions for 96 hours (acute) and 16 days (subchronic) (Gundersen et al. 1994). From this study, Amigos Bravos extrapolates what mortality rates "would be" when projected out to 3 months (109 days). However, since the study was only conducted for 16 days, there is no technical basis for making this extrapolation. Moreover, 16 days is far too short of an exposure period for rainbow trout to be considered acceptable for use in deriving chronic water quality criteria according to USEPA guidance (USEPA 1985), and thus, these data should not be considered for purposes of updating or otherwise evaluating the validity of aquatic life criteria.

Some of the acute LC50 values presented by Gundersen et al. (1994) conducted at pH 8.25 – 8.29 were considered acceptable for use in criteria derivation according to USEPA guidelines (USEPA 1985), and in fact were used for derivation of hardness-normalized species mean acute values for rainbow trout in both my and Mr. Canton's 2009 direct testimony (*See* Exhibit 2 at pages 4 and 15, and Exhibit 4 at page 9). However, there was little indication that Al was significantly more toxic than when fish were exposed to pH of 7.6 in these same studies (Gundersen et al. 1994).

VII. CONCLUSION

In my opinion, there is no technical basis to support Amigos Bravos' contention that the hardness-based criteria adopted by the WQCC in the 2009 Triennial Review would not be protective at pH greater than 7.5, particularly under chronic exposure conditions. The USEPA-approved hardness-based Al criteria for waters of pH between 6.5 – 9.0 were derived according to USEPA guidance (USEPA 1985), and so the levels of aquatic life protection afforded by these criteria are consistent with the goals of the Clean Water Act. More importantly, returning to the 1988 AWQC Al as the basis of New Mexico's water quality standards for Al would represent a retreat to an outdated scientific approach that does not address the important influence of hardness on Al toxicity in freshwater. Therefore, I recommend that the WQCC reject Amigos Bravos's proposal to repeal the hardness-based Al criteria and return to the outdated pre-2009 criteria.

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STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

IN THE MATTER OF THE TRIENNIAL REVIEW OF STANDARDS FOR INTERSTATE AND INTRASTATE SURFACE WATERS, 20.6.4 NMAC

WQCC No. 14-05(R)

AFFIDAVIT OF ROBERT W. GENSEMER, Ph.D.

STATE OF COLORADO)
) ss.
COUNTY OF DENVER)

I, Robert W. Gensemer, Ph.D., being first duly sworn, depose and state that I am the individual whose prepared Direct Testimony accompanies this Affidavit, and that said Direct Testimony is true and correct to the best of my knowledge and belief.

Robert W. Gensemer, Ph.D.

SUBSCRIBED AND SWORN TO before me this 11th day of December 2014.

Sharon Korver
Notary Public

SHARON KORVER

My Commission Expires: April 30, 2015.

Robert W. Gensemer, Ph.D.
Vice President and Senior Ecotoxicologist

Dr. Gensemer has 30 years of academic and industrial experience in aquatic ecology and limnology, ecotoxicology, phytoplankton ecology, plant toxicology, and the environmental toxicology of metals and polycyclic aromatic hydrocarbons (PAHs). His project experience includes general aquatic toxicology, the conduct and oversight of ecological risk assessments for both aquatic and terrestrial habitats, sediment remedial investigations under EPA's Superfund program, and the development and modification of ambient water quality criteria for protection of aquatic life. One of Dr. Gensemer's primary areas of technical expertise is the development and basis of aquatic life criteria for Clean Water Act compliance, including the development and updating of toxicity databases, criteria derivation and modification, site-specific criteria development, and the use and development of biotic ligand models (BLMs) for derivation of site-specific metals criteria. He has provided expert testimony in state water quality hearings (including NM, CO, and WV) to update both statewide and regional criteria, and has assisted in the development, modification, and negotiation of numerous permitted effluent discharge limits. He is also leading national efforts to review and/or implement new scientific approaches for aquatic life protection, including the national implementation of BLM-based copper criteria, and to review the technical basis of EPA's recent efforts to propose changes to definitions of "waters of the United States."

EDUCATION
Ph.D., Biological Sciences, University of Michigan, 1989
B.A., Botany, Ohio Wesleyan University, 1982

EXPERIENCE IN THE INDUSTRY
30 years

EXPERIENCE WITH GEI
5 years

PROFESSIONAL ASSOCIATIONS
Society of Environmental Toxicology and Chemistry
Rocky Mountain Chapter, Society of Environmental Toxicology and Chemistry
Water Environment Federation

PROFESSIONAL HISTORY

2009 – Present	Vice President and Senior Ecotoxicologist, GEI Consultants, Denver, CO
2008 – 2009	Water Division Manager, Parametrix, Inc., Albany, OR
2007 – 2009	Affiliate Faculty, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR
2002 – 2009	Senior Toxicologist, Parametrix Inc., Albany, OR
2006 – 2007	Operations Manager, Parametrix Environmental Research Laboratory, Albany, OR
2003 – 2005	Toxicology Division Manager, Parametrix Inc., Albany, OR
2002	Assistant Department Manager, ENSR International, Fort Collins Environmental Toxicology Laboratory
1999 – 2002	Senior Project Manager, ENSR International, Fort Collins Environmental Toxicology Laboratory
1998 – 1998	Associate Director for Undergraduate Studies, Center for Energy and Environmental Studies, Boston University
1995 – 1998	Assistant Professor, Boston University, Department of Biology, and Center for Energy and Environmental Studies
1994 – 1995	Research Associate, Centre for Toxicology, University of Guelph
1990 – 1994	Postdoctoral Research Fellow, Department of Biology, University of Waterloo
1993 & 1992	Lecturer (sessional), Department of Biology, University of Waterloo
1982 – 1989	Department of Biology, Limnology Laboratory, University of Michigan

GENSEMER TESTIMONY
EXHIBIT 1

GEI PROJECT EXPERIENCE

New Mexico Water Quality Standards Triennial Review, Montgomery & Andrews, Los Alamos, NM. Expert Testimony and Technical Reviewer. Dr. Gensemer provided technical support in the development of specific proposals to amend and update New Mexico's water quality standards during their current Triennial Review. These proposals included updates to numeric aquatic life criteria for aluminum, cadmium, and zinc, acceptance of the Biotic Ligand Model for copper, and the incorporation of EPA methods for site-specific modification of water quality standards. The outcome of this Triennial Review was notable in that the proposed updates for aluminum included the first hardness-based criteria for Al to be proposed and accepted by the U.S. EPA for any state. Support also included the presentation of technical exhibits and direct testimony during the state Triennial Review hearings, and preparation of technical responses to comments received from other stakeholders during throughout the Triennial Review process.

Aluminum Toxicity Testing and Database Development, European Chemicals Registration, European Aluminium Association, Brussels, Belgium. Project Manager. Dr. Gensemer is the project manager for GEI's participation in a multi-national collaborative effort to conduct new aquatic toxicity tests for aluminum in support of European chemicals registration requirements under the REACH program. Laboratory studies focused on tests to elucidate mechanisms of aluminum toxicity under circumneutral or basic pH conditions, and to support development of a Biotic Ligand Model for derivation of regulatory aquatic life criteria. Database development services included conducting a literature search, study review for scientific relevance and reliability, and generation of the toxicity database using IUCLID5. GEI also participated in preparation of the final Chemical Safety Report required under REACH, and is now in the process of completing preparation of manuscripts for submittal to peer-reviewed scientific journals.

Expert Testimony for Colorado Basic Standards Hearing, Colorado Mining Association, Denver, CO. Lead Scientist and Expert Witness. Dr. Gensemer provided expert testimony regarding updates to the aquatic life criteria for aluminum and iron in the 2010 Basic Standards Hearing for the State of Colorado. Led preparation of expert reports, presented expert testimony and rebuttal testimony, leading to successful adoption of new aquatic life criteria for aluminum derived on the basis of water hardness.

Expert Testimony for Arkansas Basin Water Quality Standards Hearing, TriLakes Water and Sanitation District, Monument, Colorado. Lead Scientist and Project Manager. Dr. Gensemer led an investigation and development of expert testimony supporting updates to the aquatic life criteria for copper in portions of Monument Creek, Colorado. The key elements of our expert testimony related to use of the Biotic Ligand Model in combination with a Fixed Monitoring Benchmark approach for development of copper criteria. This led to the first ever regulatory adoption in the United States of an aquatic life criterion using the Fixed Monitoring Benchmark method.

Expert Testimony for Study to Support Site-specific Iron Standards, Peabody Energy, and TriState Generation and Transmission, Denver, CO. Expert Witness. Dr. Gensemer presented expert testimony before the Colorado Water Quality Control Commission to propose extension of the Temporary Modifications of water quality standards at a coal mine in Colorado to allow for completion of a scientific study of ecological communities in streams with elevated iron concentrations owing to natural conditions of elevated suspended solids. This testimony also included development of a study plan to conduct field investigations to support ultimate development of a site-specific standard for iron at the site.

Expert Testimony for Proposed Site-specific Copper Standards using the Biotic Ligand Model, Upper Thompson Sanitation District, Denver, CO. Expert Witness. Dr. Gensemer assisted with the presentation of expert testimony before the Colorado Water Quality Control Commission to propose site-specific copper standards for the Upper Thompson River using the Biotic Ligand Model. GEI's proposal was the culmination of extensive analysis of water chemistry data throughout the Upper Thompson watershed, and also included development of a decisional framework for regulatory implementation of copper standards using the Biotic Ligand Model.

Technical Support for Development of Saltwater Aquatic Life Criteria for Copper, Copper Development Association, Denver, CO. Senior Project Scientist. Dr. Gensemer is the lead scientist and project manager for a scientific review of the effects of copper on the olfactory or behavioral effects of copper on marine fish. This work is being conducted in support of new aquatic life criteria for saltwater organisms being developed using the Biotic Ligand Model as its computational basis. The primary goal of this review is to evaluate the level of aquatic life protection afforded by these proposed criteria to these potentially important sublethal effects.

Regulatory Support for Implementation of Aquatic Life Criteria for Copper Using the Biotic Ligand Model, International Copper Association, New York, NY. Project Manager. Dr. Gensemer is the project manager and technical lead for a multi-year effort to support the implementation of EPA's latest aquatic life criteria for copper that use the Biotic Ligand Model (BLM) as the computational basis of these criteria. The BLM represents a significant scientific advancement as a method for the development of aquatic life criteria for metals, yet have not been implemented by most States and Tribes. The project includes the development of technical support testimony, communications, and educational activities in support of each state's triennial review process.

Scientific Review of Olfactory and Behavioral Effects of Copper on Saltwater Fish, International Copper Association, New York, NY. Senior Project Scientist. Dr. Gensemer is the lead scientist and project manager for a scientific review of the effects of copper on the olfactory or behavioral effects of copper on marine fish. This work is being conducted in support of new aquatic life criteria for saltwater organisms being developed using the Biotic Ligand Model as its computational basis. The primary goal of this review is to evaluate the level of aquatic life protection afforded by these proposed criteria to these potentially important sublethal effects.

Iron Pre-Filtration Study, Colorado Mining Association, Denver, CO. Expert Testimony and Technical Reviewer. Dr. Gensemer provided technical support in preparation of recommended updates to statewide metal criteria for the Colorado Water Quality Control Commission and the 2010 Basic Standards Hearing. He also presented expert testimony with respect to updates to aquatic life criteria for aluminum.

Review of Watershed Science Supporting Concepts of Ecological Connectivity, Hunton & Williams LLP, Washington, DC. Lead Project Scientist. Dr. Gensemer helped lead a review of scientific studies supporting the concept of whether headwaters and adjacent wetlands were hydrologically, biologically, or chemically connected to perennial waters that are the traditional focus of Clean Water Act regulation. GEI reviewed the available science, prepared a summary report of our findings, and supported the Waters Advocacy Coalition in preparing for future EPA rulemakings related to possible changes to which waterways or landscape features are considered jurisdictional under the Clean Water Act.

Comments on Science Advisory Board Review of Connectivity Report, Hunton & Williams, LLP, Washington, DC. Project Manager. As part of EPA's proposed rulemaking to redefine "waters of the United States", EPA developed a scientific report that evaluated the physical, chemical, and biological connectivity between waters currently considered jurisdictional under the Clean Water Act, and adjacent waters not currently considered jurisdictional. Dr. Gensemer reviewed EPA Science Advisory Board's peer evaluation of this connectivity report on behalf of the Waters Advocacy Coalition, and provided technical comments on their behalf during public comment periods.

Review of Proposed Rulemaking to Redefine Waters of the United States under the Clean Water Act. Hunton & Williams, LLP, Washington, DC. Lead Project Scientist. GEI prepared technical comments on behalf of the Waters Advocacy Coalition during the public comment period on proposed rulemaking to redefine "waters of the United States" under the Clean Water Act. Dr. Gensemer helped prepare the overall technical response strategy, reviewed draft deliverables, and worked with our clients in finalizing comments challenging the technical basis for asserting federal jurisdiction over waters not currently regulated under the Clean Water Act.

Technical Support for NPDES Permit Renewal, Confidential Coal Mining Client, St. Clairsville, OH. Senior Technical Expert. In response to concerns over total dissolved solids discharges from an active coal mine, GEI has been collaborating on studies to better evaluate the ecological effects of total dissolved solids to better evaluate the need for NPDES effluent limitations. Dr. Gensemer is a senior technical advisor to the GEI technical team, and participates in client planning meetings and will ultimately serve as an expert technical witness representing GEI's work.

Development of a Site-Specific Osmotic Pressure Criterion for Discharge from a Former Coal Mine Site in Pennsylvania, Dinsmore & Shohl LLP, CO. Senior Technical Advisor. Provided overall technical and strategic advice to the GEI project team tasked with developing a site-specific osmotic pressure standard to support NPDES permit renewal at an inactive coal mining site. Dr. Gensemer reviewed draft deliverables, and participated with the rest of the GEI team in client meetings to develop the technical strategy and direction for proposed studies needed to develop the site-specific standard.

General Outreach Related to Development of Aquatic Life Benchmark for Conductivity, National Mining Association, Washington, DC. Senior Ecotoxicologist. Dr. Gensemer was one of the lead project scientists for a scientific review of a proposed aquatic life benchmark from the U.S. Environmental Protection Agency which was related to the effects of mountaintop mining and valley fill coal mining techniques on benthic macroinvertebrate populations and headwaters communities in southern West Virginia. He led preparation of a technical review report submitted during public review of the draft conductivity benchmark, and assisted in communicating the results of GEI's review to EPA's Scientific Advisory Board. Dr. Gensemer also assisted in the design and interpretation of independent field studies to analyze the potential for conductivity to accurately predict aquatic life impairment in this region.

Headwaters and Longitudinal Studies, National Mining Association (NMA), Washington, DC. Senior Ecotoxicologist. Dr. Gensemer was one of the lead project scientists for a series of field studies evaluating the effects of mountaintop mining and valley fill coal mining techniques on benthic macroinvertebrate populations and headwaters communities in southern West Virginia. These projects were conducted to help identify potential issues associated with the derivation of a proposed water quality benchmark for conductivity in Central Appalachian streams. Dr. Gensemer's specific role included assistance with field study design, oversight of data analysis and report preparation, review of final deliverables, and project management.

Nutrient Standards Support, Colorado Wastewater Utility Council, Colorado Wastewater Utility Council, Denver, CO. Project Manager. Dr. Gensemer provided technical support on the development of the Colorado Nutrient Criteria and changes to Aquatic Life Biocriteria. This included participation in the Water Quality Forum Work Groups, providing general feedback and technical support on nutrients, and review of documents provided by Water Quality Control Division (WQCD) and other parties.

Remedial Investigation/Feasibility Study, Confidential Client, Greater New York Area, NY. Project Manager and Technical Lead. Dr. Gensemer is the GEI Project Manager in support of a Superfund remedial investigation, and provides oversight of joint consultant activities, as well as EPA contractors, for evaluation of ecological and human health risk in an urban waterway subject to multiple inputs of contaminants, including combined sewer overflow (CSO) discharges. Dr. Gensemer also coordinates the review and comment on general remedial investigation reports and data deliverables, and assists the client's technical and legal teams to develop and support overall project strategy.

Expert Litigation Support for Site Contamination by Perfluorooctanoic Acid (PFOA), Confidential Client, Confidential Location, U.S. Project Manager and Technical Expert. Dr. Gensemer prepared an expert technical report that reviewed and commented upon reports prepared by the Plaintiff's technical experts in a case alleging ecological risks to a water supply wellfield from exposure to Perfluorooctanoic Acid (PFOA). Based upon review of the Plaintiff reports and other scientific literature, this expert report refuted RCRA claims of imminent and substantial endangerment to the environment from PFOA. Dr. Gensemer also provided expert technical witness support to assist the client with refuting the Plaintiff's claims.

Expert Litigation Support for Review of Coal Mine Discharge Permit, Confidential Client, Charleston, WV. Project Manager, Lead Scientist, and Expert Witness. Provided technical support and expert testimony in front of the West Virginia Environmental Quality Board in a third-party action challenging the NPDES discharge permit for a surface coal mine in West Virginia. Technical issues primarily related to effects of total dissolved solids on benthic macroinvertebrate communities, and the application of draft USEPA benchmarks.

Sediment Site Remedial Investigation/Feasibility Study, Confidential Client, Greater New York area. Risk Assessment Lead. Dr. Gensemer is the risk assessment lead for a Superfund remedial investigation regarding the potential role of legacy Manufactured Gas Plan (MGP) activities within the context of other potential stressors in an urban estuary. For this project, he provided oversight of the development of a comprehensive database of chemical stressors, physical stressors, and habitat stressors, provided support for an assessment of the health of the benthic community using available data from population sampling of the benthic invertebrates, and developed ecological and human health risk assessment workplans for use in the remedial investigation, and specific workplans for surface sediment sampling and toxicity tests.

CERCLA PRP Group Technical Subcommittee Chair, Confidential Client, Greater New York Area, NY. Subcommittee Chair. Dr. Gensemer chaired the technical subcommittee of a five-party group undertaking a Superfund remedial investigation and feasibility study (RI/FS) of contaminated sediments in an urban waterway. In this role, Dr. Gensemer was responsible for setting meeting agendas, coordination of technical document reviews, and served as liaison with the legal subcommittee and executive committee of the five-party group.

Baseline Ecological Risk Assessment for the Portland Harbor Remedial Investigation, GSI Water Solutions, Inc., Portland, OR. Project Manager and Lead Scientist. Dr. Gensemer currently supports the City of Portland, via subcontract to GSI Water Solutions, to provide technical support related to completion of the baseline ecological risk assessment for the Portland Harbor remedial investigation under Superfund. He provides technical review of draft risk assessment deliverables, along with strategic advice concerning risk assessment revisions to address comments from EPA and their government partners.

Former Canton Airport – Ecological Risk Assessment, Department of Conservation & Recreation, Canton, MA. Risk Assessment Lead. Dr. Gensemer provided technical oversight of assessments designed to determine the likelihood for continuing ecological risks following a proposed remediation at the former Canton Airport site. Preliminary remediation goals were developed and a residual ecological risk assessment was conducted to address potential risks to both aquatic and terrestrial receptors following site remediation.

Amesbury Former MGP – Phase II & III Remedial Investigation, National Grid, Amesbury, MA. Senior Project Scientist. Dr. Gensemer helped evaluate screening-level ecological risk assessment for a terrestrial and wetland site with legacy MGP-related contamination, and provided strategic advice regarding potential development of ecologically-based remedial action goals.

PREVIOUS EXPERIENCE

Baseline Ecological Risk Assessment for the Portland Harbor Remedial Investigation, Environmental Protection Agency, Region 10, Portland, OR. Lead Project Scientist. While working for a previous firm, Dr. Gensemer was the lead project scientist providing technical support to EPA for the baseline ecological risk assessment being conducted for the Portland Harbor Remedial Investigation being conducted under the auspices of CERCLA (or "Superfund"). His primary roles included attendance at technical advisory group meetings, review of technical documents, assistance with preparation of comments, and providing general scientific support to EPA and their partners. Detailed technical work included review of site data, preparation of the problem formulation for the baseline ecological risk assessment, review and development of toxicity reference values for protection of aquatic organisms and aquatic-dependent wildlife, and development of a weight of evidence-based risk evaluation framework.

Preparation of Comments on Draft Industrial Stormwater General Permit, Copper Development Association, Lacey, WA. Lead Project Scientist. Dr. Gensemer provided expert technical support services to assist the client in development of comments on Washington Department of Ecology's latest draft Industrial Stormwater General Permit. Comments focused on the scientific relevance of the proposed numeric copper benchmarks which were substantially lower than previous benchmarks, and used a fundamentally different technical approach for their derivation.

Scientific Peer Review for Development of a Priority Persistent Pollutant List in Oregon, Portland, OR. Lead Project Scientist. Dr. Gensemer participated in two science peer review panels for the Oregon Department of Environmental Quality to support development of a list of priority persistent pollutants as dictated by Oregon Senate Bill 737. The first peer review panel helped compile scientific screening methods for development of the priority-persistent pollutant list (P3L) based on the physical and chemical properties of potentially toxic organic and inorganic chemicals. The final P3L of 118 chemicals includes current use pesticides, personal care products, pharmaceuticals, and legacy contaminants. The second peer review panel helped develop risk-based screening thresholds of P3L chemicals to help identify which chemicals were of the highest priority for development of toxics reduction plans for wastewater treatment plants throughout the state.

Screening-level and Baseline Ecological Risk Assessments for Mining Pit Lakes, Round Mountain Gold Corporation, Round Mountain, NV. Scientific Peer Review. Dr. Gensemer provided general technical peer review and assisted in project planning for an ecological risk assessment to determine risks to avian wildlife, terrestrial wildlife, and human health receptors for the future pit lake in the current permitted Round Mountain pit, and proposed expansion future pit lakes at Round Mountain and Gold Hill. Both screening-level and baseline ecological risk assessments were conducted according to EPA and Nevada guidance. Assessments were conducted at three specific time periods: 2 years post closure, 25 years post closure, and near lake level equilibrium (200 years post closure).

Updated Scientific Review of the Use and Application of Biomarkers for Polycyclic Aromatic Hydrocarbons in Aquatic Ecosystems, American Petroleum Institute, Washington, D.C. Lead Project Scientist. Dr. Gensemer was the project manager and senior scientist to conduct an updated technical overview of the state-of-the-science regarding biomarkers of polycyclic aromatic hydrocarbon (PAH) exposure and effects in aquatic ecosystems. The primary focus of the review was to present a technical understanding of, and suggested applications for, the most important and widely-used PAH biomarkers, and to evaluate whether or not biomarkers can be used reliably as indicators of ecological effects. The document provides scientists and risk managers with accessible information regarding the selection and proper interpretation of PAH biomarkers, and to understand both the technical benefits and limitations to their use in NRDA, ecological risk assessments, and other environmental applications.

Background Information Summary for Development of Listing Processes for Persistent, Bioaccumulative, and Toxic Chemicals, Oregon Association of Clean Water Agencies, and League of Oregon Cities, Portland, OR. Lead Project Scientist. Dr. Gensemer was the project manager and chief scientist tasked with development of a report to summarize background information regarding the regulatory and scientific approaches used by other governments (state, federal, and international) to identify and rank persistent, bioaccumulative, and toxic (PBT) chemicals. The primary goal of this report was to compile and summarize PBT ranking schemes used by various government and international organizations, and to prepare an analysis that compared and contrasted the various PBT chemical listing processes to provide a basis for proposing a list of chemicals that meet the definition of "persistent pollutant" under Oregon Senate Bill 737.

Evaluating Ozone as a Treatment for Removal of Nonindigenous Species in Marine Vessel Ballast Water, BP, U.S. Fish and Wildlife Service and NOAA, and Nutech O3, Inc., Seattle, WA. Lead Project Scientist. Dr. Gensemer served as project manager as part of a large multi-investigator study to evaluate the efficacy and environmental safety of ozone gas as a biocide for removal of nonindigenous marine organisms to prevent their introduction to remote coastal habitats from marine shipping ballast water. His project responsibilities included review and preparation of manuscripts and technical support, laboratory study design, and conduct of laboratory toxicity tests to quantify the efficacy and safety of ozonated seawater to surrogate laboratory species, and preparation of technical reports and peer-reviewed scientific publications.

Ambient Water Quality Criteria for Cyanide, Water Environment Research Foundation, Alexandria, VA. Principal Investigator. Dr. Gensemer was the project manager and principal investigator for a scientific reassessment of the EPA's Ambient Water Quality Criteria for cyanide. This project entailed a thorough review of the recent scientific literature, conducting of new aquatic toxicity tests for marine organisms, and application of new methods for analytical chemistry of free cyanides. All work was conducted to derive recommended ambient water quality criteria for protection of aquatic life in strict accordance with EPA guidance. The project's ultimate goal is to develop updated, integrated criteria that are protective, not only of aquatic life, but also of benthic organisms, threatened and endangered species, and aquatic-dependent wildlife.

AWWQRP Special Studies Project, Arid West Water Quality Research Project, Pima County Wastewater Management, Tucson, AZ. Principal Investigator. Dr. Gensemer was the principal investigator for two studies that were conducted to fill critical data gaps identified in earlier studies conducted under the auspices of the Arid West Water Quality Research Project. This project consisted of 1) conducting additional ammonia toxicity tests concurrently with GEI to confirm the relative roles of sodium vs. hardness in controlling ammonia toxicity, and 2) evaluating how EPA's Recalculation Procedure might apply to the newest version of the National AWQC for copper which is based on the Biotic Ligand Model.

Scientific Review of Proposed Water Quality Standards for the Herbicide, Acetochlor, Monsanto Corporation, St. Louis, MO. Lead Project Scientist. Dr. Gensemer conducted a scientific review of the methods and approaches used by Monsanto in recommending alternative water quality standards for acetochlor from those proposed by the Minnesota Pollution Control Agency (MPCA). Specifically, this review focused on where Monsanto's proposed methods and approaches differed from those used by MPCA, and evaluated whether these differences were supportable given the available plant toxicology data for acetochlor, and whether they were consistent with U.S. Environmental Protection Agency guidance for derivation of ambient water quality criteria for protection of aquatic life as well as MPCA's application of this guidance to derive their water quality standards for acetochlor.

Ammonia Toxicity in Very Hard Waters and Potential Use of the Water Effect Ratio, Arid West Water Quality Research Project, Pima County Wastewater Management, Tucson, AZ. Principal Investigator. Dr. Gensemer was principal investigator in a collaborative study to evaluate the toxicity of ammonia to freshwater organisms in very hard waters, and to use this information to determine whether the water-effect ratio might be a valid means of deriving site-specific water quality criteria for ammonia in very hard effluent-dependent waters in the arid southwestern U.S.

Relevance of the EPA Recalculation Procedure and Development of a User's Guide for Development of Site-specific Water Quality Criteria in Effluent-dependent Waters, URS, under the Arid West Water Quality Research Project, Pima County Wastewater Management, Tucson, AZ. Principal Investigator. Dr. Gensemer prepared a "user's guide" for use of EPA's Recalculation Procedure to modify national ambient water quality criteria on a site-specific basis. This user's guide was prepared in concert with a larger collaborative study to evaluate the scientific reliability of the Recalculation Procedure in effluent-dependent waters of the arid western U.S., and to recommend changes to make the process more scientifically robust in these unique environments.

Reliability of the Biotic Ligand Model for Copper in Very Hard Waters, Arid West Water Quality Research Project, Pima County Wastewater Management, Tucson, AZ. Principal Investigator. Dr. Gensemer served as project manager for a study to test the scientific reliability of the Biotic Ligand Model for copper in waters characteristic of effluent-dependent waters in the arid western U.S. The study primarily consisted of copper toxicity tests in effluent-dependent waters, coupled with a scientific comparison of empirical results to model predictions to evaluate their accuracy. His primary roles included project management, client stewardship, and presentation of project results.

Colorado Statewide Selenium Database, Colorado Wastewater Utility Council, Pueblo, CO. Project Manager. Dr. Gensemer was the project manager for development of a statewide selenium database to help support regulatory updates to water quality criteria for protection of aquatic life and wildlife in Colorado waters. Project tasks included compiling data, creating the database, and providing technical assistance with regards to options for site-specific modification of selenium standards. Dr. Gensemer's primary roles included project management, client stewardship, and giving project presentations.

Development of Cyanide Site-Specific Objectives, HydroQual, Inc., Los Angeles, CA. Lead Project Scientist. Dr. Gensemer served as project manager for a study to evaluate options for development of site-specific water quality objectives for the Sanitation Districts of Los Angeles County. His contributions included literature reviews, general scientific support, and conduct of preliminary laboratory toxicity studies to evaluate the potential use of water- effect ratios.

Preparation of Scientific Comments on Draft Selenium AWQC, American Petroleum Institute, and Colorado Wastewater Utility Council, Pueblo, CO. Project Manager. Dr. Gensemer participated in preparation of scientific comments to EPA in response to their public call for comments following release of the latest draft AWQC in 2004. Our comments focused on technical issues regarding studies used in derivation of the draft AWQC, as well as comments on major implementation issues and concerns with using a fish-tissue based chronic criterion concentration, rather than the aqueous concentrations typically used for AWQC.

Evaluation of Water Quality Criteria for Arid West Watercourses, Arid West Water Quality Research Project, Pima County Wastewater Management, Tucson, AZ. Principal Investigator. Dr. Gensemer was the project manager for evaluation of water quality criteria for arid west watercourses. This project evaluated several EPA AWQC documents (selenium, copper, ammonia, and diazinon) for their relevance to the unique hydrological, geochemical, and biological conditions of ephemeral and effluent-dominated watercourses in the arid West. Criteria evaluation also included general aspects of national criteria development and implementation methods.

Herbicide Ecological Risk Assessments in Support of a Programmatic Environmental Impact Survey, Bureau of Land Management, Western U.S. Risk Assessment Team Leader. Dr. Gensemer was the team leader for Herbicide Ecological Risk Assessments in Support of Programmatic EIS for the western U.S. Ecological risk assessments were conducted in support of a programmatic EIS for the Bureau of Land Management as part of their weed management programs. EPA risk assessment guidance was used as the basis of screening human health and ecological risks of up to five herbicides: diquat, fluoridone, imazapic, sulfometuron methyl, and diflufenzopyr. Herbicide risk evaluations were then used to support the biological assessments of several other weed management techniques. Dr. Gensemer's primary duties included helping develop the conceptual project approach and provided peer review for major work products.

Toxicity of Cadmium and Silver in Las Vegas Wash, City of Las Vegas, Douglas County, and City of Henderson, Las Vegas, NV. Project Manager. Dr. Gensemer was the project manager of a study to evaluate the toxicity of cadmium and silver in the very hard waters of the Las Vegas Wash. Studies included laboratory tests in reconstituted waters that mimic the ionic composition of the Las Vegas Wash in an attempt to better understand factors that control toxicity in an unusual ionic matrix. Studies were designed to support NPDES permit negotiations and potential development of site-specific water quality standards.

Database for the Toxicity of Lead to Aquatic Organisms, Int'l Lead Zinc Research Organization, Research Triangle, Chapel Hill, NC. Project Manager. Dr. Gensemer served as project manager for the compilation of a Pb toxicity database. He compiled a list of aquatic toxicity literature for lead, which were then ranked for relevancy and reliability criteria, and compiled into a database for use by the lead industry in preparing ecological risk assessments.

Molybdenum Ambient Water Quality Criteria Database, Cyprus Climax Metals Company, Henderson, CO. Lead Project Scientist. Dr. Gensemer was the lead project scientist for an evaluation of the existing aquatic toxicity data for molybdenum to determine the reliability of the data and to identify additional studies required for AWQC for protection of aquatic life. These studies were reviewed for scientific reliability and relevance for derivation of AWQC according to EPA guidance.

PUBLICATIONS

DeForest, D.K., Meyer, J.S., Gensemer, R.W., Gorsuch, J.W., and Adams, W.J. 2014. Protectiveness of copper aquatic life criteria/guidelines against olfactory impairment in fish: An international Comparison. Annual Meeting of the Society of Mining, Metallurgy, and Exploration, Preprint 14-062.

Roark, S. A., C. F. Wolf, G. D. De Jong, R. W. Gensemer, and S. P. Canton. 2013. Influences of subsampling and modeling assumptions on the U.S. Environmental Protection Agency field-based benchmark for conductivity. *Integrated Environmental Assessment and Monitoring* 9: 533-534.

Gensemer, R.W., Baker, S.D., and Canton, S.P. 2011. Challenges for Implementation of Copper Aquatic Life Criteria Using the Biotic Ligand Model: What are We Waiting For? Proceedings of the Impaired Waters Symposium 2011, Water Environment Foundation, pp. 542-553.

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PRESENTATIONS

Claytor, C.A., Roark, S.A., Gensemer, R.W., Hermanson, B., Bradley, K.B., and Murray, D.A. 2014. Keeping our eyes on the prize: Re-thinking risk assessment for improved preliminary remediation goals. Poster presentation at the 35th Annual Meeting of the Society of Environmental Toxicology and Chemistry – North America, Vancouver, BC. November 9-13.

DeForest, D.K., Meyer, J.S., Gensemer, R.W., Gorsuch, .JW., and Adams, W.J. 2014. Protectiveness of copper aquatic life criteria/guidelines against olfactory impairment in fish: An international comparison. Platform presentation at the 2014 Annual Meeting of the Society for Mining, Metallurgy, and Exploration, Salt Lake City, UT. February 23-26.

DeForest, D.K., Meyer, J.S., Gensemer, R.W., Gorsuch, J.W., and Adams, W.J. 2014. Protectiveness of copper aquatic life criteria/guidelines against olfactory impairment in fish: An international comparison. Platform presentation at the 35th Annual Meeting of the Society of Environmental Toxicology and Chemistry – North America, Vancouver, BC. November 9-13.

DeForest, D.K., Meyer, J.S., Gensemer, R.W., Gorsuch, J.W., Shephard, B.K., Zodrow, J.M., and Adams, W.J. 2014. Protectiveness of aquatic life criteria for copper against olfactory and behavioral effects in freshwater and saltwater fish. Platform presentation at the 2014 Salish Sea Ecosystem Conference, Seattle, WA. April 30 - May 2.

Gensemer, R.W., Claytor, C.A., Baker, S.D., DeForest, D.K., Meyer, J.S., and Gorsuch, J.W. 2014. Regulatory implementation of the copper BLM: What have we learned and how are we doing? Platform presentation at the 35th Annual Meeting of the Society of Environmental Toxicology and Chemistry – North America, Vancouver, BC. November 9-13.

Gondek, J., Claytor, C.A., Canton, S.P., Gensemer, R.W., and Gorsuch, J.W. 2014. A decision framework for data quality and usability in implementation of the Biotic Ligand Model for setting site-specific copper criteria. Platform presentation at the 35th Annual Meeting of the Society of Environmental Toxicology and Chemistry – North America, Vancouver, BC. November 9-13.

Kovach, A.K., Canton, S.P., Claytor, C.A., Gondek, J., Gensemer, R.W., and Gorsuch, J.W. 2014. Investigating the Effects of Using Estimated Water Quality Parameters in Generating Copper Water Quality Criteria Using the Biotic Ligand Model. Platform presentation at the 35th Annual Meeting of the Society of Environmental Toxicology and Chemistry – North America, Vancouver, BC. November 9-13.

Meyer, J.S., DeForest, D.K., Gensemer, R.W., Gorsuch, J.W., and Adams, W.J. 2014. Protectiveness of copper aquatic life criteria/guidelines against olfactory impairment in fish: An international comparison. Platform presentation at the 24th Annual Meeting of the Society of Environmental Toxicology and Chemistry – Europe, Basel, Switzerland. May 11-15.

Murray, D.A., Gensemer, R.W., and Claytor, C.A. 2014. Review of Risk Assessment Methods to Evaluate Potential Human Health Effects From Exposure to PPCPs in the Environment. Poster presentation at the 35th Annual Meeting of the Society of Environmental Toxicology and Chemistry – North America, Vancouver, BC. November 9-13.

Tobiason, S.A., Lewis, N., Gensemer, R.W., and DeForest, D.K. 2014. Potential Water Quality Criteria for Copper in Oregon State Fresh Waters based on the Biotic Ligand Model. Platform presentation at the 35th Annual Meeting of the Society of Environmental Toxicology and Chemistry – North America, Vancouver, BC. November 9-13.

Gensemer, R.W., J. Gondek, S. Baker, S. Canton, T.S. Foster, W.F. Burks, and J. Gorsuch. Adoption of a new risk-based approach for deriving water quality criteria for copper in Colorado. Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2013, Nashville, TN.

Gondek, J., R.W. Gensemer, W. Stubblefield, A. Cardwell, R.C. Santore, A.C. Ryan, W. Adams, and E. Nordheim. A comparative analysis of aquatic HC_{05} values for aluminum using Biotic Ligand Model- vs. hardness-normalized toxicity data. Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2013, Nashville, TN.

Love, N., Gensemer, R., Baker, S., Canton, S., Skigen, S., Sanderson, S., and Fry, E. Studies to Support Implementation of Aquatic Life Criteria for Poorly Soluble Metals. Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2013, Nashville, TN.

S. Roark, G. De Jong, J. Lynch, A. Gevertz, R. Gensemer, and S. Canton. An analysis of replicate macroinvertebrate samples to assess uncertainty in measures of presence and absence of taxa in West Virginia streams. Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2013, Nashville, TN.

Meyer, J.S., DeForest, D.K., Gensemer, R.W., Shephard, B.K., Zodrow, J.M., Gorsuch, J.W., Adams, W.J. U.S. EPA biotic ligand model-based aquatic life criteria are protective against copper-caused impairment of olfaction in salmonid fishes. European Annual Meeting of the Society of Environmental Toxicology and Chemistry. May 2013, Glasgow, Scotland.

R.W. Gensemer, D.K. DeForest, J.W. Gorsuch, and W.J. Adams. Regulatory Implications of Chemosensory and Behavioral Effects of Copper to Fish. Annual Meeting of the Society of Mining, Metallurgy, and Exploration. February 2013, Denver, CO.

R.W. Gensemer, S. Canton, and S. Baker. Studies to Support Implementation of Aquatic Life Criteria for Poorly Soluble Metals. Annual Meeting of the Colorado Mining Association. February 2013, Denver, CO.

J.S. Meyer, D.K. DeForest, R.W. Gensemer, J.W. Gorsuch, and W.J. Adams. Aquatic Life Criteria Are Protective Against Copper-Caused Impairment of Olfaction in Salmonid Fishes. Annual Meeting of the Society of Mining, Metallurgy, and Exploration. February 2013, Denver, CO.

K.B. Bradley, R.W. Gensemer, B. Hermanson, and S.A. Roark. Looking Back to See Ahead: The Current and Future Role of Ecological Risk Assessment in Sediment Remedial Decisions. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2012, Long Beach, CA.

W.A Stubblefield, A.S. Cardwell, W.J. Adams, R.W. Gensemer, E. Nordheim, and R.C. Santore. The toxicity of aluminum to 6 different aquatic species, at a pH of 6. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2012, Long Beach, CA.

S.A Roark, C.F. Wolf, G.D. DeJong, R.W. Gensemer, and S.P. Canton. Inferring absence of taxa using fixed-count subsamples of aquatic invertebrates: uncertainty in the US EPA field-based benchmark for conductivity. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2012, Long Beach, CA.

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R.W Gensemer, D.K. DeForest, and J. Meyer. Regulatory Implications of Chemosensory and Behavioral Effects of Anthropogenic Chemicals to Fish. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2012, Long Beach, CA.

J. Gondek, R.W. Gensemer, S.D. Baker, C. Claytor, and J. Gorsuch. Alternatives for Derivation of Aquatic Life Criteria for Copper using the Biotic Ligand Model. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2012, Long Beach, CA.

A.S. Cardwell, W.A. Stubblefield, W.J. Adams, R.W. Gensemer, E. Nordheim, and R.C. Santore. Evaluation of aluminum chronic toxicity to the fathead minnow and zebrafish using a flow-through pH-control toxicity test system. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2012, Long Beach, CA.

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S.P. Canton, J.S. Lynch, R.W. Gensemer, G.D. DeJong, and C.F. Wolf. Longitudinal Effects of Coal Mining/Valley Fills on Benthic Invertebrate Communities of Streams in Southern West Virginia. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2011, Boston, MA.

S.P. Canton, G.D. DeJong, and R.W. Gensemer. Do Water Quality and Habitat Conditions Affect Macroinvertebrate Communities in Headwater Streams in Southern West Virginia? North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2011, Boston, MA.

R.W. Gensemer, and S.P. Canton. Field vs. Laboratory-based Approaches for Derivation of Aquatic Life Criteria: Just Because We Can, Does It Mean We Should? North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2011, Boston, MA.

K. Bradley, C. Claytor, A. Leifer, and R.W. Gensemer. Residual Ecological Risk Assessment Case Study: Assessing Risk in Wetlands Habitat. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. November 2011, Boston, MA.

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Barber K., S.P. Canton, R.W. Gensemer, and D. Terry. Consideration of Physical Stressors in Ecological Risk Assessment at Urban Sediment Remediation Sites. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. Portland, OR, November 2010.

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Gensemer R.W., S. Canton, W. Adams, R. Santore, A. Ryan , W. Stubblefield, A. Cardwell , P. Rodríguez, D. DeForest, and E. Nordheim. Scientific Alternatives for Deriving Aquatic Life Criteria for Aluminum as a Function of pH, Hardness, and Dissolved Organic Carbon. North America Annual Meeting of the Society of Environmental Toxicology and Chemistry. Portland, OR, November 2010.

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Gensemer, R.W., D.K. DeForest, R.D. Cardwell, D. Dzombak, R. Santore, and M. Stewart. New Analysis of Cyanide Toxicology and Ambient Water Quality Criteria: An Integrated Approach to Protection of the Aquatic Environment. Water Environment Foundation, TMDL 2007 Specialty Conference. Bellevue, WA, June 2007.

Van Genderen, E., Gensemer, R.W., Smith, C., Santore, R., Ryan, A., Ramage, K., Curley, E., and Meyerhoff, R. Evaluation of Copper Criteria in Very Hard Water. Water Environment Foundation, TMDL 2007 Specialty Conference. Bellevue, WA, June 2007.

Wall, Lareina, Steven Canton, Michael Carney, Robert Gensemer, Mark Murphy, Ed Curley, Karen Ramage, and Richard Meyerhoff. Evaluation of the USEPA Recalculation Procedure to Derive Site-Specific Criteria in Arid West Effluent Dependent/Dominated Waters – an Integral Step in TMDL Development. Water Environment Foundation, TMDL 2007 Specialty Conference. Bellevue, WA, June 2007.

Gensemer, R.W., and Reiley, M., co-chairs for Special Session: Research Needs for Water Quality Protection in Regulatory Programs: Regional and National Trends. Society of Environmental Toxicology and Chemistry, Annual Meeting, Montrèal, Canada, November 2006.

Gensemer, R.W., D.K. DeForest, R.D. Cardwell, D. Dzombak, R. Santore, and M. Stewart. Reassessment of Cyanide Ambient Water Quality Criteria: An Integrated Approach to Protection of the Aquatic Environment. Society of Environmental Toxicology and Chemistry, Annual Meeting, Montrèal, Canada, November 2006.

Canton, S.P., Wall, L.G., Carney, M.W., Wolf, C., Gensemer, R., Murphy, M., Curley, E., Ramage, K., and Meyerhoff, R. Evaluation of the USEPA Recalculation Procedure to Derive Site-Specific Criteria in Arid West Effluent Dependent/Dominated Waters - Is it Worth the Effort? Society of Environmental Toxicology and Chemistry, Annual Meeting, Montrèal, Canada, November 2006.

Carney, M.W., Canton, S.P., Wall, L.G., Gensemer, R.W., Murphy, M., Curley, E., Ramage, K., and Meyerhoff, R. National Ambient Water Quality Criteria Updates Resulting From an Evaluation of the Recalculation Procedure in Arid West Effluent Dependent Waters. Society of Environmental Toxicology and Chemistry, Annual Meeting, Montrèal, Canada, November 2006.

Wall, L.G., Canton, S.P., Carney, M.W., Wolf, C., Gensemer, R.W, Murphy, M., Curley, E., Ramage, K., and Meyerhoff, R. Evaluation of the USEPA Recalculation Procedure to Derive Site-Specific Criteria in Arid West Effluent Dependent/Dominated Waters – Potential Regional Method Adjustments. Society of Environmental Toxicology and Chemistry, Annual Meeting, Montrèal, Canada, November 2006.

Gensemer, R.W., D.K. DeForest, R.D. Cardwell, D. Dzombak, R. Santore, and M. Stewart. Reassessment of Cyanide Ambient Water Quality Criteria: An Integrated Approach to Protection of the Aquatic Environment. Water Environment Foundation WEFTEC meeting, Dallas, TX, November 2006.

Gensemer, R.W., Volosin, J., J.M. Clark, and R.D. Cardwell. Are Water Quality Criteria for Cyanide Protective of Aquatic-Dependent Wildlife? Society of Environmental Toxicology and Chemistry, Annual Meeting and World Congress, Portland, OR, November 2004.

Caldwell, R., R.W. Gensemer, and R.D. Cardwell. The Toxicity of Free Cyanide to Yellow Rock Crab (*Cancer irroratus*) first stage zoeae. Society of Environmental Toxicology and Chemistry, Annual Meeting and World Congress, Portland, OR, November 2004.

Gensemer, R.W., R.S. Caldwell, S. Paulus, and P. Crawford. Derivation of Toxicity Reference Values for the Acute and Chronic Toxicity of RDX to Marine Organisms. Society of Environmental Toxicology and Chemistry, Annual Meeting and World Congress, Portland, OR, November 2004.

DeForest, D.K., R.W. Gensemer, and M. Stewart. Review and Analysis of Potential Cyanide Toxicity to Freshwater Threatened and Endangered Species. Society of Environmental Toxicology and Chemistry, Annual Meeting and World Congress, Portland, OR, November 2004.

Stubblefield, W.A., R.W. Gensemer, W. Cooper, and G. Ruiz. Ballast Water Treatment Strategies: Evaluation of Efficacy and Post-treatment Environmental Concerns. Society of Environmental Toxicology and Chemistry, Annual Meeting and World Congress, Portland, OR, November 2004.

Caldwell, R., R.W. Gensemer, and R.D. Cardwell. The Toxicity of Free Cyanide to Yellow Rock Crab (*Cancer irroratus*) first stage zoeae. Pacific Northwest Regional Chapter of the Society of Environmental Toxicology and Chemistry, Port Townsend, WA, May 2004.

Gensemer, R.W., Dethloff, G.M., Stubblefield, W.A., and Cooper, W.J. Toxicity of Ozonated Ballast Water to Marine Organisms. Society of Environmental Toxicology and Chemistry, Annual Meeting, Austin, TX. November 2003.

Dethloff, G.M., Gensemer, R.W., Fischer, D.C., Neher, M., and Paulsen, D. Water Quality Characteristics and Metal Toxicity in Very Hard Waters. Society of Environmental Toxicology and Chemistry, Annual Meeting, Austin, TX. November 2003.

DeForest, D.K., Brix, K.V., Adams, W.J., Gensemer, R.W., Curley, E. and Sierra, K.R. Relevance and Applicability of Ambient Water Quality Criteria for Selenium in Arid West Streams. Society of Environmental Toxicology and Chemistry, Annual Meeting. Salt Lake City, NV. November 2002.

Dethloff, G.M., Tilquist, H., Gensemer, R.W., Curley, E., and Sierra, K.R. The recovery of arid western stream assemblages from disturbance, and its relevance to the frequency of allowed AWQC excursions. Society of Environmental Toxicology and Chemistry, Annual Meeting. Salt Lake City, NV. November 2002.

Gensemer, R.W., Dethloff, G.M., Gerath, M., Curley,E., and Sierra, K.R. Application of Ambient Water Quality Criteria to Ephemeral and Effluent-dependent Waters. Society of Environmental Toxicology and Chemistry, Annual Meeting. Salt Lake City, NV. November 2002.

Pillard, D.A. and Gensemer, R.W. Adverse Effects of Pavement Anti-icers and Deicers to Ponderosa Pine. Society of Environmental Toxicology and Chemistry, Annual Meeting. Salt Lake City, NV. November 2002.

Santore, R.C., Sopher, E., Mathew, R., Paquin, P.R., Gensemer, R.W., Naddy, R.B., Medine, A., Curley, E., and Sierra, K. Use of the Biotic Ligand Model to Evaluate Bioavailability of Copper in Arid West Watercourses. Society of Environmental Toxicology and Chemistry, Annual Meeting. Salt Lake City, NV. November 2002.

Cooper, W.J., P.A. Dinnel, R.W. Gensemer, R.P. Herwig, J.A. Kopp, G.M. Ruiz, G. Sonnevil, W.A. Stubblefield, and E. VanderWende. Ozone, seawater and aquatic nonindigenous species: testing a full-scale ozone ballast water treatment system on an American oil tanker. Eleventh International Conference on Aquatic Invasive Species, Alexandria, VA. February 2002.

Gensemer, R.W., R.B. Naddy, W.A. Stubblefield, J.R. Hockett, K. Brix, D. DeForest, R. Santore, and P. Paquin. Evaluating copper toxicity to *Ceriodaphnia dubia* in waters greater than 400 mg/L hardness. Society of Environmental Toxicology and Chemistry, Annual Meeting. Baltimore, MD, November 2001.

Gensemer, R.W., and D.A. Pillard. Use of chlorophyll fluorescence to detect plant stress from anti-icers/deicers. Society of Environmental Toxicology and Chemistry, Annual Meeting. Nashville, TN, November 2000.

Gensemer, R.W., R.C. Playle, W.A. Stubblefield, and J.R. Hockett. Aluminum bioavailability and toxicity at circumneutral and higher pH. Society of Environmental Toxicology and Chemistry, Annual Meeting. Philadelphia, PA, November 1999.

Naddy, R.B., F.W. Vertucci, R.W. Gensemer, and W.A. Stubblefield. Evaluation of exposure-effects relationships of metals in the benthic macroinvertebrate community in the Upper Clark Fork River, Montana. Society of Environmental Toxicology and Chemistry, Annual Meeting. Philadelphia, PA, November 1999.

Walsh, J.T., R.H. Michener, L. Kaufman, and R.W. Gensemer. Use of stable isotopes to evaluate trophic responses in standardized aquatic microcosms to combined pesticide contamination and nutrient loading. Society of Environmental Toxicology and Chemistry, Annual Meeting. Philadelphia, PA, November 1999.

Rie, M.T., Lendas, K.A., Woodin, B., Stegeman, J.J., Gensemer, R.W., and Callard, I.P. Hepatic bioindicator enzymes in a sentinel species (*Chrysemys picta*) from Cape Cod, Massachusetts: Seasonal, sex and location related differences. Society for Environmental Toxicology and Chemistry, annual meeting. Charlotte, NC, November 1998.

Walsh, J.T., S. Kustron, L. Kaufman, and R.W. Gensemer. Effects of Nutrients on Amphipod Responses to the Insecticide Heptachlor Epoxide. Society for Environmental Toxicology and Chemistry, annual meeting. Charlotte, NC, November 1998.

Marsh, D.E., J. Prystupa, and R.W. Gensemer. Development of photosynthetic assays for the toxicity of organics and metals using submerged rooted macrophytes. National Institute of Environmental Health Sciences, Superfund Basic Research Program conference, Cambridge, MA, March 1998.

Gensemer, R.W., N. Cardinale, and L. Anderson. Interactions between phosphorus limitation and anthracene toxicity to microalgae as detected by chlorophyll fluorescence induction. Society for Environmental Toxicology and Chemistry, annual meeting. San Francisco, CA, November 1997.

Marsh, D.E., J. Prystupa, and R.W. Gensemer. Development of photosynthetic assays for the toxicity of organics and metals using submerged rooted macrophytes. Society for Environmental Toxicology and Chemistry, annual meeting. San Francisco, CA, November 1997.

Walsh, J.T., L. Kaufman, and R.W. Gensemer. Nutrient constraints on pesticide toxicity in standardized aquatic microcosms. Society for Environmental Toxicology and Chemistry, annual meeting. San Francisco, CA, November 1997.

Gensemer, R.W., M. Caggiano, and B. Simms. UV-induced changes in humic acid and its effects of PAH toxicity to the aquatic macrophyte *Lemna gibba*. American Society for Limnology and Oceanography, Aquatic Sciences meeting. Santa Fe, NM, February 1997.

Marsh, D.E., and R.W. Gensemer. Development of photosynthetic assays for the toxicity of solvents, hydrocarbons, and metals using submerged rooted macrophytes. National Institute of Environmental Health Sciences, Superfund Basic Research Program conference, Chapel-Hill, NC, February, 1997.

Gensemer, R.W., and M. Caggiano. UV-induced changes in humic acid and its effects on PAH phototoxicity to aquatic macrophytes. Annual meeting of the Society for Environmental Toxicology and Chemistry, Washington, D.C., November 1996.

Marsh, D.E. and R.W. Gensemer. Photosynthetic endpoints for the toxicity of organics and heavy metals using freshwater phytoplankton. Annual meeting of the Society for Environmental Toxicology and Chemistry, Washington, D.C., November 1996.

Rie, M.T., O. Putz, R.W. Gensemer, and I.P. Callard. Cadmium: Distribution and impact on reproduction in the female little skate (*Raja erinacea*). Annual meeting of the Society for Environmental Toxicology and Chemistry, Washington, D.C., November 1996.

J.T. Walsh, S. Akashi, L. Kaufman, and R.W. Gensemer. Interactive effects of nutrient availability and heptachlor treatment on Standardized Aquatic Microcosms. Annual meeting of the Society for Environmental Toxicology and Chemistry, Washington, D.C., November 1996.

Gensemer, R.W., M. Caggiano, M. Rie, and B. Simms. Using photosynthetic biomarkers to quantify the amelioration of PAH phototoxicity by humic acid. Sixth Symposium on Environmental Toxicology and Risk assessment: Modeling and Risk Assessment. American Society for Testing and Materials, Committee E-47. Orlando, FL. April 1996.

X.-D. Huang, B.M. Greenberg, C.A. Marwood, K.R. Solomon, R.W. Gensemer, and R. Popovic. Inhibition of photosynthesis as an endpoint for the photoinduced toxicity of intact and photooxidized PAHs. Sixth Symposium on Environmental Toxicology and Risk assessment: Modeling and Risk Assessment. American Society for Testing and Materials, Committee E-47. Orlando, FL. April 1996.

Gensemer, R.W., K.R. Solomon, K.E. Day, L. Ren, and B.M. Greenberg. Validating biomarkers of creosote phototoxicity to the aquatic plant *Lemna gibba*. Annual meeting of the Society for Environmental Toxicology and Chemistry, Vancouver, B.C. November 1995.

Munro, K.A., K.T. Bestari, J.H. McCann, R.D. Robinson, R.W. Gensemer, and K.R. Solomon. Evaluation of fish population effects due to creosote exposure in aquatic mesocosms. 22nd Annual Aquatic Toxicity Workshop and Environmental Effects Symposium. St. Andrews, N.B. October 1995.

Gensemer, R.W. Validating biomarkers of creosote phototoxicity to the aquatic plant *Lemna gibba*. Annual meeting of the North Atlantic Chapter of the Society for Environmental Toxicology and Chemistry, Plymouth, MA, July 1995.

Gensemer, R.W., C.A. Marwood, K.E. Day, R. Robinson, K.R. Solomon, and B.M. Greenberg. Fluorescence induction as a bioindicator of creosote toxicity in plants. Annual Meeting of the Canadian Network of Toxicology Centres, Toronto, Ontario. May, 1995.

Marwood, C.A., K.R. Solomon, R.W. Gensemer, and B.M. Greenberg. Mesocosm studies of creosote: Fluorescence induction in plants as a bioindicator. Annual Meeting of the Canadian Network of Toxicology Centres, Toronto, Ontario. May, 1995.

Gensemer, R.W., L. Ren, K.E. Day, K.R. Solomon, and B.M. Greenberg. Fluorescence Induction as a Biomarker of Creosote Phototoxicity to the Aquatic Macrophyte *Lemna gibba*. 5th Symposium on Environmental Toxicology and Risk Assessment, American Society for Testing and Materials, Denver, CO. April, 1995.

Gensemer, R.W., K.R. Solomon, K.E. Day, P.V. Hodson, M.R. Servos, and B.M. Greenberg. Plant bioindicators for polycyclic aromatic hydrocarbon toxicity in aquatic microcosms. 15th Annual SETAC meeting, Denver, CO. November, 1994.

McCann, J.H., K.R. Solomon, and R.W. Gensemer. Population structure changes in zooplankton following PAH exposure in aquatic mesocosms. 15th Annual SETAC meeting, Denver, CO. November, 1994.

Munro, K.A., K.R. Solomon, R.W. Gensemer, G.J. VanDerKraak, K.E. Day, and M.R. Servos. Validating bioindicators of PAH effects in fish: Evaluating responsiveness to creosote exposure in aquatic mesocosms. 15th Annual SETAC meeting, Denver, CO. November, 1994.

Gensemer, R.W., K.R. Solomon, and B.M. Greenberg. The use of mesocosms to assess creosote toxicity in aquatic plants: Biomarkers and their validation at the population level. 21st Annual Aquatic Toxicity Workshop, Sarnia, Ontario. October, 1994.

McCann, J.H., K.R. Solomon, and R.W. Gensemer. Population structure changes in zooplankton following PAH exposure in aquatic microcosms. 21st Annual Aquatic Toxicity Workshop, Sarnia, Ontario. October, 1994.

Gensemer, R.W., R.E.H. Smith, and H.C. Duthie. Interactions of pH and aluminum on cell length reduction in *Asterionella ralfsii* var. *americana* Körn. 13th International Diatom Symposium, Acquafredda di Maratea, Italy. September 1994.

Gensemer, R.W., D.G. Dixon, and B.M. Greenberg. Amelioration of the UV-induced phototoxicity of polycyclic aromatic hydrocarbons to *Lemna gibba* by humic acid. Annual meeting of the Society of Environmental Chemistry and Toxicology, Houston, Texas. November 1993.

Gensemer, R.W., R.E.H. Smith, and H.C. Duthie. Interactions of pH and aluminum on cell length and colony structure in a freshwater diatom common to Kejimkujik waters. Workshop on the Kejimkujik Watershed Studies, Kejimkujik National Park, Nova Scotia. October 1993.

Gensemer, R.W., R.E.H. Smith, H.C. Duthie, and S.L. Schiff. pH tolerance and metal toxicity in the planktonic diatom *Asterionella*: Influences of synthetic and natural dissolved organic carbon. Society of Canadian Limnologists annual meeting, Trent University, Peterborough, Ontario. January 1993.

Gensemer, R.W., R.E.H. Smith, H.C. Duthie, and S.L. Schiff. Role of natural and synthetic DOC in pH tolerance by populations of the planktonic diatom *Asterionella* from lakes in Kejimkujik National Park, Nova Scotia. American Society of Limnology and Oceanography annual meeting, Halifax, Nova Scotia. June 1991.

Gensemer, R.W. Changes in cellular morphology of *Asterionella ralfsii* var. *americana*: the role of aluminum and growth rate. International Conference on Acidic Deposition: Its Nature and Impacts. Glasgow, Scotland. September 1990.

Gensemer, R.W. Aluminum chemistry in an artificial culture system: implications for metal ion bioavailability estimations. International Conference on Acidic Deposition: Its Nature and Impacts. Glasgow, Scotland. September 1990.

Gensemer, R.W. Changes in cell size and silica content of silica-limited populations of *Asterionella ralfsii* var. *americana*: the role of aluminum and growth rate. North American Diatom Symposium, Lake Itasca, MN. October 1989.

Gensemer, R.W. The effect of aluminum on silica limited growth in the acidophilic diatom *Asterionella ralfsii*. American Society of Limnology and Oceanography. Boulder, CO. June 1988.

Gensemer, R.W. The effects of aluminum on P and Si limitation in *Asterionella ralfsii*. North American Diatom Symposium Treehaven, Wisconsin. October 1987.

Riseng, C.R., and R.W. Gensemer. The response of an acidophilic and a circumneutral clone of *Asterionella* to aluminum: The importance of pH and trace metal interactions. Phycological Society of America. Columbus, Ohio. August 1987.

Gensemer, R.W. The pH-dependent response of an acidophilic and a circumneutral clone of the planktonic diatom *Asterionella* to aluminum. American Society of Limnology and Oceanography. Madison, Wisconsin. June 1987.

Bowers, J.A., R.W. Gensemer, and R.M. Dorazio. The role of diel vertical migration in the predator-prey relationships between *Mysis relicta* and cladocera in Lake Michigan. American Society of Limnology and Oceanography. Madison, Wisconsin. June 1987.

Gensemer, R.W. The interaction of pH and Al chemistry: Its effect on the growth of three freshwater phytoplankton. Phycological Society of America. Kingston, Rhode Island. June 1986.

Bowers, J.A., and R.W. Gensemer. Improved population estimates of *Mysis relicta* in Lake Michigan. International Association for Great Lakes Research. Scarborough, Ontario. May 1986.

Gensemer, R.W., and S.S. Kilham. Growth rates of five freshwater algae in well-buffered acidic media. International Association for Great Lakes Research. St. Catharines, Ontario. May 1984.

INVITED TALKS/SEMINARS

2014: Claytor, C.A., R.W. Gensemer, and B. Hermanson. New methods for developing water quality criteria. Environmental Law Education Center, Water Quality Conference, April 2014. Portland, OR.

Gensemer, R.W., C.A. Claytor, and B. Hermanson. The Biotic Ligand Model for copper – overview and implementation. Presented with M. Campbell as part of a special session: Ideas for tackling Oregon's copper water quality standard. Oregon Association of Clean Water Agencies Annual Meeting, July 2014. Bend, OR.

2012: R.W. Gensemer, S.P. Canton, C.A. Claytor, D. Murray, K. Bradley, and D. Terry. Competing Regulatory Demands for Making Risk-based Cleanup Decisions at Sediment Sites. 4th International Symposium and Exhibition on the Redevelopment of Manufactured Gas Plant Sites (MGP2012). Chicago, IL.

2011: R.W. Gensemer, S.P. Canton, G. DeJong, C. Wolf, and C. Claytor. 2011. Should There be an Aquatic Life Aquatic Water Quality Criterion for Conductivity? West Virginia Mine Drainage Task Force, Annual Symposium, March 2011, Morgantown, WV.

Gensemer, R.W. Ecological and Human Health Risks from Toxic Pollutants: What are the ultimate goals for toxics reduction? Environmental Law Education Center, 2011 Conference on Water Quality and Toxics, March, 2011, Portland, OR.

2009: Gensemer, R.W. Evaluating the Aquatic Life Risks of Contaminants of "Emerging" Concern: Ecological Effects of the P3 List. Environmental Law Education Center, 2009 Toxics Conference, Portland, Oregon, June 2009.

2007: Gensemer, R.W. Scientific Review of Cyanide Ecotoxicology and Evaluation of Ambient Water Quality Criteria. Water Environment Research Foundation Program Area Meeting. Berkeley, CA, December 2007.

2004: Gensemer, R.W. Re-evaluation of Water Quality Criteria for Cyanide, In: "Looking to the Future by Reevaluating Water Quality Criteria Now." Workshop sponsored by Water Environment Research Foundation at the WEFTEC Annual Meeting, New Orleans, LA, October 2004.

Gensemer, R.W. Participant in Water Quality/Surface Water Panel of Nevada Water Resources Association Annual Conference, Mesquite, NV, February 2004.

Ryti, R, J. Markwiese, R.W. Gensemer, and R.D. Meyerhoff. Ecological Risk Assessment Methods for Arid Environments. Workshop held at the Society of Risk Analysis Annual Meeting, Palm Springs, CA, December 2004.

2003: Gensemer, R.W., DeForest, D., Gerath, M., Brix, K.V., Santore, R., Curley, E., Sierra, K.R. Application of Ambient Water Quality Criteria to Ephemeral and Effluent-dependent Waters in the Arid West. Arid West "Extant Criteria Study" Symposium, Colorado Department of Public Health and Environment, Denver, CO. July 2003.

2002: Gensemer, R.W., G.M. Dethloff, M. Gerath, D. DeForest, K. Brix, and R. Santore. Evaluating water quality criteria for designated uses in ephemeral and effluent-dependent watercourses of the arid west. USEPA National Symposium: Designating Attainable Uses for the Nation's Waters. June, 2002.

2001: Can biomarkers predict ecological effects in aquatic ecosystems? Environmental Health Seminar Series, Colorado State University, CO.

Extant Criteria Evaluation Study: Overview and Preliminary Results. Colorado Water Quality Forum Presentation, Denver, CO.

Extant Criteria Evaluation Study: Overview and Preliminary Results. Colorado Wastewater Utility Council Presentation, Denver, CO.

2000: Aluminum bioavailability and toxicity to aquatic organisms at basic pH. Environmental Health Seminar Series, Colorado State University, Fort Collins, CO.

Can biomarkers predict ecological effects? Which ones are useful and effective? Northwest Toxicity Assessment Group. Portland, OR.

1998: Evaluating contaminant stress in aquatic plants using physiological bioindicators: are they ecologically meaningful? Savannah River Ecology Lab, Aiken, SC.

Evaluating contaminant stress in aquatic plants using chlorophyll fluorescence induction. ENSR Consulting, Fort Collins, CO.

Evaluating contaminant stress in aquatic plants using chlorophyll fluorescence induction. USEPA Atlantic Ecology Lab, Narragansett, RI.

1997: Evaluating contaminant stress in aquatic plants using physiological bioindicators: are they ecologically meaningful? Hagler-Bailly Inc., Boulder, CO.

Evaluating contaminant stress in aquatic plants using physiological bioindicators: are they ecologically meaningful? Department of Biology, Kent State University, Kent, OH.

1996: The development and significance of suborganismal assays to assess the impact of chemical contaminants on aquatic plants. Department of Environmental and Plant Biology, Ohio University, Athens, OH.

The use of suborganismal endpoints in environmental toxicology. Presentation to Advanced Topics in Environmental Health class (SPEH 830), Boston University School of Public Health. Boston, MA.

1995: The use of biomarkers in ecotoxicology: at what ecological level should we assess the impact of pollutants? Lunch Seminar Series, Center for Energy and Environmental Studies, Boston University, Boston, MA.

The development and validation of aquatic plant biomarkers to assess the impact of polycyclic aromatic hydrocarbons. Environmental Sciences Seminar Series, University of Massachusetts Boston, Boston, MA.

1994: Dissolved organic carbon as a moderator of environmental contaminant toxicity to aquatic plants. University of Nevada Las Vegas, Las Vegas, NV.

Dissolved organic carbon as a moderator of environmental contaminant toxicity to aquatic plants. Boston University, Boston, MA.

1993: Freshwater diatoms as bioindicators of acidification and trace metal pollution in humic lakes. University of Toledo, Toledo, Ohio.

Freshwater diatoms as bioindicators of acidification and trace metal pollution in humic lakes. Framingham State College, Framingham, Massachusetts.

Freshwater diatoms as bioindicators of acidification and trace metal pollution in humic lakes. Wright State University, Dayton, Ohio.

Re-interpreting the history of acid lakes on the basis of the physiological ecology of planktonic diatoms. Biology Department Seminar Series, University of Toronto, Erindale campus, Mississauga, Ontario.

1992: pH tolerance and metal toxicity in planktonic diatoms: The influence of dissolved organic carbon. Naturalist seminar series, The Academy of Natural Sciences, Philadelphia, PA.

pH tolerance and metal toxicity in planktonic diatoms: The influence of dissolved organic carbon. Eco-Lunch series, York University, Toronto, Ontario.

1991: Physiological and morphological effects of aluminum and pH on the acidophilic diatom *Asterionella*. Limnology seminar, Queen's University, Kingston, Ontario.

1990: Effects of aluminum and pH on the physiological ecology of acidophilic diatoms. GIROQ Lunch Seminar Series, Laval University, Québec.

1989: The influence of aluminum and pH on the physiological ecology of diatoms in acidic habitats. Plant Ecology Seminar Series, Department of Biology, University of Indiana.

The influence of aluminum and pH on the physiological ecology of acidophilic diatoms. Guest Seminar Series, Department of Biology, University of Waterloo.

The influence of aluminum and pH on the physiological ecology of acidophilic diatoms. Resource Ecology and Management Seminar Series, School of Natural Resources, University of Michigan.

OTHER PROFESSIONAL ACTIVITIES

Participant – Water Quality Committee for Oregon Association of Clean Water Agencies. October 2007 to December 2011.

Program Committee and Co-chair of Exhibits Subcommittee – North America Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC), Portland, OR, November 2010.

Editorial Board – *Integrated Environmental Assessment and Management*. January 2007 to December 2009.

Editor-in-Chief – *SETAC Globe*: a newsletter for the Society for Environmental Toxicology and Chemistry. January 2004 to January 2007.

Chair – *Integrated Environmental Assessment and Management* Implementation Committee, Society for Environmental Toxicology and Chemistry. November 2002 to November 2004.

Chair – New Journal Task Force, Society for Environmental Toxicology and Chemistry. May 2001 to November 2002.

Editorial Board – *Environmental Toxicology and Chemistry*. January 2001 to December 2003.

North American Editor – *SETAC Globe*: a newsletter for the Society for Environmental Toxicology and Chemistry. January 2000 to December 2003.

Member – Publications Advisory Council for Society for Environmental Toxicology and Chemistry. January 2000 to January 2007.

Member – American Society for Testing and Materials, committee E47 (Biological Effects and Environmental Fate), plant toxicology subcommittee. Active participation in standard development and review. April 1995 to present.

Symposium Co-chair – 10th Symposium on Environmental Toxicology and Risk Assessment: Science, Policy, and Standardization: Implications for Environmental Decisions. American Society of Testing and Materials. April 2000.

Member, Board of Directors – North Atlantic Chapter of the Society for Environmental Toxicology and Chemistry. June 1997 to January 1999. Vice President, June 1998 to January 1999.

Chair, Short-course Committee – North Atlantic Chapter of the Society for Environmental Toxicology and Chemistry. 1998.

Member – Barnstable County Scientific Advisory Board, Barnstable, MA. Advised Barnstable County officials regarding scientific aspects of Massachusetts Military Reservation Superfund site cleanup and potential environmental effects. January 1995 to January 1999.

Grant Proposal Peer Review – National Sciences and Engineering Research Council, Canada.

Peer Review of Manuscripts - Have reviewed manuscripts for a number of scientific publications, including:

American Society for Testing and Materials publications, *Environmental Toxicology and Chemistry*, *The Bulletin of The New Jersey Academy of Science*, *Conservation Biology*, *Integrated Environmental Assessment and Management*, *Journal of Environmental Quality*, *Journal of Great Lakes Research*, *Journal of Environmental and Experimental Botany*, *Canadian Journal of Fisheries and Aquatic Science*, *Canadian Journal of Botany*, *Hydrobiologia*, *European Journal of Phycology*, *Water Air and Soil Pollution*, *Water Research*, *Limnology and Oceanography*, and *Environmental Science and Technology*.

University Teaching – Oregon State University (2006 – 2008): Ecological Risk Assessment.

University Teaching, Assistant Professor - Boston University (1995-1998): Environmental Ecology, Ecotoxicology.

University Teaching – University of Waterloo (1992-1993): Ecology, Marine Biology, Field Biology.

Graduate Student Teaching – University of Michigan (1982-1988): Introductory Biology Laboratory, General Ecology, Limnology Laboratory (coordinator), Microbiology lab (coordinator), Plant Physiology Laboratory.

Updated Freshwater Aquatic Life Criteria for Aluminum (Exhibit 2 of Direct Testimony of Robert W. Gensemer, Ph.D.)

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GENSEMER TESTIMONY
EXHIBIT 2

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ACRONYMS

ACR	acute-chronic ratio
Al	aluminum
AWQC	ambient water quality criteria
CCC	criterion continuous concentration (chronic criterion)
CMC	criterion maximum concentration (acute criterion)
EC50	median effect concentration –point estimate for 50% effect
FACR	final ACR
FAV	final acute value
FCV	final chronic value
GMAVs	genus mean acute values
LC50	median lethal concentration –point estimate for 50% lethality
LOEC	lowest observed effect concentration
NOEC	no-observed effect concentrations
SMAVs	species mean acute values
USEPA	U.S. Environmental Protection Agency

EXECUTIVE SUMMARY

The USEPA's current ambient water quality criteria (AWQC) for aluminum (Al) were first released in 1988. The acute and chronic criteria of 750 and 87 µg/L, respectively, were subsequently adopted as Al water quality standards for New Mexico. The applicability of the chronic Al criterion to a wide variety of natural waters has been questioned because, as noted in USEPA (2006), there is evidence that Al toxicity is greater in low hardness waters and field data exist that indicate there are many high quality waters in the U.S. that contain Al concentrations greater than 87 µg/L, when either total recoverable or dissolved Al is measured. Since release of the USEPA's current criteria in 1988, several acute and chronic Al toxicity studies have been published in the scientific literature, many of which meet USEPA guidelines for AWQC development (USEPA 1985). Therefore, this report first reviews the basis for the existing Al criteria and then provides recommendations for updated criteria based on Al toxicity studies published since the late 1980s. A similar effort was conducted by the Arid West Water Quality Research Project (AWWQRP 2006), which resulted in conclusions similar to this report.

Overall, this review identifies acute Al toxicity data for six additional freshwater species, but no additional chronic toxicity data. The most significant outcome of this review is the development of recommended acute and chronic Al criteria that are hardness-dependent. These recommended hardness-dependent criteria were derived using the same methods used by the USEPA to derive hardness-dependent criteria for a variety of other metals (e.g., cadmium, lead, nickel, zinc). The resulting hardness-dependent aluminum criteria are recommended as follows:

$$\text{Acute Criterion} = e^{(1.3695[\ln(\text{hardness})]+1.8309)}$$

$$\text{Chronic Criterion} = e^{(1.3695[\ln(\text{hardness})]+0.9162)}$$

For example, at hardness levels of 50, 100, and 200 mg/L as $CaCO_3$, the chronic Al criteria are 530, 1,371, and 3,541 µg/L, respectively, and the acute Al criteria are 1,324, 3,421, and 8,839 µg/L. The recommended hardness-dependent chronic criteria are protective of the brook trout and striped bass studies that were originally used to lower the existing chronic criterion to 87 µg/L. Acceptance of these updated hardness-dependent Al criteria will result in a more consistent level of aquatic life protection across a range of hardness conditions and decrease the likelihood that Al will be inappropriately identified as potentially detrimental to designated aquatic life uses within New Mexico waters.

1. INTRODUCTION

The current ambient water quality criteria (AWQC) for aluminum (Al) were released in 1988 (USEPA 1988). Background information on Al chemistry in freshwater systems can also be found in USEPA (1988) and in Sposito (1996). Of particular importance in deriving AWQC for Al is the pH of the water used in toxicity tests. Between a pH of 6.5 and 9.0, Al occurs largely as poorly soluble polymeric hydroxides and as complexes with humic acids, phosphate, sulfate, and other anions (USEPA 1988; Sposito 1996). Waters with a pH <6.5 are below the acceptable pH range identified by the USEPA, and such waters favor the dissolution of Al into more bioavailable monomeric and ionic forms. Consistent with the USEPA's existing criteria for Al, the updated Al criteria recommended here only consider toxicity studies conducted within the pH range of 6.5 to 9.0, and thus should only apply to surface waters with pH levels within this range.

This report reviews the scientific literature conducted since publication of the 1988 AWQC for Al, and uses these data to recommend updated criteria for protection of aquatic life derived according to USEPA guidance (USEPA 1985). Section 2 of this report summarizes the basis of the existing Al criteria and then Section 3 summarizes additional Al toxicity studies published after release of the 1988 AWQC document. Sections 4-6 then use these data to recommend updates to freshwater aquatic life criteria for Al in a format that is consistent with USEPA guidance.

2. AMBIENT WATER QUALITY CRITERIA DERIVATION

The national AWQC developed by USEPA for protection of aquatic life set maximum threshold concentrations of contaminants for both freshwater and marine environments. These criteria are derived from empirical toxicity data and are designed to be stringent enough to protect most sensitive species potentially exposed to a contaminant in any water body in the United States. Below these thresholds, no adverse effects on aquatic community function are anticipated, although if present, the most sensitive species could be impacted as the AWQC are designed to protect all but the most sensitive 5% of species. If data suggest that a commercially or recreationally important species is not protected at this level, then an AWQC value can be adjusted to provide sufficient protection for these species as well.

To understand how AWQC are developed, it is useful to review the guidelines and terminology provided in USEPA (1985), but the general approach is briefly summarized below. The first step is to compile acute and chronic toxicity data that meet the USEPA (1985) guidelines for the relevance and reliability of each study. A minimum database of acceptable studies representing at least 8 specific taxonomic families of aquatic organisms is also required. For each species with acceptable acute toxicity data, the species mean acute value (SMAV) is calculated as the geometric mean of available 48 to 96-hr median lethal concentrations (LC50s) or median effect concentrations (EC50s) for each species. The genus mean acute value (GMAV) is then calculated as the geometric mean of available SMAVs for each genus. The lowest 5th percentile of the distribution of available GMAVs is identified as the final acute value (FAV), which is divided by two to determine the criterion maximum concentration (CMC) which is more commonly termed the "acute criterion." The FAV is divided by two because USEPA determined setting the CMC equal to the FAV (i.e., without dividing by two) was not sufficiently protective since it could induce up to 50% mortality to sensitive species. It is important to note that the 5th percentile is calculated based solely on the four most sensitive GMAVs and the total number of GMAVs (USEPA 1985).

The chronic criterion may be derived in a manner similar to the CMC, but chronic toxicity data are typically unavailable for a sufficient number of species. It is thus typically necessary to apply an acute-chronic ratio (ACR) to the FAV to estimate the final chronic value (FCV). Unless other data are available to suggest the FCV is under-protective of the aquatic community (including aquatic plants and protection from bioaccumulative substances), the criterion continuous concentration (CCC), or chronic criterion, is set equal to the FCV.

3. SUMMARY OF EXISTING CRITERIA

The USEPA's current acute and chronic Al criteria for protection of aquatic life are 750 and 87 µg/L, respectively. Development of these criteria followed the *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (USEPA 1985), which was briefly summarized above. Specifically, the USEPA identified acute LC50 values for 15 aquatic species, which resulted in the calculation of 15 SMAVs. These 15 SMAVs represented 14 genera, which resulted in the calculation of 14 GMAVs. The 5th percentile of these GMAVs, or FAV, was calculated to be 1,496 µg/L. Division of the FAV by two resulted in an acute criterion (CMC) of 750 µg/L. Because limited chronic Al toxicity data were available, the FCV was calculated using an ACR. The USEPA identified ACRs of 0.9958, 10.64, and 51.47. Because the two highest ACRs were based on acutely insensitive species, these were not considered in development of the final ACR (FACR). However, because the remaining ACR of 0.9958 was less than 2, the USEPA (1985) guidelines required that the FACR be set to 2, otherwise the chronic criterion would be higher than the acute criterion. This results in a FCV of 750 µg/L (equivalent to the CMC). Finally, the USEPA (1988) considered "other data" that were considered scientifically sound, but were from studies that did not strictly meet the guidelines for calculation of the FCV. From the "other data" cited in USEPA (1988), adverse effects were reported for two "important" species at Al concentrations below the FCV of 750 µg/L: (1) a 24 percent reduction in weight of young brook trout (*Salvelinus fontinalis*) was observed at an Al concentration of 169 µg/L (Cleveland et al. Manuscript) and (2) 58 percent striped bass (*Morone saxatilis*) mortality occurred at an Al concentration of 174.4 µg/L (Buckler et al. Manuscript). Aluminum concentrations of 88 and 87.2 µg/L from these same two studies resulted in negligible toxicity. Accordingly, the USEPA set the chronic criterion (CCC) at 87 µg/L.

Since the release of the current AWQC for Al in 1988, several acute and chronic Al toxicity studies have been published in the scientific literature. Many of these toxicity studies meet the USEPA (1985) guidelines for AWQC development and also result in additional data for deriving an Al ACR. As discussed below, there is also evidence that the toxicity of Al to aquatic life is hardness-dependent (i.e., Al toxicity is greater in softer waters and decreases as water hardness increases).

4. SUMMARY OF NEW TOXICITY STUDIES

The USEPA (1985) guidelines for AWQC development specify minimum study requirements for consideration in the development of acute and chronic criteria for protection of aquatic life. For example, acute toxicity studies must have an exposure duration of 96 hours (although 48 hours is acceptable for more short-lived species, such as cladocerans and midges), organisms must not be fed during the study, and the endpoint must be mortality, immobilization or a combination of the two. Chronic toxicity studies must be conducted using exposure durations that encompass the full life cycle or, for fish, early life stage and partial life cycle studies are acceptable. In addition, toxicant concentrations in the exposure solutions must be analytically verified in chronic studies. Finally, under the USEPA (1985) guidelines, toxicity studies that do not meet the specific study requirements may still be retained as "other data" if the study was otherwise scientifically valid. Such "other data" are not used in the calculation of the CMC and FCV, but may be used to justify lowering the acute or chronic criteria for a toxicant if the species and endpoint tested are considered to be "biologically or recreationally important," and if the CMC or FCV were determined to be inadequately protective of these species or endpoints.

The following sections summarize the Al toxicity data published since 1988 that we considered acceptable for updating the Al criteria. Our primary source for these new data was a study conducted on behalf of the *Arid West Water Quality Research Project* (AWWQRP 2006), in which a thorough literature review was conducted, and similar recommendations made for updating aquatic life criteria for Al (and other chemicals). While the studies used in the present report are, for the most part, the same as those used in AWWQRP (2006), we recommend different final criteria equations to maximize consistency with USEPA guidance for derivation of aquatic life criteria (USEPA 1985).

4.1 ACUTE TOXICITY

As summarized in Section 3, the acute Al toxicity database used to derive the current acute Al criterion was based on 14 GMAVs, which in turn was based on 15 SMAVs. The updated acute Al toxicity database includes seven additional species with tests considered to be of an acceptable type and duration according to USEPA (1985):

- *Asellus aquaticus*, isopod (Martin and Holdich 1986)
- *Crangonyx pseudogracilis*, amphipod (Martin and Holdich 1986)
- *Cyclops viridis*, copepod (Storey et al. 1992)
- *Gammarus pulex*, amphipod (Storey et al. 1992)
- *Tubifex tubifex*, worm (Khangarot 1991)
- *Hybognathus amarus*, Rio Grande silvery minnow (Buhl 2002)
- *Salmo salar*, Atlantic salmon (Hamilton and Haines 1995)

This results in acute Al toxicity data for a total of 22 species representing 19 genera. In addition, new acute toxicity studies were identified for several species already included in the 1988 AWQC, including the cladoceran *Ceriodaphnia dubia* (ENSR 1992a; Soucek et al. 2001), rainbow trout (*Oncorhynchus mykiss*) (Thomsen et al. 1988; Gundersen et al. 1994), and fathead minnow (*Pimephales promelas*) (Buhl 2002; ENSR 1992b). All acceptable acute LC50 and EC50 values for Al are summarized in Table 1a.

4.2 CHRONIC TOXICITY

The 1988 AWQC for Al included chronic toxicity data for three species: (1) the cladoceran *C. dubia*; (2) the cladoceran *Daphnia magna*; and (3) the fathead minnow *P. promelas*. As part of this update, a 16%-effect concentration (EC16) for reproductive effects in *D. magna* (Biesinger and Christensen 1972) was added to the chronic toxicity data set. The chronic toxicity value from Biesinger and Christensen (1972) was likely excluded in USEPA (1988) because Al test concentrations were not analytically verified. However, this study is included here because the chronic value is consistent with the corresponding measured value from the Kimball manuscript (which was an unpublished study used in the 1988 AWQC), thus reducing some of the uncertainty associated with the Al concentrations not being analytically verified. This study also provides additional useful information for deriving an ACR, as discussed further below. No additional chronic toxicity studies were identified that meet the USEPA's guidelines (i.e., life cycle study or an early life stage or partial life cycle study for fish). All acceptable chronic toxicity studies are summarized in Table 2a.

A total of four ACRs were derived: 0.9958 and 0.9236 for *C. dubia*, 12.19 and 51.47 for *D. magna*, and 10.64 for fathead minnows (Table 2b). It is uncertain why the *D. magna* ACR of 51.47 is considerably higher than the other ACRs, including the other *D. magna* ACR of 12.19. However, the combination of the high hardness (220 mg/L) and pH (8.30) would likely have mitigated the toxicity of Al compared to waters with a hardness of 45.3 mg/L and pH of 6.5-7.5 used in tests to derive the *D. magna* ACR of 12.19 from Biesinger and Christensen (1972). Therefore, it is more appropriate to select an ACR from tests conducted under conditions that likely maximize Al toxicity. The *D. magna* acute values from the two studies differed by a factor of 10, but the chronic values differed by just a factor of two (Table 2b). Because the *D. magna* ACR of 51.47 is driven by an insensitive acute value under high hardness and high pH conditions, this value was excluded from the final ACR. Calculating the geometric mean of the remaining ACRs results in a final ACR of 4.9918.

In USEPA (1988), it was noted that a Final Plant Value, as defined in USEPA (1985), was not obtained because there were no plant toxicity studies conducted with an important aquatic plant species in which Al was measured and in which the endpoint measured was biologically important. No new published algal or aquatic plant studies have been obtained, so this conclusion has not changed for the present update.

4.3 OTHER DATA

In USEPA's AWQC documents, "other" data are those from studies that were not conducted in such a way as to be strictly "acceptable" according to USEPA (1985) guidance, but that may still contain data that might be useful in adjusting final criteria concentrations. Within the pH range 6.5 – 9.0, only two other studies have been published after the 1988 Al AWQC were released, but that were not already considered Sections 4.1 or 4.2: (1) a rainbow trout study by Thomsen et al. (1988) and (2) an Atlantic salmon study by Hamilton and Haines (1995). These are discussed below.

Thomsen et al. (1988) exposed rainbow trout (*O. mykiss*) eggs to aqueous Al concentrations in water with calcium concentrations of either 1 or 150 mg/L and a pH level of 7. The Al exposure continued through 25 days post-hatch. The LC50 values (measured at day 25 post-hatch) were 3,800 and 71,000 µg Al/L in waters containing calcium concentrations of 1 and 150 mg/L, respectively. The increased mortality observed in the low calcium treatment may be explained more by the low calcium treatment than by increased toxicity of Al due to higher bioavailability. As Thomsen et al. (1988) noted, the greatest reduction in survival was observed in relation to the calcium ion concentrations in the test water (survival was reduced by 24 percent in the low calcium water compared to the high calcium water without the addition of Al). Hatching time was also increased from 1.2 days in high calcium water to 4.5 days in low calcium water. Overall, neither study meets the requirements to be included as an acceptable acute test because the exposure duration was too long (ranged from approximately 26-30 days). This study also is not an acceptable chronic test because the study was not sufficient long to meet the early life stage requirements for rainbow trout tests (60 days post-hatch). Further, much of the mortality observed in the low calcium treatment appears to be a result of the low calcium concentration itself.

Hamilton and Haines (1995) exposed Atlantic salmon (*S. salar*) alevins to aqueous Al concentrations of 0 or 200 µg/L for 30 days. The test water pH was 6.5 and the hardness was 6.8 mg/L, which is unusually low compared to water hardness typically encountered in either field or laboratory situations. This study does not meet the USEPA's (1985) specific requirements for a chronic study because it does not meet the definitions of an early life stage or partial life cycle study, but it does provide useful data that the USEPA would typically categorize as "other data." The mean weight of alevins exposed to 200 µg Al/L was significantly reduced ($p<0.05$) relative to the control, which resulted in a lowest observed effect concentration (LOEC) of <200 µg/L.

4.4 UNUSED DATA

In USEPA's AWQC documents, studies are identified that were not used or considered for AWQC development because the study was scientifically flawed or limited, or otherwise inappropriate for derivation of AWQC. For example, studies are not used if control organisms did not respond adequately (e.g., unacceptably high mortality) or if the test water contained elevated levels of other contaminants. In addition, studies are not used if the test species is not resident to North America. All of the unused studies published since the current Al criteria were derived are not summarized here, except for a brook trout (*S. fontinalis*) study that is briefly summarized below given the importance of brook trout to the derivation of the 1988 chronic Al criterion.

Cleveland et al. (1991) exposed brook trout to an aqueous Al concentration of 303.9 µg/L for 56 days at a pH of 7.2 (fish were also exposed to Al at pH levels of 5.0 and 6.0, but these tests are not discussed here because the pH levels were <6.5). This study did not include a control, although only 1 percent mortality was observed following 56 days. It is unknown whether growth was affected, which is important since Cleveland et al. (1989) observed that growth is a more sensitive endpoint than survival for brook trout exposed to Al. Given the lack of a growth endpoint and due to the absence of a control treatment, this study was not sufficiently robust to identify either an acceptable chronic value for Al (for inclusion in Table 2) or as information to be evaluated as "other data". Therefore, it was not considered for use in updating Al criteria.

5. HARDNESS-TOXICITY RELATIONSHIP

Under the USEPA (1985) guidelines for AWQC development, methods are provided for adjusting criteria if it can be demonstrated that toxicity varies as a function of a given water quality parameter. The most common example is the relationship between water hardness and toxicity for several divalent metals. For example, the current acute and chronic criteria for cadmium, lead, nickel, and zinc are all hardness-dependent (i.e., the criteria concentrations increase with increasing water hardness; USEPA 2006). For Al, the existing data also suggest that toxicity increases with increasing water hardness, or with other water quality parameters that covary with hardness. Therefore, expressing updated Al criteria on the basis of a hardness equation—rather than as a single fixed value—is now warranted.

The general approach for deriving hardness-dependent criteria entails use of an analysis of covariance to derive a log-linear slope that relates standard toxicity values (e.g., LC50s) to water hardness (USEPA 1985). To evaluate whether there is a significant statistical relationship between hardness and toxicity, there must be definitive acute values (i.e., undefined "less than" or "greater than" toxicity values are not used) from Al toxicity studies that expose organisms over a range of water hardness values such that the highest hardness is at least three times higher than the lowest, and the highest hardness is also at least 100 mg/L higher than the lowest. There were three species that met this minimum requirement: (1) *C. dubia*; (2) *D. magna*; and (3) fathead minnow.

For *C. dubia*, acute LC50s were available at hardness levels of 26, 46, 50, 96, 98.5, and 194 mg/L (as $CaCO_3$). The LC50 at a hardness of 194 mg/L was >99,600 µg/L, which should not be used to derive the hardness-toxicity relationship because it is not a definitive value. However, if this test is not included in the hardness-toxicity evaluation, the range in hardness for the remaining *C. dubia* toxicity studies is 26 to 98.5 mg/L, which does not meet the requirement that the range between the lowest and highest hardness must be >100 mg/L. Nevertheless, because the *C. dubia* data clearly demonstrate a relationship between hardness and toxicity over an acceptable range of hardness values, the *C. dubia* data were included in the pooled slope, but the LC50 of >99,600 µg/L was excluded because it was not a definitive value.

The slope relating aluminum toxicity to water hardness was significantly different from zero ($p<0.05$) for all three species. In addition, the slopes were similar for all three with overlapping 95 percent confidence intervals. Accordingly, a final pooled slope of 1.3695 was derived based on the data for these three species. The individual slopes for each species and the pooled slope for combined species, as well as the data used to derive the pooled slopes, are provided in Tables 1b and 1c. The raw data used to define the relationship between hardness and toxicity, as well as the pooled slope, are plotted in Figure 1.

6. REVISED ALUMINUM CRITERIA

6.1 ACUTE CRITERION

The pooled slope of 1.3695 was used to adjust the acute values in Table 1a to a hardness of 50 mg/L, except for cases where this was not possible because water hardness was not reported. Species mean acute values were calculated as the geometric mean of acceptable hardness-adjusted acute values for each species. To delineate cases in which not all toxicity values were appropriate for inclusion into a particular SMAV, the bold, underlined LC50 and EC50 values in Table 1a were ultimately used to derive the SMAVs. The SMAVs, adjusted to a hardness of 50 mg/L, ranged from >2,164 µg/L for the cladoceran *Ceriodaphnia dubia* to >338,321 µg/L for the midge *Tanytarsus dissimilis*. Genus mean acute values were calculated as the geometric mean of SMAVs and ranked from high to low (Table 3). The total number of GMAVs was 17 and the four lowest GMAVs were used to calculate the FAV following the USEPA (1985) guidelines. The FAV, at a hardness of 50 mg/L, was calculated to be 2,648 µg/L (Table 3). The FAV was then divided by two, resulting in a CMC, or acute criterion, of 1,324 µg/L at a hardness of 50 mg/L. The resulting equation for deriving the CMC over a range of hardness levels is:

$$\mathrm{CMC} = e^{(1.3695[\ln(\mathrm{hardness})]+1.8309)} \qquad \textbf{Eq. 1}$$

The hardness relationship was derived based on empirical data within a hardness range of 26 to 220 mg/L, so application of this equation to hardness levels outside of this range should be treated with caution.

6.2 CHRONIC CRITERION

Chronic Al toxicity values did not meet the minimum data requirements for calculating the FCV as the 5th percentile of empirically derived chronic values. Accordingly, it was necessary to apply an ACR to the FAV (consistent with the calculation of the FCV for Al in USEPA [1988]). At a hardness of 50 mg/L, division of the FAV of 2,648 µg/L (see Section 5.1) by the final ACR of 4.9918 (see Section 3.2) results in a FCV of 530 µg/L (Table 3). The resulting equation for deriving the FCV over a range of hardness levels is:

$$FCV = e^{(1.3695[\ln(hardness)]+0.9162)} \qquad \textbf{Eq. 2}$$

Similar to the acute hardness equation, because the hardness relationship was derived based on empirical data within a hardness range of 26 to 220 mg/L, application of this equation to hardness levels outside of this range should be treated with caution.

6.3 PROTECTIVENESS OF THE CHRONIC CRITERION TO BROOK TROUT AND STRIPED BASS

As discussed in Section 3, USEPA (1988) derived a FCV of 750 µg/L based on a FAV of 1,496 µg/L and an ACR of 2 (i.e., 1,496 µg/L / 2 = 750 µg/L). However, two chronic studies that did not meet strict acceptability criteria (USEPA 1985) for calculation of the FCV were ultimately considered to be important enough to warrant lowering of the FCV to ensure protection of the two species tested. Based on the Cleveland et al. and Buckler et al. manuscripts cited in the 1988 AWQC, the USEPA lowered the chronic criterion to 87 µg/L in order to ensure protection of brook trout (*Salvelinus fontinalis*) and striped bass (*Morone saxatilis*). The following briefly summarizes these studies, and evaluates the level of protection that the updated criteria equations 1 and 2 would provide for these species.

6.3.1 Brook Trout

USEPA (1988), citing an unpublished Cleveland et al. manuscript (and now published as Cleveland et al. 1989), reported that Al concentrations of 169 and 350 µg/L resulted in 3 percent and 48 percent larval brook trout mortality, respectively, after a 60 day exposure, and Al concentrations of 88 and 169 µg/L resulted in a 4 percent and 24 percent reduction in weight, respectively. Following the USEPA (1985) guidelines, the chronic value from this study would typically be defined as the geometric mean of the no-observed effect concentration (NOEC) and LOEC for the most sensitive endpoint (growth), which is 88 and 169 µg/L, respectively. The chronic value for this test would, therefore, be 122 µg/L. It should be noted that this test was conducted in very soft water with a hardness of 12.3 mg/L. Based on the hardness-toxicity slope of 1.3695, this converts to an estimated chronic value of 833 µg/L at a hardness of 50 mg/L. Given that the FCV at a hardness of 50 mg/L is 530 µg/L, this suggests that brook trout would be adequately protected by the revised criterion[1].

In addition, the GMAV of 3,600 µg Al/L for brook trout reported in Table 1a is well above the FAV of 2,648 µg Al/L (Table 3), even though water hardness was not reported in this study (Decker and Menendez 1974) and so could not be included in the FAV derivation. Finally, an additional chronic brook trout study cited in Table 6 of the 1988 AWQC (Hunn et al. 1987) reports a chronic growth reduction at 283 µg Al/L, but in extremely soft waters (0.57 mg/L hardness). It would likely not be meaningful to apply a hardness slope to

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[1] Given that the very low hardness of 12.3 mg/L is below the range of hardness levels used to develop the pooled hardness slope, there is some uncertainty associated with this evaluation.

such a low water hardness, but given that the chronic value from Cleveland et al. (1989) conducted in harder water was lower than that of Hunn et al. (1987), a revised chronic criterion using Equation 2 would still be considered protective. Therefore, the available toxicity data suggest that the revised chronic criteria reported here would also be protective of both chronic and acute Al toxicity to brook trout, and so the calculated FCV does not need to be lowered to protect this species.

6.3.2 Striped Bass

USEPA (1988), citing the unpublished Buckler et al. manuscript (and now published as Buckler et al. 1987), reports that Al concentrations of 87.2 and 174.4 µg/L, at a pH of 6.5, resulted in 0 percent and 58 percent mortality of 160 day-old striped bass, respectively, after a 7 day exposure. USEPA (1988) also reported that Al concentration of 174.4 and 348.8 µg/L resulted in 2 percent and 100 percent mortality in 160 day-old striped bass at a pH of 7.2 (i.e., Al was more toxic at pH 6.5 than at pH 7.2). In addition, citing the Buckler et al. manuscript, USEPA (1988) reported that an Al concentration of 390 µg/L resulted in 0 percent mortality of 159 and 195 day-old striped bass at both a pH of 6.5 and 7.2 following a 7 day exposure. These values were identical to those in the published version of the study in Buckler et al. (1987). Additional 7 day toxicity tests of younger life stages were reported in Buckler et al. (1987). However, control survival in these other studies was marginal: (1) 72-78 percent and 79 percent for 11 day old fish at a pH of 7.2 and 6.5, respectively; and (2) 80 percent and 48 percent for 13 day old fish at a pH of 7.2 and 6.5, respectively. Conversely, control mortality was 0 percent in studies with 160 day old fish at pH levels of 6.5 and 7.2. However, if it is assumed that control mortality in the range of 20-28 percent is acceptable for younger life stages, a measured Al concentration of approximately 131 µg/L was associated with 75 percent mortality in 13 day old fish at a pH of 7.2, which was significantly greater ($p<0.05$) than in the respective control that had 20 percent mortality. In another study with 11 day old fish at a pH of 7.2, survival was not significantly reduced relative to the control up to a higher Al concentration of 179 µg/L, but was significantly reduced ($p<0.05$) at an Al concentration of 358 µg/L. At a pH of 6.5, control mortality was 21 percent (compared to 26 percent in the pH 7.2 control), but survival in Al treatments ≥22 µg/L was significantly reduced ($p<0.05$) compared to the pH 7.2 control (and presumably compared to the pH 6.5 control, but this was not reported).

Overall, Al toxicity to striped bass is highly variable depending on the age of the test organism and the pH of the water (6.5 vs. 7.2). Lowest observed effect concentrations range from 22 to <393 and NOECs range from 87 to >390 (in other words, the ranges of NOECs and LOECs from the various tests substantially overlap). Even within a similar age the NOECs and LOECs are highly variable, with NOECs for 159 day old fish being >390 µg/L and LOECs for 160 day old fish being 174 to 348 µg/L. Given this variability, we suggest that the striped bass toxicity data be excluded from consideration in updating the chronic Al criterion. Nevertheless, the chronic value reported in USEPA (1988) for striped bass in soft water[2] is 123 µg/L, which, assuming a water hardness of 14 mg/L, results in a chronic value

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[2] Buckler et al. (1987) did not report the hardness of the test water, although the authors did note that hardness was monitored. They characterized the test water as soft. The test solution was created using well water passed through a water softener, which was then treated by reverse osmosis and passed through anionic, cationic, and mixed-bed exchange resins. The alkalinity and hardness of the well water were 237 and 272 mg/L, respectively. The alkalinity of the resulting test water was 12 mg/L. If we assume that the ratio of well water-to-test water alkalinity applies to hardness, we can estimate that the hardness of the test water was approximately 14 mg/L.

of 703 µg/L at a hardness of 50 mg/L. Therefore, the available toxicity data suggest that the revised chronic criteria reported here (530 µg/L) would also be protective of chronic Al toxicity to striped bass, and so the calculated FCV does not need to be lowered to protect this species.

7. PROPOSED CHANGES TO 20.6.4 NMAC

Proposed changes to the current 20.6.4 NMAC (August 2007) are shown with additions underlined, and deletions indicated by strikethrough. Please note that this proposal *does not* contain comparisons with NMEDs *Proposed Amendments to the Standards for Interstate and Intrastate Surface Waters 20.6.4 NMAC* from December 16, 2008 or as further revised on July 6, 2009. Based on the criteria updates recommended in this report, the following changes are proposed:

In Section 20.6.4.900.I, the following hardness-dependent equation parameters for acute and chronic criteria for aluminum should be added:

I.(1) Acute aquatic life criteria:

The equation to calculate acute criteria in µg/L is $\exp(m_A[\ln(\text{hardness})] + b_A)(\text{CF})$, where the parameters are as follows:

Metal (dissolved)	**m_A**	**b_A**	**Conversion factor (CF)**
Aluminum	1.3695	1.8309	None

This equation shall be extended to hardness levels no lower than 25 mg/L, and no higher than 250 mg/L, as $CaCO_3$.

I.(2) Chronic aquatic life criteria:

The equation to calculate chronic criteria in µg/L is $\exp(m_C[\ln(\text{hardness})] + b_C)(\text{CF})$, where the parameters are as follows:

Metal (dissolved)	**m_C**	**b_C**	**Conversion factor (CF)**
Aluminum	1.3695	0.9162	None

This equation shall be extended to hardness levels no lower than 25 mg/L, and no higher than 250 mg/L, as $CaCO_3$.

In Section 20.6.4.900.J, the numeric criteria table entry for aluminum should be revised to refer to hardness-dependent equations in Section 20.6.4.900.I:

Pollutant total, unless indicated	CAS Number	Domestic Water Supply µg/L unless indicated	Irrigation µg/L unless indicated	LivestockWatering µg/L unless indicated	Wildlife Habitat µg/L unless indicated	Aquatic Life		Human Health µg/L	Cancer Causing (C) or Persistent (P)
						Acute µg/L	Chronic µg/L		
Aluminum, dissolved	7429-90-5		5,000			~~750~~ See 20.6.4.900.I	~~87~~ See 20.6.4.900.I		

The following table provides selected values of the calculated acute and chronic Al criteria (µg/L) at various levels of water hardness:

Hardness as $CaCO_3$ (mg/L)		Aluminum, dissolved
25	Acute	512
	Chronic	205
30	Acute	658
	Chronic	264
40	Acute	975
	Chronic	391
50	Acute	1324
	Chronic	530
60	Acute	1700
	Chronic	681
70	Acute	2099
	Chronic	841
80	Acute	2520
	Chronic	1010
90	Acute	2961
	Chronic	1186
100	Acute	3421
	Chronic	1371
200	Acute	8839
	Chronic	3541

Hardness as $CaCO_3$ (mg/L)		Aluminum, dissolved
250 – 400	Acute	11999
	Chronic	4807

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Table 1a. Acute Toxicity of Aluminum to Aquatic Animals

Species Latin Name	Species Common Name	Method	Chemical	pH	Hardness (mg/L as CaCO3)	LC50 or EC50 (µg Al/L)	LC50 or EC50 Adjusted to Hardness of 50 mg/L (µg Al/L)	Species Mean Acute Value at Hardness of 50 mg/L (µg Al/L)	Reference
Acroneuria sp.	Stonefly	S,M	$AlCl_3$	7.46	47.4	>22,600	>24,315	>24,315	Call 1984
Asellus aquaticus	Isopod	S,U	$Al_2(SO_4)_3$	6.75	50	4,370	4,370	4,370	Martin and Holdich 1986
Ceriodaphnia dubia	Cladoceran	S,M	$AlCl_3$	7.42	50	1,900	1,900	>2,164	McCauley et al. 1986
Ceriodaphnia dubia	Cladoceran	S,M	$AlCl_3$	7.86	50	1,500	1,500	-	McCauley et al. 1986
Ceriodaphnia dubia	Cladoceran	S,M	$AlCl_3$	8.13	50	2,560	2,560	-	McCauley et al. 1986
Ceriodaphnia dubia	Cladoceran	S,M	$AlCl_3$	7.5	26	720	1,763	-	ENSR 1992a
Ceriodaphnia dubia	Cladoceran	S,M	$AlCl_3$	7.6	46	1,880	2,107	-	ENSR 1992a
Ceriodaphnia dubia	Cladoceran	S,M	$AlCl_3$	7.8	96	2,450	1,003	-	ENSR 1992a
Ceriodaphnia dubia	Cladoceran	S,M	$AlCl_3$	8.1	194	>99,600	>15,554	-	ENSR 1992a
Ceriodaphnia dubia	Cladoceran	S,M	-	7.6	98.5	2,880	1,138	-	Soucek et al. 2001
Ceriodaphnia sp.	Cladoceran	S,M	$AlCl_3$	7.36	47.4	2,300	2,475	3,134	Call 1984
Ceriodaphnia sp.	Cladoceran	S,M	$AlCl_3$	7.68	47.4	3,690	3,970	-	Call 1984
Crangonyx pseudogracilis	Amphipod	S,U	$Al_2(SO_4)_3$	6.75	50	9,190	9,190	9,190	Martin and Holdich 1986
Cyclops viridis	Copepod	S,U	Al_2O_3	6.9	-	>27,000	-	-	Storey et al. 1992
Daphnia magna	Cladoceran	S,M	$Al_2(SO_4)_3$	7.05	220	38,200	5,022	4,735	Kimball manuscript
Daphnia magna	Cladoceran	S,M	$AlCl_3$	7.61	45.4	>25,300	>28,875	-	Brooke et al. 1985
Daphnia magna	Cladoceran	S,U	$AlCl_3$	7	45.3	3,900	4,465	-	Biesinger and Christensen 1972
Dugesia tigrina	Flatworm	S,M	$AlCl_3$	7.48	47.4	>16,600	>17,859	>17,859	Brooke et al. 1985
Gammarus pulex	Amphipod	S,M	Al_2O_3	6.9	-	>2,700	-	-	Storey et al. 1992
Gammarus pseudolimnaeus	Amphipod	S,M	$AlCl_3$	7.53	47.4	22,000	23,669	23,669	Call 1984
Physa sp.	Snail	S,M	$AlCl_3$	7.46	47.4	55,500	59,711	32,922	Call 1984
Physa sp.	Snail	S,M	$AlCl_3$	6.59	47.4	>23,400	>25,175	-	Call 1984
Physa sp.	Snail	S,M	$AlCl_3$	7.55	47.4	30,600	32,922	-	Call 1984
Physa sp.	Snail	S,M	$AlCl_3$	8.17	47.4	>24,700	>26,574	-	Call 1984
Tanytarsus dissimilis	Midge	S,U	$Al_2(SO_4)_3$	6.85-7.71	17.43	>79,900	>338,321	>338,321	Lamb and Bailey 1981
Tubifex tubifex	Worm	R,U	$Al(NH_4SO_4)_2$	7.6	245	50,230	5,698	5,698	Khangarot 1991

Table 1a. Acute Toxicity of Aluminum to Aquatic Animals (continued)

Species Latin Name	Species Common Name	Method	Chemical	pH	Hardness (mg/L as CaCO3)	LC50 or EC50 (µg Al/L)	LC50 or EC50 Adjusted to Hardness of 50 mg/L (µg Al/L)	Species Mean Acute Value at Hardness of 50 mg/L (µg Al/L)	Reference
Hybognathus amarus	Rio Grande silvery minnow	S,M	$AlCl_3$	8.1	140	>59,100	**>14,428**	>14,428	Buhl 2002
Ictalurus punctatus	Channel catfish	S,M	$AlCl_3$	7.54	47.4	>47,900	**>51,534**	>51,534	Call 1984
Lepomis cyanellus	Green sunfish	S,M	$AlCl_3$	7.55	47.4	>50,000	**>53,794**	>53,794	Call 1984
Oncorhynchus mykiss	Rainbow trout	S,M	$AlCl_3$	6.59	47.4	7,400	**7,961**	>7,547	Call 1984
Oncorhynchus mykiss	Rainbow trout	S,M	$AlCl_3$	7.31	47.4	14,600	**15,708**	-	Call 1984
Oncorhynchus mykiss	Rainbow trout	S,M	$AlCl_3$	7.46	47.4	8,600	9,253	-	Call 1984
Oncorhynchus mykiss	Rainbow trout	S,M	$AlCl_3$	8.17	47.4	>24,700	>26,574	-	Call 1984
Oncorhynchus mykiss	Rainbow trout	F,M	$AlCl_3$	8.25	23.2	6,170	**17,660**	-	Gundersen et al. 1994
Oncorhynchus mykiss	Rainbow trout	F,M	$AlCl_3$	8.25	35	6,170	**10,056**	-	Gundersen et al. 1994
Oncorhynchus mykiss	Rainbow trout	F,M	$AlCl_3$	8.29	83.6	7,670	**3,794**	-	Gundersen et al. 1994
Oncorhynchus mykiss	Rainbow trout	F,M	$AlCl_3$	8.29	115.8	6,930	**2,194**	-	Gundersen et al. 1994
Oncorhynchus tshawytscha	Chinook salmon	S,M	$NaAlO_2$	7	28	>40,000	**>88,495**	>88,495	Peterson et al. 1974
Perca flavescens	Yellow perch	S,M	$AlCl_3$	7.55	47.4	>49,800	**>53,578**	>53,578	Call 1984
Pimephales promelas	Fathead minnow	S,M	$AlCl_3$	8.1	140	>59,100	>14,428	>5,869	Buhl 2002
Pimephales promelas	Fathead minnow	S,M	$Al_2(SO_4)_3$	7.34	220	35,000	**4,601**	-	Kimball manuscript
Pimephales promelas	Fathead minnow	S,M	$AlCl_3$	7.61	47.4	>48,200	>51,857	-	Call 1984
Pimephales promelas	Fathead minnow	S,M	$AlCl_3$	8.05	47.4	>49,800	>53,578	-	Call 1984
Pimephales promelas	Fathead minnow	S,U	$Al_2(SO_4)_3$	7.6	-	>18,900	**-**	-	Boyd 1979
Pimephales promelas	Fathead minnow	S,M	$AlCl_3$	7.8	26	1,160	**2,840**	-	ENSR 1992b
Pimephales promelas	Fathead minnow	S,M	$AlCl_3$	7.6	46	8,180	**9,170**	-	ENSR 1992b
Pimephales promelas	Fathead minnow	S,M	$AlCl_3$	8.1	96	20,300	**8,308**	-	ENSR 1992b
Pimephales promelas	Fathead minnow	S,M	$AlCl_3$	8.1	194	44,800	**6,996**	-	ENSR 1992b
Salmo salar	Atlantic salmon	S,M	$AlCl_3$	6.5	6.8	599	**9,2051**	9,205	Hamilton and Haines 1995
Salvelinus fontinalis	Brook trout	F,M	$Al_2(SO_4)_3$	6.5	-	3,600	**-**	-	Decker and Menendez 1974

* Bold, underlined values were used to calculate species mean acute values.

S = static, R = renewal, F = flow-through, U = unmeasured, M = measured

Table 1b. Results of Covariance Analysis of Freshwater Acute Toxicity Versus Hardness

Species	N	Slope	R^2 Value	95% Confidence Limits	Degrees of Freedom
Ceriodaphnia dubia	8	2.0674	0.751	0.8770, 3.2578	6
Daphnia magna	2	1.4439	-	-	0
Fathead minnow	5	1.5298	0.903	0.6082, 2.4514	3
All of the above	15	1.7125	0.805	1.2071, 2.2179	12

Table 1c. List of Studies Used to Estimate Acute Aluminum Hardness Slope

Species	Hardness (mg/L)	LC50 or EC50 (µg Al/L)	Reference
Ceriodaphnia dubia	26	720	ENSR 1992a
	46	1,880	ENSR 1992a
	50	1,500	McCauley et al. 1986
	50	1,900	McCauley et al. 1986
	50	2,560	McCauley et al. 1986
	96	2,450	ENSR 1992a
	98.5	2,880	Soucek et al. 2001
	194	>99,600	ENSR 1992a
Daphnia magna	45.3	3,900	Biesinger and Christensen 1972
	220	38,200	Kimball Manuscript
Fathead minnow	26	1,160	ENSR 1992b
	46	8,180	ENSR 1992b
	96	20,300	ENSR 1992b
	194	44,800	ENSR 1992b
	220	35,000	Kimball Manuscript

Table 2a. Chronic Toxicity of Aluminum to Aquatic Animals

Species Latin Name	Species Common Name	Test	Chemical	pH	Hardness (mg/L as CaCO3)	Limits (µg Al/L)	Chronic Value (µg Al/L)	Reference
Ceriodaphnia dubia	Cladoceran	LC	$AlCl_3$	7.15	50	1,400-2,600	1,908	McCauley et al. 1986
Ceriodaphnia dubia	Cladoceran	LC	$AlCl_3$	7.75	50	1,100-2,400	1,624	McCauley et al. 1986
Ceriodaphnia dubia	Cladoceran	LC	$AlCl_3$	7.55	47.4	4,900-12,100	7,700	Call 1984
Daphnia magna	Cladoceran	LC	$Al_2(SO_4)_3$	8.30	220	540-1,020	742.2	Kimball manuscript
Daphnia magna	Cladoceran	LC	$AlCl_3$	6.5-7.5	45.3	-	320[a]	Biesinger and Christensen 1972
Pimephales promelas	Fathead minnow	ELS	$Al_2(SO_4)_3$	7.24-8.15	220	2,300-4,700	3,288	Kimball manuscript

[a] This value is an EC16 for reproductive effects. It was included in Table 6 ("Other Data") of USEPA (1988), presumably because Al concentrations were not measured. However, it was included in Table 2 of this updated criteria evaluation because it provides information on the chronic sensitivity of *D. magna* in water of a moderate hardness (45.3 mg/L) and the result seems reasonable in comparison to the chronic value of 742.2 µg/L at a hardness of 220 mg/L (Kimball manuscript).

Table 2b. Aluminum Acute-Chronic Ratios

Species Latin Name	Species Common Name	pH	Hardness (mg/L as CaCO3)	Acute Value (µg Al/L)	Chronic Value (µg Al/L)	Acute-Chronic Ratio	Species Mean Acute-Chronic Ratio
Ceriodaphnia dubia	Cladoceran	7.15	50	1,900	1,908	0.9958	0.9590
Ceriodaphnia dubia	Cladoceran	7.75	50	1,500	1,624	0.9236	-
Daphnia magna	Cladoceran	8.30	220	38,200	742.2	51.47	-
Daphnia magna	Cladoceran	6.5-7.5	45.3	3,900	320	12.19	12.19[a]
Pimephales promelas	Fathead minnow	7.24-8.15	220	35,000	3,288	10.64	10.64
						Final ACR:	**4.9918**

[a] The acute-chronic ratio of 51.47 for *D. magna* was excluded from the species mean acute-chronic ratio because it was approximately 50 times higher than that observed for *C. dubia* and the acute-chronic ratio of 12.19 is more consistent with that observed for *P. promelas*.

Table 3. Ranked Genus Mean Acute Values with Species Mean Acute-Chronic Ratios

Rank	Genus Mean Acute Value (µg Al/L)	Species	Species Mean Acute Value (µg Al/L)	Species Mean Acute Chronic Ratio
17	>338,321	*Tanytarsus dissimilis* (midge)	>338,321	-
16	>53,794	*Lepomis cyanellus* (green sunfish)	>53,794	-
15	>53,578	*Perca flavescens* (yellow perch)	>53,578	-
14	>51,534	*Ictalurus punctatus* (channel catfish)	>51,534	-
13	32,922	*Physa* sp. (snail)	32,922	-
12	>24,315	*Acroneuria* sp. (stonefly)	>24,315	-
11	23,669	*Gammarus pseudolimnaeus* (amphipod)	23,669	-
10	>18,189	*Dugesia tigrina* (flatworm)	>18,189	-
9	>14,428	*Hybognathus amarus* (Rio Grande silvery minnow)	>14,428	-
8	9,205	*Salmo salar* (Atlantic salmon)	9,205	-
7	9,190	*Crangonyx pseudogracilis* (amphipod)	9,190	-
6	>7,547	*Oncorhynchus mykiss* (rainbow trout)	>7,547	-
		Oncorhynchus tshawytscha (chinook salmon)	>88,495*	-
5	>5,869	*Pimephales promelas* (fathead minnow)	>5,869	10.64
4	5,698	*Tubifex tubifex* (worm)	5,698	-
3	4,735	*Daphnia magna* (cladoceran)	4,735	12.19
2	4,370	*Asellus aquaticus* (isopod)	4,370	-
1	>2,604	*Ceriodaphnia dubia* (cladoceran)	>2,164	0.9590
		Ceriodaphnia sp. (cladoceran)	3,134	-

* SMAV for chinook salmon excluded from the GMAV for *Oncorhynchus*. See text for details.

Acute Criterion:

Final Acute Value = 2,648 µg/L (calculated at a hardness of 50 mg/L from Genus Mean Acute Values)

Criterion Maximum Concentration = (2,648 µg/L) / 2 = 1,324 µg/L (at a hardness of 50 mg/L)

Pooled Slope = 1.3695 (see Table 1)

ln (Criterion Maximum Intercept) = ln (CMC) – [slope x ln(50)] = ln (1,324) – [1.3695 x ln(50)] = 1.8309

Criterion Maximum Concentration = $e^{(1.3695[\ln(\text{hardness})] + 1.8309)}$

Final Acute-Chronic Ratio = 4.9918

Chronic Criterion:

Final Chronic Value = (2,648 µg/L) / 4.9918 = 530 µg/L (at a hardness of 50 mg/L)

Pooled Slope = 1.3695 (see Table 1)

ln (Final Chronic Intercept) = ln (FCV) – [slope x ln(50)] = ln (530) – [1.3695 x ln(50)] = 0.9162

Final Chronic Value = $e^{(1.3695[\ln(\text{hardness})] + 0.9162)}$

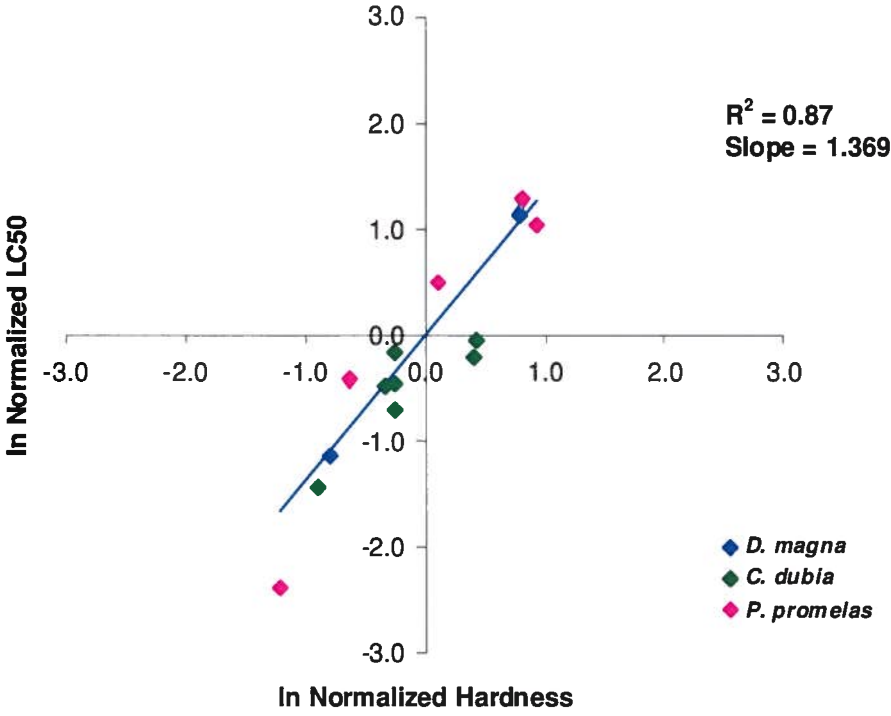

Figure 1. Relationship between Hardness and Acute Aluminum Toxicity

PRE-FILED REBUTTAL TESTIMONY
Robert W. Gensemer, Ph.D.
Parametrix, Inc., Albany, Oregon
On behalf of Los Alamos National Security, LLC
2009 Triennial Review of Surface Water Quality Standards

On behalf of Los Alamos National Security, LLC (LANS), I submit the following Pre-Filed Rebuttal Testimony in response to testimony presented by the New Mexico Environment Department (NMED) and other parties on or before August 28, 2009 in matters pertaining to proposed updates of aquatic life criteria for three metals: aluminum, zinc, and cadmium. Both LANS and Chevron Mining, Inc. submitted nearly identical proposal for updates to these criteria, and most of the comments below relate to earlier differences between LANS and Chevron Mining, Inc. in metals criteria proposals that have now, to the best of my knowledge, been resolved.

Rebuttal to Testimony of Pam Homer, NMED

The New Mexico Environment Department (NMED) submitted the *New Mexico Environment Department's Notice of Intent to Present Technical Testimony* on August 28, 2009 (hereafter cited as the *NMED Notice of Intent*). On page 126 of the *NMED Notice of Intent*, several comments were made expressing concerns over revised criteria for aluminum, cadmium, and zinc that were proposed by Los Alamos National Security, LLC (LANS 2009 a,b,c) and by Chevron Mining Inc. (CMI) via documents prepared for them by GEI Consultants. In general, NMED's concerns focused on differences between the numeric aquatic life criteria proposed by LANS and CMI, and that these proposals changed over time from CMI's initial proposals on September 30, 2008, up through proposals submitted by CMI on August 28, 2009. NMED did not receive the final criteria proposals from LANS (2009 a,b,c) until August 28, 2009, and so could not have responded to them in the *NMED Notice of Intent.*

The following repeats comments made in the *NMED Notice of Intent*, along with brief responses that we believe will address these concerns.

- **NMED Comment:** *Chevron Mining, Inc. (CMI) and LANS/DOE propose revised criteria for aluminum, cadmium and zinc. CMI submitted an initial proposal on September 30, 2008, supported by technical documents prepared by GEI Consultants, Inc. CMI submitted its formal proposal on June 1, 2009 using the same technical documentation, but the proposal differed from the earlier version. Aluminum in particular was significantly different, and there were also unexplained discrepancies between the versions for the other metals. LANS/DOE proposes similar but not identical criteria as CMI, but provides only a general technical justification.*

  LANS Response: The June 1, 2009 proposals submitted by LANS were based in part upon a review of the September 30, 2008 proposals submitted by CMI, but the criteria proposed by LANS at that time were different than the initial CMI proposals because they also reflected additional scientific analysis by LANS consultants (Parametrix, Inc.). As indicated in their June 1, 2009 submittal, LANS

GENSEMER TESTIMONY
EXHIBIT 3

consultants continued their review of the relevant scientific literature for all three metals criteria throughout the summer, culminating in submission of revised final proposals on August 28, 2009 (LANS 2009 a,b,c). These final proposed criteria are now essentially identical to those submitted by CMI on August 28, 2009. In our opinion, both sets of final criteria proposals reflect the most scientifically rigorous and consistent grounds upon which to base aluminum, cadmium, and zinc criteria for protection of aquatic life in New Mexico waters.

- **NMED Comment:** *The Department immediately contacted both CMI and LANS/DOE to point out these discrepancies within and between their proposals, requested explanations and revised proposals, and also encouraged a unified approach. Nonetheless, CMI did not provide revised technical documents to the Department until August 5, 2009, and did not file a corrected and revised proposal until August 21, 2009. Notably, CMI did not include its revised technical documents with the revised proposal. [...] To complicate matters still further, EPA provided the Department with comments on CMI's June 1 proposal and technical documents. These comments indicate significant issues with the technical basis for the proposed criteria, which may not be fully addressed by the most recent versions of these documents. Exhibit 69, Technical Comments on the Chevron Mining, Inc. Criteria Proposals, July 30, 2009.*

LANS Response: Once notified of these concerns regarding the discrepancies within and between the CMI and LANS criteria proposal, LANS consultants expended additional time and resources to ensure that our metals criteria were as consistent as possible with the scientific literature and with USEPA guidance. As a result, our final metals criteria proposals (LANS 2009 a,b,c) did end up differing not only from CMI's original September 2008 proposals, but from both CMI and LANS proposals submitted to NMED on June 1, 2009. As stated above, LANS is confident that their final criteria proposals not only are consistent with EPA guidance and our interpretation of the scientific literature, but are also essentially identical with CMI's final metals criteria proposals submitted on August 28, 2009. Therefore, we believe that the "discrepancies within and between their proposals" have now been resolved.

Furthermore, given the similarity in our criteria proposals, LANS has elected to respond to EPA comments on CMI's earlier metals criteria proposals as presented in *Exhibit 69, Technical Comments on the Chevron Mining, Inc. Criteria Proposals, July 30, 2009.* These comments and LANS' responses are presented separately below.

- **NMED Comment:** *The Department generally supports efforts to update the existing criteria with relevant new data. However, the Department declines to comment on CMI and LANS/DOE's proposals because 1) the CMI proposal was submitted a week before this testimony was due, and it is unclear what technical documents are intended to support the proposal or how those documents address the issues raised by EPA; and 2) LANS/DOE has indicated that it intends to update its proposal but declined to do so before August 28, and has never provided any specific technical support for its proposal. As a result, the proposals are a moving target without clear technical support. The technical support for these proposals* *must be available for any meaningful evaluation to occur, and there must be adequate time for review. The recalculation of criteria involves many steps -- reviewing acute and chronic toxicity studies, selecting or rejecting studies and particular data points, identifying resident and commercially or recreationally significant species, identifying and developing possible relationships to other water quality parameters, justifying assumptions, validating calculations -- any one of which can significantly affect the resulting equation, criteria values, and level of protection afforded.*

LANS Response: LANS and their consultants fully appreciate and understand the many complex steps involved in reviewing acute and chronic toxicity studies, and we support the need to rigorously follow EPA guidance to ensure that aquatic life and their uses are fully and adequately protected. We recognize that the June 1, 2009 preliminary criteria proposals submitted by LANS did not provide all of the detail needed to justify our assumptions and provide the basis of a thorough technical review by NMED and EPA. However, the final LANS proposals submitted on August 28, 2009 (LANS 2009 a,b,c) do provide the necessary levels of detail and transparency to facilitate such a review. LANS and their consultants welcome the opportunity to discuss the technical merits of their final criteria proposals with NMED and EPA. And as stated above, given the similarity in our criteria proposals, LANS has elected to respond to EPA comments on CMI's earlier metals criteria proposals as presented in *Exhibit 69, Technical Comments on the Chevron Mining, Inc. Criteria Proposals, July 30, 2009*. These comments and LANS' responses are presented separately below.

Rebuttal to EPA Comments on Chevron Mining Inc.'s Proposal for Updated Metals Criteria.

Russell Nelson of EPA provided comments to NMED on the Chevron Mining Inc. (CMI) proposals for revised aluminum (Al), cadmium (Cd), and zinc (Zn) surface water criteria for protection of aquatic life in New Mexico. These comments (*Exhibit 69, Technical Comments on the Chevron Mining, Inc. Criteria Proposals, July 30, 2009)* were provided on July 30, 2009 and, therefore, do not respond to the most current versions of CMI's proposals that were submitted on August 28, 2009. It appears that EPA commented on the February 2009 version of the CMI proposal for Al, as the page numbering referred to in the comments matches this submittal. It is not immediately clear which versions of the Cd and Zn proposals EPA commented on, although it appears that the comments on these metals apply equally to the August proposals submitted by CMI.

Los Alamos National Security, LLC (LANS) also submitted direct testimony on August 28, 2009 that also provided proposed revisions to aquatic life criteria for Al, Cd, and Zn (LANS 2009a, b, c). Given that these criteria proposed by LANS are essentially identical to those ultimately proposed by CMI in their August 28, 2009 testimony, the following presents clarifications or rebuttals to technical issues raised in the July 30, 2009 EPA comments to CMI which we feel also pertain to the aquatic life criteria proposed by LANS.

ALUMINUM

- **EPA Comment:** *Is the hardness Al toxicity relationship appropriate? If so, does the NMED agree with how they derived the relationship? It would be useful if the proposal included the complete dataset that was taken into consideration when deriving the criteria. Only 9 toxicity tests for 3 species were used to develop the acute hardness relationship. This is only a small subset of the full toxicity dataset. Although small subsets of the full dataset have been used to develop hardness relationships for some of the 304(a) criteria, it is not clear if in this situation, the relationship was created by cherry picking the data (which some have argued was done for the Cu hardness slope in the 1984 criteria document, which is why the BLM derived criteria are much better) or if the relationship is actually toxicologically relevant. It would be useful to have additional review of the hardness relationship and discussion on it included in the criteria derivation.*

  LANS Response: In evaluating and developing hardness-toxicity relationships for use in ambient water quality criteria development, the EPA guidelines (USEPA 1985) require that, for any given species, toxicity data must (1) be available for a range of hardness values such that the highest hardness value is at least three times higher than the lowest hardness value and (2) the highest hardness value must also be at least 100 mg/L (as $CaCO_3$) higher than the lowest hardness value on an absolute basis. Because these minimum data requirements are typically not met for most studies contained in a toxicity data set, it is common for the hardness-toxicity relationship to be based only a subset of the data from which the aquatic life criteria are derived. The LANS criteria proposal (LANS 2009a) presented a full explanation of which studies were selected (and in some cases, rejected) for use in developing the hardness relationship. All other acute toxicity data were summarized in Table 1a, so that the complete dataset from which the LANS proposed criteria were derived were presented. Overall, it should be emphasized that the hardness-toxicity relationship was evaluated and developed using methods that were consistent with the EPA guidelines for criteria development (USEPA 1985) and with hardness-dependent criteria that have been developed previously for other metals.

- **EPA Comment:** *Assuming NMED believes the acute toxicity hardness relationship is appropriate, a follow up question would be: Would NMED expect a similar hardness relationship for acute and chronic toxicity? On pg. 18, GEI states 'Use of the acute-hardness slope in the chronic equation should be applied cautiously given the limited chronic toxicity data do not strongly support this assumption. However, the lack of support may be an artifact of difficulties associated with conducting chronic toxicity tests with a poorly soluble compound, rather than a true lack of relationship.*

  With metals that are mostly dissolved at neutral pH, it is safe to assume that the relationship would be similar. This is what has been done for many of the 304(a) criteria. Al, on the other hand, is not soluble at neutral pH and generally *precipitates out of solution creating an aluminum floc. It is not clear if one should expect similar hardness relationships for acute and chronic exposure, when acute toxicity at times is more so the result of suffocation (due to the Al floc) than an interaction at the gill site. The mode of acute and chronic toxicity may be different. I am not familiar enough with Al toxicity to answer this question.*

LANS Response: We recognize that uncertainties exist in applying any acute metals hardness slope to chronic criteria, even if mechanisms of toxicity are relatively well understood. In our opinion, mechanisms of chronic metals toxicity are usually not well understood compared to acute toxicity, and even for metals that are dissolved at neutral pH and have ionoregulatory mechanisms of acute toxicity (e.g., copper), it is not always certain that chronic toxicity mechanisms (or hardness relationships, by extension) are similar to acute. While it may indeed be more "safe to assume" that acute and chronic toxicity slopes may be similar for dissolved metals, it is still not uncommon to apply acute hardness slopes to chronic criteria even if toxicity mechanisms are not fully understood.

In the case of aluminum, we agree that mechanisms of toxicity in the circumneutral pH range are most likely related to suffocation (due to the Al floc) rather than ionoregulatory disturbance, although gill binding may still be able to explain/predict toxicity at pH 6.5 or slightly higher (Teien et al. 2006). Although the literature is more limited, this mechanism (i.e., suffocation by Al floc) is also likely to be responsible for chronic and sublethal Al toxicity (Gensemer and Playle 1999). So even though Al toxicity at circumneutral pH may not be directly related to ionoregulatory mechanisms for which hardness is well known to mitigate metals toxicity (including Al at acid pH), the empirical hardness relationship for acute Al toxicity is still very consistent (LANS 2009a). Given that mechanisms of acute and chronic Al toxicity may be relatively similar, it is logical to suggest that an acute hardness relationship can be extended to derivation of chronic criteria. Furthermore, new research demonstrates that increasing hardness mitigates chronic Al toxicity to freshwater algae at pH 6 and 7 (Rodríguez et al. 2009). Therefore, we suggest it is reasonable to apply the acute hardness slope to development of chronic Al criteria.

In addition, empirical chronic Al toxicity data do show a tendency for chronic values to be lower at lower hardness, and most species can be shown to be reasonably "protected by" a harness-based chronic criteria equation (see Figure 1 and discussion below). While we recognize that a statistical relationship between empirical chronic Al toxicity data and hardness has not yet been established, we contend that the hardness-based Al criteria derived in LANS (2009a) is protective of chronically-sensitive species, particularly the brook trout and striped bass studies that were used to lower the current national AWQC to 87 µg/L (both of which having been conducted in extremely soft waters; see LANS 2009a for additional discussion). Therefore, we feel that the hardness-dependent chronic equation presented in LANS (2009a) is a reasonable basis for deriving chronic criteria, and is likely to be protective of chronically sensitive species in soft water.

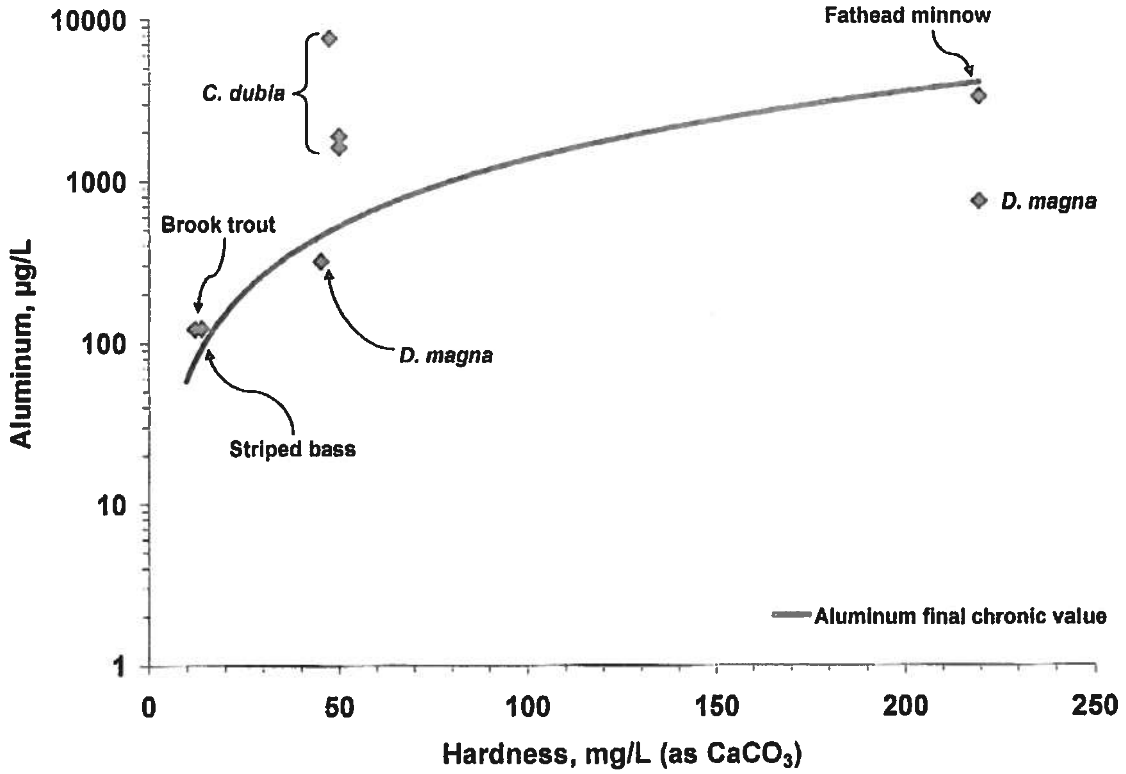

Figure 1: Comparison of hardness-dependent chronic aluminum criteria to empirical chronic toxicity values.

- **EPA Comment:** *Does NMED agree with how GEI calculated the ACR and FCV? GEI states that the SMACRs are "roughly" within a factor of 10. They took the geometric mean of all three SMACRs (0.9772, 10.6448, 12.0448). Does NMED agree with that approach?*

  LANS Response: Best professional judgment is often applied in selecting the appropriate ACR for deriving chronic criteria, particularly when ACRs are rather variable (as they are for Al, ranging from 1 to 12 for two acutely sensitive cladoceran species). In this case, LANS also agreed that using these three studies to derive the ACR was appropriate, as was the elimination of a much higher ACR for *Daphnia magna* of 51.47 because this test did not show Al to be acutely sensitive, and was conducted under elevated hardness and pH conditions that tend to mitigate acute Al toxicity. Ultimately, the final ACR of 4.99 appears to be a reasonable value when the proposed hardness-dependent chronic criteria are plotted versus empirical chronic toxicity data (Figure 1; which is based on the hardness-dependent chronic Al criteria proposed in LANS 2009a). This figure compares hardness-dependent chronic Al criteria (solid line) to the empirical chronic toxicity values presented in Table 2a of LANS (2009a). The chronic Al criteria in the figure reflect both the influence of the ACR and of the hardness-toxicity relationship. As shown, the hardness-dependent chronic criteria are protective of (i.e., the criteria equation line is nearly equal to or lower than) the chronic values for the chronically sensitive brook trout and striped bass, which form the basis for the EPA's current chronic criterion of 87 µg/L. This chronic criteria line would also be considered to be protective of all but one of the other chronic values plotted on Figure 1. Therefore, the ACR (and hardness relationships) used to derive the proposed chronic Al criteria are a reasonable basis upon which to derive the chronic criteria for Al.

- **EPA Comment:** *Note that the specific ERAB comments call for the supporting documentation should clarify the form of Al. The GEI doc states on pg. 20 that the proposal is for total AL. Those comments also suggest it would be preferential to take pH into consideration rather than hardness. This is why Region 8 supported the current footnote that many States, including CO has adopted, which clarifies that the chronic criterion of 87 µg/L would be applied to waterbodies where pH is <7.0. Since the preferred method of developing a pH relationship is not possible at this time, the footnote is a good alternative that recognizes increased Al toxicity at low pH.*

LANS Response: EPA raises two issues in this comment. The first expressed a need to clarify the form of Al to be used for criteria implementation. The criteria proposed by LANL and CMI were expressed on a dissolved aluminum basis to be consistent with current New Mexico criteria which are also expressed as dissolved aluminum. Technically, the national criteria are intended to be implemented on the basis of "acid-soluble" aluminum, rather than either total or dissolved Al (USEPA 1988). "Acid-soluble" metal is operationally defined as the aluminum that passes through a 0.45 µm-porosity filter membrane after the sample has been acidified to a pH between 1.5 and 2.0. However, many states (including New Mexico) still express their aluminum criteria on the basis of dissolved aluminum.

The basis for the possible use of acid-soluble aluminum for criteria implementation is discussed at length on pages 10 – 14 of the national criteria document (USEPA 1988). Briefly, acid-soluble Al is a more accurate measure of solid and colloidal phases of Al "that are toxic to aquatic life or can be readily converted to toxic forms under natural conditions (USEPA 1988)." Acid soluble aluminum also avoids measurement of more recalcitrant and truly non-toxic solid phases (e.g., suspended clays) that would be measured using total recoverable methods "because the digestion procedure will probably dissolve some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions" (USEPA 1988).

Therefore, expressing Al criteria on the basis of total aluminum measured in the field would not be an accurate representation of the toxicology data used to derive either the existing criteria or our proposed updated criteria. Furthermore, use of dissolved aluminum for criteria implementation is consistent both with national guidance, and with current New Mexico water quality criteria. While the national criteria suggest acid-soluble as the most appropriate form of aluminum, there is currently no standard method available under 40 CFR Part 136. Therefore, it is most appropriate and consistent with both national and current state guidance to express aluminum criteria on the basis of dissolved aluminum concentrations.

The second issue raised by EPA addresses the possibility of taking pH into account for deriving Al criteria. The proposed hardness-dependent Al criteria are intended to apply to pH levels ranging from 6.5 to 9.0, which is consistent with the EPA's current Al criteria. As noted in GEI's proposed Al criteria report, "Preliminary review of published reports that tested aquatic organism toxicity over a wider range of acidic pH values did indicate a strong relationship between measured Al toxicity and pH, with more acidic waters having greater Al toxicity. However, this relationship reached an asymptote at approximately pH = 6, again with no observable pH versus Al toxicity relationship found in the required pH range of 6.5-9.0. As such, no pH factor is included in this update to Al criteria." From our knowledge of the Al toxicity literature, we agree that a reliable statistical relationship between toxicity and pH in the pH range of 6.5 – 9.0 has never been demonstrated for most aquatic organisms.

The EPA's current Al chronic criterion of 87 µg/L is based on a 60-day study with brook trout (*Salvelinus fontinalis*) and a 7-day study with striped bass (*Morone saxatilis*). The brook trout study (Cleveland et al. 1989) was conducted in a test water with a hardness of 12.3 mg/L and pH of 6.5-6.6. Because single hardness and pH levels were tested, the data do not provide any indication of which parameter, hardness or pH, was the dominant factor influencing the Al toxicity observed. In the striped bass study (Buckler et al. 1987), 160-day old fish were exposed to Al in soft water (approximately 14 mg/L) at pH levels of either 6.5 or 7.2. An Al concentration of 174.4 µg/L resulted in 58% mortality at pH 6.5, but 2% mortality at pH 7.2. This would suggest that pH had an important influence on the Al toxicity observed (i.e., increased toxicity at lower pH). However, additional toxicity data reported in Buckler et al. (1987) do not reflect a similar effect of pH on toxicity. For example, in 159-day old fish, an Al concentration of 390 µg/L resulted in 0% mortality in waters with both a pH of 6.5 and 7.2 (so no pH effect, and at a higher Al concentration). Accordingly, the influence of pH in this study is equivocal.

There is an additional study in Table 6 ("other data") of the EPA's current ambient water quality criteria document for Al (USEPA 1988) that evaluated the toxicity of Al at multiple pH levels. Holtze (1983) exposed rainbow trout (*Oncorhynchus mykiss*) embryos and larvae to an Al concentration of 1,000 µg/L for 8 days at pH levels of 6.5 and 7.2 and observed no effect at either pH (water hardness was 14.3 mg/L). In another test, Holtze (1983) exposed eyed rainbow trout embryos to an Al concentration of 1,000 µg/L for 8 days and observed 14.2% mortality at pH 6.5 and a higher mortality of 21.6% at pH 7.2.

Overall, based on the limited data available, the influence of pH (6.5 vs. 7.2) under circumneutral conditions on Al toxicity is not consistent. Few published data are available for studies in which both pH and hardness were varied at this pH range. However, defaulting to a chronic Al criterion of 87 µg/L when the pH of the water is less than 7.0 appears to be quite conservative, particularly in light of the EPA's current caveat that they are "aware of field data indicating that many high quality waters in the U.S. contain more than 87 µg aluminum/L, when either total recoverable or dissolved is measured."

- **EPA Comment:** *GEI provided an explanation in Section 3.1 for the decision to use the lower value of 16,600 µg/L for Girardia instead of 1988 value of 23,000 µg/L (which was estimated using the geometric mean) based on more recent data* *suggesting the lower value may be more appropriate. In this explanation, the authors suggest that Charles Stephan (personal communication to David Moon, 2004) indicated that the 23,000 µg/L value is the "real" value that should be used. In fact, Stephan's comment was that it is inappropriate to use a GMAV of 16,600 µg/L for Dugesia in the calculation of the FAV. EPA concluded that the LC50 must be greater than 23,000 µg/L because, on the average, acute LC50s are about a factor of 2 higher than concentrations that cause a low level of acute mortality. Because 16,600 µg/L resulted in no adverse effects, EPA concluded that the LC50 must be greater than 23,000 µg/L, and therefore set the GMAV at > 23,000.*

LANS Response: This comment has no influence on the criteria calculation because *Girardia* is not among the four most sensitive genera. In general, the EPA does not use estimated values in criteria development tables, so it is unclear why EPA did so here. Use of the lower Al concentration is a more conservative interpretation for *Girardia*, and matches the interpretation used favored by LANS (2009a). But because *Girardia* is not an acutely sensitive species (i.e., not one of the four most sensitive genera), the absolute value of the genus mean acute value for this species ultimately has no influence on the outcome of the criteria calculations.

CADMIUM

- **EPA Comment:** *The State's submission should provide a scientifically defensible rationale for inclusion of the studies by Suedel et al., (1997), Davies and Brinkman, (1994) and Buhl and Hamilton, (1991) since these have been previously rejected.*

  LANS Response: The LANS Cd criteria proposal (LANS 2009c) also included toxicity data from these three studies. LANS continues to support inclusion of these studies for the reasons summarized in the following bullets:

  - **Suedel et al. (1997):** As noted in LANS (2009c), the test organisms in the Suedel et al. (1997) study were fed. According to the EPA guidelines (USEPA 1985), "results of acute tests during which the test organisms were fed should not be used, unless data indicate that the food did not affect the toxicity of the test material." Based on a comparison of LC50 values for *Ceriodaphnia dubia*, *Daphnia magna*, and *Pimephales promelas* from Suedel et al. (1997) to LC50s from other studies, it does not appear that food had a significant or consistent effect on the LC50s. As such, the LC50s from Suedel et al. (1997) were included in the revised Cd criteria proposal. This resulted in the addition of two new species (the midge *Chironomus tentans* and the amphipod *Hyalella azteca*) and augmented the dataset for three other species (the cladocerans *C. dubia* and *D. magna*, and the fathead minnow *P. promelas*). This study was not rejected in the EPA's latest AWQC document for Cd (USEPA 2001), as it was not cited.
  - **Davies and Brinkman (1994):** Similar to the Suedel et al. (1997) study discussed in the previous bullet, this study was not cited in USEPA (2001) and, therefore, was not previously rejected. We are not aware of any

technical reasons why this study should not be included for development of Cd criteria.

- **Buhl and Hamilton (1991):** Acute data from Buhl and Hamilton (1991) were included in Table 1 of USEPA (2001) for juvenile coho salmon and juvenile rainbow trout and Table 6 for coho salmon alevins, rainbow trout alevins, and Arctic grayling (alevins and juveniles). In the LANS Cd criteria proposal, we likewise included the rainbow trout and coho salmon toxicity data in our Table 1, and continue to support use of these data as they meet the guidelines for AWQC development (USEPA 1985).

- **EPA Comment:** *EPA acknowledges the intention to follow the 1985 Guidelines in protecting commercially and recreationally sensitive fish species. Therefore, we recommend using the SMAV of* Salvelinus fontinalis *(1.76) as the FAV in the calculation of the CMC to protect a commercially and recreationally important species.*

LANS Response: In the LANS (2009c) submittal, we set the FAV equal to the rainbow trout SMAV, rather than the brook trout SMAV, for the following reason. In the EPA's current 2001 AWQC document for Cd, the FAV based on the 5th percentile of GMAVs was 2.763 µg/L. The SMAVs for brown trout (1.613 µg/L), brook trout (<1.791 µg/L), rainbow trout (2.108 µg/L), and bull trout (2.152 µg/L) were all lower than the calculated FAV. The EPA lowered the FAV to equal the rainbow trout SMAV, rather than the brown trout or brook trout SMAV, because the data for these latter two species were generated from static tests, while flow-through tests are available for rainbow trout and bull trout. USEPA (1985) guidance clearly prefers use of flow-through rather than static tests, and so the same logic was applied in LANS (2009c). This still results in lowering the calculated FAV to protect a salmonid with similar acute sensitivity to that of brook trout, but using a more scientifically reliable SMAV value.

ZINC

- **EPA Comment:** *In examining the studies utilized in deriving GMAVs for the most sensitive species, there were some studies that have been rejected in literature reviews in the past. The Buhl and Hamilton 1990 study with* Thymallus arcticus, *was rejected for "duration, insufficient control, and no hardness." In addition, this study was static and zinc concentrations were unmeasured. If this study is not included,* T. arcticus *would have to be excluded from the species list, and would therefore not be one of the most sensitive species included in the calculation of the FAV.*

LANS Response: We do not agree that this study should be excluded, as the duration was 96 hours, hardness was measured, and the test included a control. We recognize that zinc exposure concentrations were not measured. However, acute toxicity studies are not always excluded from acute criteria development because test concentrations are unmeasured, even though measured tests are still preferred

(USEPA 1985). Therefore, this study was retained in our proposed criteria updates (LANS 2009b).

- **EPA Comment:** *The third study cited for* Cottus bairdi, *with an LC50 value of 590, is cited incorrectly. The study was NOT conducted by Brinkman and Woodling, but is cited within their paper. The study was actually conducted by Davies et al., 2002.*

  LANS Response: LANS (2009b) also cited the Brinkman and Woodling study for this LC50 value, but we agree that this citation should be corrected to cite Davies et al. 2002, with no resulting change in the proposed criteria.

- **EPA Comment:** *Hyne et al. (2005) cited for numerous values for* Ceriodaphnia dubia *should be flagged, due to unacceptable levels of DO during the exposure period. Not sure whether this is enough to exclude the study from the findings.*

  LANS Response: The DO levels were not explicitly cited in the paper, although it was stated that studies were acceptable if DO did not fall below 3 mg/L. The hardness-adjusted LC50s for *C. dubia* from this study overlap with those from other studies, so the results do not seem anomalous. Therefore, toxicity data from Hyne et al. (2005) were included in the LANS (2009b) Zn criteria proposal.

- **EPA Comment:** *Actually analyzing the 4 cumulative probabilities closest to the 5th percentile would include the 5th most sensitive species. The 5th most sensitive species,* Tropocyclops prasinus, *only has one data value; this study has been previously rejected due to "insufficient control."*

  LANS Response: In the LANS (2009b) Zn criteria submittal, the *T. prasinus* SMAV was calculated based on Zn LC50s of 52 and 264 µg/L (non-hardness-adjusted) from the study by Lelande and Pinel-Alloul (1986). This resulted in *Tropocyclops* being the 14th most sensitive GMAV. The study did include a control, with a Zn concentration of 1 µg/L. Although raw concentration-response data are not provided in the paper, the logarithmic toxicity curve for Zn provided in the paper shows 0% mortality well above the Zn concentration in the control and, accordingly, control mortality appears to have been 0% or otherwise negligible. Therefore, we concluded that this study was acceptable for use in developing Zn criteria.

  We also agree that it is acceptable (USEPA 1985) to base the Final Acute Value calculation on the GMAVs for genera with sensitivity closest to the 5^{th} percentile, even if this is not the lowest 4 GMAVs as is typically done. However, doing so would have only a minor impact on the final Zn criteria calculations, and our approach is consistent with current national criteria calculations for zinc (USEPA 1995). Therefore, we concluded that the LANS (2009b) proposal that uses the four lowest GMAVs still represents an acceptable approach for deriving Zn criteria.

- **EPA Comment:** Ranatra elongata, *water scorpion, (top of page 6) is not a resident species of the U.S., and should not be included in the calculation.*

  LANS Response: While the species *R. elongata* may not be considered to be a U.S. resident species, the genus is present in the U.S. (Arnett 2000). Given that toxicant sensitivities are generally consistent among different species within the same genus, we contend that it is preferable to use as many SMAV values as possible for defining GMAV values, so long as the values are relatively consistent with one another (as per USEPA 1985), and the genus is resident to the U.S. In essence, we contend that the benefits of including additional data outweigh strict adherence to EPA guidance for this particular issue. Furthermore, updates to zinc criteria that were recently promulgated in Colorado[1] (with EPA approval) also include this toxicity value for *R. elongata* for these same reasons.

- **EPA Comment:** Moina irrasa, *a cladoceran, distribution and residency in the U.S. should be reviewed. Most reports found occur in China.*

  LANS Response: Similar to *R. elongata*, we continue to favor inclusion of toxicity data for *Moina irrasa* in our Zn criteria proposal. While it is possible that the species *M. irrasa* may not be considered to be a U.S. resident species, the genus is present in the U.S. (ITIS 2009). Given that toxicant sensitivities are generally consistent among different species within the same genus, we contend that it is preferable to use as many SMAV values as possible for defining GMAV values, so long as the values are relatively consistent with one another (as per the 1985 Guidelines), and the genus is resident to the U.S. In essence, we contend that the benefits of including additional data outweigh strict adherence to EPA guidance for this particular issue. Furthermore, updates to zinc criteria that were recently promulgated in Colorado[2] (with EPA approval) also include this toxicity value for *M. irrasa* for these same reasons.

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[1] See Regulation No. 31 at 31.16 (Table III), and more background at 31.44.J (Colorado Department of Public Health and Environment, Water Quality Control Commission. 2007. The Basic Standards and Methodologies for Surface Water).

[2] See Regulation No. 31 at 31.16 (Table III), and more background at 31.44.J (Colorado Department of Public Health and Environment, Water Quality Control Commission. 2007. The Basic Standards and Methodologies for Surface Water).

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GEI Consultants

Geotechnical
Water Resources
Environmental and
Ecological Services

Ambient Water Quality Standards for Aluminum – Review and Update

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GENSEMER TESTIMONY
EXHIBIT 4

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1.0 Introduction

At the request of Chevron Mining Inc., GEI Consultants, Inc (GEI), Ecological Division, has evaluated the technical basis for current water quality standards for aluminum (Al) for the protection of aquatic life, based on the United States Environmental Protection Agency (USEPA) criteria derivation and recalculation procedures (Stephan et al. 1985, USEPA 1994). This analysis was initiated using the existing criteria document and national Al toxicity databases (USEPA 1988), which are the basis for current New Mexico surface water quality standards.

The purpose of this analysis was to revise and update acute and chronic Al standards using the USEPA criteria derivation methods. This report is based primarily on an overall evaluation of the USEPA recalculation procedure for Arid West effluent-dependent waters (AWWQRP 2006), which included an analysis of potential updates to Al standards. The first step of any USEPA recalculation procedure is a technical review of the most up-to-date USEPA ambient water quality criteria (AWQC) document to determine if 1) suitable and correct data were included in national toxicity databases and 2) USEPA criteria development methods were followed for deriving standards. USEPA Guidelines for Deriving Numerical Water Quality for the Protection of Aquatic Organisms and their Uses (Stephan et al. 1985), hereafter referred to as 1985 Guidelines, provide details on the acceptable data and criteria derivation methods, including minimum data requirements for the toxicity database, often referred to as the "eight-family rule" (Stephan et al. 1985). The next step is an update of national toxicity databases, with an emphasis on literature available since the most recently published databases. Following the compilation of literature and development of the revised database, each acute and chronic standard is recalculated using methods described in the 1985 Guidelines.

The USEPA established national aquatic life criteria for Al in a 1988 report entitled *Ambient Water Quality Criteria for Aluminum* (USEPA 1988), hereafter referred to as the 1988 Aluminum Document. This document established a working toxicity database with recommended AWQC to protect freshwater organisms. This report and its accompanying recommended AWQC for Al are now 21 years old. Since publication of this report, information on the environmental significance of freshwater organism Al exposure and available toxicity studies has increased, allowing an update to these AWQC.

2.0 Background

Aluminum is the most abundant metal and the third most abundant element in the earth's crust. As such, it is commonly found in waterways as a result of natural runoff, erosion of clay-based soils, and other geologic sources. Acid rain deposition has dramatically increased the amount of Al appearing in many biological systems, increasing exposure of soluble Al to aquatic species. Other anthropogenic sources include wastewater effluent (from pharmaceuticals, cooking practices, water supplies, and aluminum-sulfate (alum) flocking of drinking water supplies or phosphorus removal in effluent, burning of coal and hydrocarbons, and suspension of fine dusts during agricultural practices (AWWQRP 2006).

Aluminum water solubility is a function of pH. In the neutral pH range, the thermodynamic stability of Al hydroxide, or gibbsite ($Al(OH)_3$), controls solubility with little monomeric Al^{3+} in solution (Gensemer and Playle 1999). Monomeric Al^{3+} becomes more available relative to gibbsite at $pH < 4.7$ and $pH > 9$. At circumneutral pH range, total Al is usually much greater than monomeric species (Gensemer and Playle 1999). Al solubility is also dependent on organic compounds in solution. At circumneutral pH ranges, dissolved organic matter, and especially weak organic acids (e.g., fulvic, citric, and humic acids), can increase Al solubility while decreasing aquatic organism toxicity. This is an important transport mechanism in Al cycling (Schlesinger 1997).

These complex speciation and complexation kinetics raise issues of how to measure Al in natural water and/or toxicity test media. Filtration and ion exchange resins are used to separate monomeric dissolved Al from particulate and polymeric forms (Van Benschoten and Edzwald 1990). Rapid speciation of Al in test solutions can be a potential problem when determining solid and dissolved species. Analytical and technical issues when characterizing dissolved from total Al in complex solutions are limited using kinetic modeling. Many authors use theoretical calculations such as REDEQL (Morel and Morgan 1972) and later replaced by MINEQL (Environmental Research Software, Hallowell, ME) that model speciation in relation to water quality parameters and total Al measurements (Lamb and Bailey 1981, Cleveland et al 1989, and Lacroix et al. 1993). Given these physical and methodological issues, USEPA originally recommended that the toxicity values for Al be regarded as total Al (USEPA 1988). However, for calculation of standards from hardness-based equations, a total recoverable Al standards basis would be over-conservative, because it would likely include Al bound in minerals, clays, and other solids fractions that are not toxic and are not likely to become toxic under natural conditions.

The 1988 Aluminum Document recommends Al criteria should be implemented on the basis of "acid-soluble" Al. While the existing New Mexico standards *values* are consistent with those in the 1988 Aluminum Document (USEPA 1988), the New Mexico standards are expressed on a dissolved Al basis. According to USEPA criteria, the acid-soluble basis is "the Al that passes through a 0.45µm membrane filter after the sample has been acidified to a pH between1.5 and 2.0 with nitric acid" (USEPA 1988). Expressing the Al standards on this basis would seem to have both toxicological and practical advantages because it captures a more complete fraction of potentially toxic Al species (when compared to only the dissolved fraction). However, there does not appear to be a current USEPA-approved methodology for the acid-soluble approach.

While a "dissolved Al" methodology might not be the absolute best approach for the revised hardness-based equations presented in this report, the characteristics of Al allow for the use of a dissolved method to reliably measure potential Al toxicity. Colloidal Al is able to pass through a 0.45 µm filter and would be included in "dissolved" measurements when it is not actually "dissolved" (as cited in Hem 1985). In fact, it is likely those colloidal particles are actually included in current dissolved data and may represent much of the fraction USEPA believes would be captured by the acid-soluble methodology recommended in the 1988 Aluminum Document. As such, we believe retention of the dissolved Al approach is appropriate for the proposed standards updates below.

The speciation and/or complexation of Al is highly dependent on ambient water quality characteristics and ultimately determine the mechanism of toxicity. Wilkinson and Campbell (1993) demonstrated the difficulty of determining Al speciation in complex solutions – such as natural waters with abundant Dissolved Organic Carbon (DOC) and silicic acid – when determining mechanisms of toxicity in fish. The primary target of Al toxicity in fish is damage to respiratory organs, such as gills (Lacroix et al. 1993). The chemical conditions at the gill surface are thought to modify Al speciation and sorption. Water passing over the gills can become more basic due to neutralization of acidic water by NH_3. This can lead to precipitation and polymerization of Al, resulting in Al deposition on the gill surface. Accumulation of Al on the gill surface epithelium and/or mucous layer has been shown to enhance rates of sloughing and hyperplasia of lamellae (Leivestad 1982). The ionoregulatory versus respiratory effects of Al on fish are pH-dependent, with the former predominating at relatively acidic pH (Gensemer and Playle 1999). Additionally, concentration of calcium in the water was shown to decrease toxic effects to fish (Muniz and Leivestad 1980). Calcium reduces Al toxicity by competing with monomeric Al binding to negatively charged fish gills and by keeping tight junctions between epithelial cells intact (Gensemer and Playle 1999).

The number of toxicity tests addressing Al toxicity in aquatic invertebrates is considerably less when compared to fish, but, in general, results indicate invertebrates are less sensitive than fish (Sparling and Lowe 1996). Mechanisms of toxicity are confounded by H+ toxicity when testing at low pH, but published evidence supports ionoregulatory effects of Al exposure. Different H+ exchange mechanisms in different invertebrates can have different impacts on their pH-dependent Al toxicity (Gensemer and Playle 1999). Havens (1990) identified significant accumulation of particulate Al on ionoregulatory and respiratory surfaces in cladocerans. Additionally, increased membrane permeability with subsequent ion loss has been reported in acid sensitive invertebrate species (Locke 1991). In mayflies, Al accumulation on respiratory surfaces reduced oxygen consumption due to physical blockage of gill chambers (Rockwood et al. 1990).

From our understanding of Al toxicity, we can identify two distinctly different mechanisms of toxicity. The first mechanism is a physical suffocation or irritation caused by particulate Al exposure, or from precipitation in the gill microenvironment (Gensemer and Playle 1999), leading to hypoxia-related toxic effects that often become manifest during acute exposure scenarios. The second mechanism is driven by dissolved monomeric Al species that disrupt ionic regulation, an effect expected with a chronic exposure regimen (although acute effects could also be observed at acidic pH). Given Al speciation and behavior in complex solutions, the mechanism responsible for toxicity will probably be dependent on pH and calcium concentration of a given solution. Therefore, understanding Al speciation chemistry and its influence on the mechanisms of toxicity to fish and invertebrates are important to interpreting the toxicological studies which form the basis of ambient water quality standards development (AWWQRP 2006).

3.0 Phase I – Technical Review of 1988 Aluminum Document

Phase I of the evaluation of the 1988 Aluminum Document consists of a thorough investigation of the data used to calculate the most recent Al standards. This document was critically reviewed for relevance of the toxicological data and adherence to USEPA methodology (Stephan et al. 1985).

3.1 Existing Acute Standards for Aluminum

The 1988 Aluminum Document (USEPA 1988) presents acute data for 14 genera, including seven species of invertebrates and seven species of fish. These 14 species in 11 families satisfy the "eight-family rule" as specified in the 1985 Guidelines. The 1988 Aluminum Document reports a calculated final acute value (FAV) of 1,496 µg/L with a criterion maximum concentration (CMC) = FAV/2 or 750 µg/L (after rounding to two significant digits).

When reviewing the reported values used in the USEPA criteria development, an apparent discrepancy regarding the species mean acute value (SMAV) for *Girardia* (= *Dugesia*) *tigrina* (AWWQRP 2006) was discovered. The authors of the toxicity test data for this species reported that the greatest Al exposure concentration for this species was 16,600 µg/L (Brooke 1985) with the ambient acute value of >16,600 µg/L, since no significant mortality was observed. However, the 1988 Aluminum Document reports >23,000 µg/L for the same species and reference. The implications of this discrepancy could be significant and would result in a *Girardia* genus mean acute value (GMAV) rank change from 6th most sensitive to 4th most sensitive. Charles Stephan, USEPA, (personal communication to David Moon, December 13, 2004) has since noted that no *G. tigrina* died at 16,600 µg/L in that study, so it was reasonable to assume that the "true" LC_{50} was potentially two times the concentration that caused a low level of acute mortality (i.e., 32,000 µg/L) – with the "real" value somewhere in between. As such, the geometric mean of 16,600 µg/L and 32,000 µg/L was then reported in the criteria document as the acute value (i.e., >23,000) for *Girardia* to account for the undefined test value.

Since the 1988 Aluminum Document was published, new data became available suggesting the undefined value (>16,600 µg/L) may actually be more appropriate. Calevro et al. (1998) tested Al toxicity in a related flatworm (*G. etrusca*) and reported that this species showed lethality, abnormal mucus production, and decreased regeneration at concentrations near 16,000 µg/L. Therefore, in this re-analysis, the existing >23,000 value is replaced with Brooke's original reported value of >16,600 µg/L for *G. tigrina*.

3.2 Existing Chronic Standards for Aluminum

The 1988 Aluminum Document presents chronic data for three genera of freshwater organisms, including two species of invertebrates and one fish species. These three species do not satisfy the "eight-family rule" as specified in the 1985 Guidelines. The chronic database assemblage did, however, satisfy the minimal requirements for calculation of an acute-to-chronic ratio (ACR) in that one of the invertebrates is an acutely sensitive species.

After calculation of three valid ACRs for the three species, it was evident that the most acutely sensitive species had lower ACRs. Given this relationship, a final ACR (FACR) was calculated using acutely sensitive *Ceriodaphnia dubia*, which resulted in a FACR that was less than 2, which then defaults to 2 according to USEPA guidance (Stephan et al. 1985). A FACR of 2 thus resulted in a chronic criterion of 750 µg/L, equal to the acute criterion, since in both cases the FAV was divided by 2.

However, USEPA did not use this calculated chronic value. Additional data on Al toxicity for *Salvelinus fontinalis* and *Morone saxatilis* (Cleveland et al. manuscript and Buckler et al. manuscript) were used by the USEPA to modify the final chronic value (FCV) to protect these two species (USEPA 1988). Interestingly, these two studies were deemed inappropriate for the Al chronic database (i.e., they are included in Table 5-6, "Other Data on Effects of Aluminum on Aquatic Organisms"), but were still used to reduce the FCV from approximately 750 to 87 µg/L.

Therefore, the 1988 Aluminum Document recommended a Criteria Chronic Concentration (CCC) of 87 µg/L at which no *M. saxatilis* died after a seven-day exposure (Buckler et al. manuscript). In the same toxicity test, 174.4 µg/L killed 58 percent of the fish. Criteria derivation methods would typically calculate the chronic value as the geometric mean of these two numbers, or 122 µg/L. However, the 87 µg/L chronic criterion was recommended and is the current value used in New Mexico.

4.0 Phase II – Update to the National Aluminum Database

A comprehensive literature review was recently conducted of Al aquatic toxicity related documents used and not used in the 1988 Aluminum Document (AWWQRP 2006). This included a review of documents published since the 1988 Aluminum Document, as well as those published prior to 1988 that were not used in criterion derivation. Available Al documents were obtained and reviewed for relevance of toxicological data and adherence to USEPA criteria development methodology (Stephen et al. 1985).

A pH range of 6.5 to 9.0 was established as a limit for data used in the update of the Al toxicity databases because the USEPA has established this as an acceptable range for pH in ambient freshwater (USEPA 1976). This circumneutral pH gradient was the same range used to derive current criteria in the 1988 Aluminum Document. From the discussion on Al speciation above, we would thus expect that toxic effects of Al in test media of circumneutral pH could be attributed to exposure to monomeric Al species. Additionally, reported total Al measurements should be substantially greater than dissolved measurements owing to the poor solubility of Al under these pH conditions.

Approximately 120 papers were reviewed, including documents cited in the 1988 Aluminum Document. We also reviewed three specific papers (Baker and Schofield 1982, Dwyer et al. 1995, and Dwyer et al. 2005) later recommended in 2007 following a preliminary review of the AWWQRP (2006) analysis of the Santa Ana River, CA, Al case study by Luis A. Cruz (Ecological Risk Assessment Branch, Health and Ecological Criteria Division, Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, Washington, DC – personal communication). Those three additional papers yielded no useable data for the updated Al database.

Much of the research into Al toxicity in aquatic organisms has been concerned with toxicity of Al in acidic solutions – specifically in research investigating effects of acid rain – with considerably fewer studies addressing toxic effects at circumneutral pH. Published reports that tested aquatic organism toxicity at circumneutral pH solutions often did so as part of tests over a wider range of acidic pH values. For example, a common experimental design in published Al toxicity studies was limiting the number of treatments and replicates at higher pH values to focus on lower pH values where Al is soluble and hence, more toxic. This experimental design resulted in very few data points with usable LC_{50}s or EC_{50}s (based on a narrow dose response within the applicable pH range of 6.5-9.0). In addition, given that most available research was conducted to test toxicity over a pH range using a constant Al exposure concentration, rather than over an Al concentration gradient, reportable end points for Al were often "greater than" values. Such undefined values were added to the toxicity database judiciously, if they could be corroborated by additional sources of published evidence, and after careful consideration of the author's qualitative effect descriptions. This aided in developing an updated Al toxicity database that did not ignore potentially important toxicity data.

4.1 New Aluminum Acute Toxicity Data

Following review of the available studies, 35 acute data points from 13 studies (Table 1) were deemed suitable for addition to the revised and updated acute toxicity database. Of the 13 studies added to the database, three were published prior to the 1988 Aluminum Document. One of these studies published prior to the 1988 Aluminum Document were not cited in either Table 1, "Acute Toxicity of Aluminum to Aquatic Animals," or Table 6, "Other Data on Effects of Aluminum on Aquatic Organisms" in the 1988 Aluminum Document and apparently represent data that were unknown to the USEPA at that time.

Of the 13 studies examined and accepted for database revision, two studies provided new data for two species that are within the top four most sensitive genera in the revised database (*Asellus aquaticus* and *Tubifex tubifex*). Martin and Holdich (1986) performed acute toxicity tests with *A. aquaticus* to a variety of heavy metals, including Al. Static renewal test exposures were conducted in soft water (hardness 50 mg/L $CaCO_3$) at a pH of 6.75. Khangarot (1991) performed acute toxicity tests with *T. tubifex* to 32 metals, including Al. Renewal test exposures were conducted in hard water (hardness 245 mg/L $CaCO_3$) at a pH of 7.6. Reported results included 96-hr LC_{50}s for both tests.

In addition to the single *Ceriodaphnia dubia* (McCauley et al. 1986) data point presented in the 1988 Aluminum Document, two more acceptable acute values are available from McCauley et al. (1986). While an LC_{50} value of 1,900 µg/L (test pH = 7.42) from this study was included in the 1988 Aluminum Document, McCauley et al. (1986) also provided two additional LC_{50} values of 1,500 µg/L (test pH = 7.86) and 2,560 µg/L (test pH = 8.13). These data were added to the updated acute database (Table 1).

While studies reporting data for the rainbow trout (*Oncorhynchus mykiss*) and smallmouth bass (*Micropterus dolomieu*) were found, data from these studies were determined to be unusable (Thomsen et al. 1988, Kane and Rabeni 1987, respectively). In the Thomsen et al. (1988) study, hardness data were not provided; instead, only calcium water quality data were provided. In addition, there is some uncertainty regarding the actual duration of the study. In the Kane and Rabeni (1987) study, the highest effect level observed was 20%, which is considerably far away from an LC_{50}. Due to the uncertainty in the accuracy of this value, and the fact that *Micropterus* would fall in the lowest four GMAV values and thus be an extremely important driver in the standards calculations, this questionable data point was not used.

Table 1: Summary of acute Al data that were deemed acceptable for standards derivation and added to the updated Al acute database.

Species	Method	Hardness (mg/L $CaCO_3$)	pH	LC_{50} (µg/L)	Reference
Ictalurus punctatus	F, M	23.1	6.5	>400	Palmer et al. 1988
Ictalurus punctatus	F, M	23.1	7.5	>400	Palmer et al. 1988
Oncorhynchus mykiss	F, M	25	7.6	<8,000	Gundersen et al. 1994
Oncorhynchus mykiss	F, M	45	7.6	<8,000	Gundersen et al. 1994
Oncorhynchus mykiss	F, M	85	7.6	<8,000	Gundersen et al. 1994
Oncorhynchus mykiss	F, M	125	7.6	<8,000	Gundersen et al. 1994
Oncorhynchus mykiss	F, M	23.2	8.25	6,170	Gundersen et al. 1994
Oncorhynchus mykiss	F, M	35	8.25	6,170	Gundersen et al. 1994
Oncorhynchus mykiss	F, M	83.6	8.29	7,670	Gundersen et al. 1994
Oncorhynchus mykiss	F, M	115.8	8.29	6,930	Gundersen et al. 1994
Pimephales promelas	F, M	21.6	6.5	>400	Palmer et al. 1989
Pimephales promelas	F, M	21.6	7.5	>400	Palmer et al. 1989
Pimephales promelas	F, M	21.6	6.5	>400	Palmer et al. 1989
Pimephales promelas	F, M	21.6	7.5	>400	Palmer et al. 1989
Pimephales promelas	F, M	23.1	6.5	>400	Palmer et al. 1988
Pimephales promelas	F, M	23.1	7.5	>400	Palmer et al. 1988
Pimephales promelas	S, M	26	7.8	1,160	ENSR 1992b
Pimephales promelas	S, M	46	7.6	8,180	ENSR 1992b
Pimephales promelas	S, M	96	8.1	20,300	ENSR 1992b
Pimephales promelas	S, M	194	8.1	44,800	ENSR 1992b
Crangonyx pseudogracilis	S, U	50	6.75	9,190	Martin and Holdich 1986
Asellus aquaticus	S, U	50	6.75	4,370	Martin and Holdich 1986
Gammarus pulex	S, U	--	6.9	>2,698	Storey et al. 1992
Ceriodaphnia dubia	S, M	26	7.5	720	ENSR 1992a
Ceriodaphnia dubia	S, M	46	7.6	1,880	ENSR 1992a
Ceriodaphnia dubia	S, M	96	7.8	2,450	ENSR 1992a
Ceriodaphnia dubia	S, M	194	8.1	>99,600	ENSR 1992a
Ceriodaphnia dubia	S, M	98.5	7.6	2,880	Soucek et al. 2001
Ceriodaphnia dubia	S, M	50	7.86	1,500	McCauley et al. 1986
Ceriodaphnia dubia	S, M	50	8.13	2,560	McCauley et al. 1986
Ceriodaphnia sp.	S, M	47.4	7.36	2,300	Call 1984
Cyclops viridis	S, U	--	6.9	>2,698	Storey et al. 1992
Salmo salar	S, M	6.8	6.5	599	Hamilton and Haines 1995
Tubifex tubifex	R, U	245	7.6	50,230	Khangarot 1991
Hybognathus amarus	S, M	140	8.1	>59,100	Buhl 2002

NOTES:

S = static renewal test exposures

F = flow-through test exposure

R = renewal test exposure

M = test media aluminum concentration was measured

U = test media aluminum concentration was not measured

In addition to the acute test results, water quality parameters in toxicity tests were also added to the updated Al database. Test solution pH and hardness values were needed to determine inclusion of data within the specified circumneutral pH range and to investigate a possible relationship to general water quality parameters, such as hardness. Most of the added studies reported hardness values of test media or reported calcium and magnesium concentrations that were used to calculate water hardness.

Of the 35 new acute data points, two provided insufficient information on water quality parameters to determine test media hardness. Unfortunately, each was for a unique species (*Cyclops viridis* and *Gammarus pulex*) found in the updated database that subsequently had to be removed during FAV derivation (see discussion below).

4.2 New Aluminum Chronic Toxicity Data

Following review of the available studies, 11 new chronic data points from nine studies (Table 2) were added to the revised chronic database. Of the nine studies added to the database, seven were published prior to the 1988 Aluminum Document. Three studies published prior to the 1988 Aluminum Document were not cited in either Table 1 ("Chronic Toxicity of Aluminum to Aquatic Animals") or Table 6 ("Other Data on Effects of Aluminum on Aquatic Organisms") of the 1988 Aluminum Document and apparently represent data that were unknown to the USEPA at the time. Four publications that were found in Table 6 ("Other Data") in the 1988 Aluminum Document were re-reviewed and deemed appropriate for use in updating the chronic database, as described below.

Table 2: Summary of chronic Al data that were deemed acceptable for standards derivation and added to the updated Al chronic database.

Species	Hardness (mg/L $CaCO_3$)	pH	NOEC- LOEC (µg/L)	Chronic Value (µg/L)	Reference
Ceriodaphnia dubia	50	7.75	1,100-2,400	1,624	McCauley et al. 1986
Ceriodaphnia dubia	47.4	7.55	6,250-12,100	8,696.26	Call 1984
Daphnia magna	45.3	7.74	--	320[a]	Biesinger and Christenson 1972
Daphnia magna	45.3	7.74	--	1,400[b]	Biesinger and Christenson 1972
Tanytarsus dissimilis	17.43	6.8	10,000-80,000	28,284	Lamb and Bailey 1981
Salvelinus fontinalis	12.5	7.2	>303.9	>303.9	Cleveland et al. 1991
Salvelinus fontinalis	7.5	6.5	169-350	243.21	Cleveland manuscript
Salvelinus fontinalis	12.5	6.5	57-88	70.82	Cleveland manuscript
Salvelinus fontinalis	7.5	6.5	88-169	122	Cleveland et al. 1989
Salvelinus fontinalis	0.567	7.81	0-300	<300	Hunn et al. 1987
Micropterus dolomieu	12.8	7.3	0-250	<250	Kane and Rabeni 1987

NOTES:

[a] EC_{16} for reduced reproduction

[b] 21 day LC_{50}

NOEC = no observable effect concentration

LOEC = lowest observable effect concentration

Biesinger and Christensen (1972) performed acute and chronic Al toxicity tests with *Daphnia magna*. Acute toxicity results were included in the USEPA acute database; yet, no explanation was given as to why chronic data from this same study were not included in the chronic database. We reviewed methods used for the chronic toxicity tests and could not find a reason to exclude these data. Therefore, two chronic values from this study were added to the database. Data from this publication were also deemed suitable for inclusion in the FACR derivation, described later.

In a 55-day Al exposure study, Lamb and Bailey (1981) tested acute and chronic toxicity in *Tanytarsus dissimilis*. The authors reported high variability in mortality rates among treatments and provided little information on statistical significance of mortality among treatments. Fortunately, a figure showing the cumulative percent mortality was provided and analyzed with information in the text to derive a chronic value of 10,000 µg/L, representing the treatment level that produced 37 percent mortality.

The Cleveland manuscript, used to lower the 1988 Aluminum Document chronic criterion, contained additional data for *Salvelinus fontinalis* that were not reported in the USEPA chronic databases. These additional chronic values were incorporated into the revised chronic database (AWWQRP 2006). *S. fontinalis* were exposed to Al in soft water with a pH of 6.5, the lowest pH in the acceptable circumneutral range. The chronic value was determined for a statistical difference in two chronic endpoints: length (growth) and mortality. The growth value was more sensitive than mortality (243 µg/L) and resulted in a chronic value of 70 µg/L in soft water.

Hunn et al. (1987) investigated influence of pH and Al on early life stages of developing *S. fontinalis*. Only two treatments, the control and 283 µg/L, were used in a 60-day larvae toxicity test using flow through exposure with very soft water. The authors reported a statistical decrease in growth ($p<0.001$) between treatment and control using a least squares deviation linear model with interaction terms representing treatment effects. Since a geometric mean could not be determined, a chronic value of <283 µg/L was added to the revised chronic database.

Five additional studies with appropriate toxicity tests were found that were not listed in the 1988 Aluminum Document. Three of these publications were published after the 1988 Aluminum Document. Cleveland et al. (1991) performed a 56-day Al exposure for *S. fontinalis* to examine effects on bioaccumulation, growth, and mortality. The authors reported 1 percent mortality in the 7.2 pH treatment at the end of the exposure period at a measured mean Al concentration of 303.88 µg/L, which resulted in an undefined chronic value of >303.88 µg/L. Although test duration was four days short of the recommended 60 days for a chronic test with this species, we decided that test methods and duration were acceptable and suitable for use. Cleveland et al. (1989) reported another chronic value for *S. fontinalis*. The authors used similar methods as in prior toxicity tests with this species and Al. After a 60-day exposure at a mean pH of 6.5, statistical differences in growth were observed. The result of this partial life cycle test, that started exposures with embryos, was the lowest chronic value added to the chronic database.

The remaining three studies entered into the updated chronic database were published prior to 1988, but were not cited in the 1988 Aluminum Document. McCauley et al. (1986) performed acute and chronic toxicity tests using *C. dubia* with different pH exposure media. The 1988 document used only one of the chronic values from a test with a pH of 7.15, but did not report the second test that was conducted at a pH of 7.61. The chronic value that was added to the updated database was from this second test. Extensive acute data were provided by Call (1984) from the University of Wisconsin Center for Lake Superior Environmental Studies laboratory, with addition of a chronic toxicity test using *Ceriodaphnia* sp. After an eight-day Al exposure, statistical differences in survival and reproduction were observed in the 12,100 µg/L treatment (lowest-observed-effect concentration [LOEC]). The updated chronic database value was derived by taking the geometric mean of this treatment concentration and the next lowest treatment of 4,900 µg/L (no-observed-effect concentration [NOEC]). Kane and Rabeni (1987) performed a 30-day partial life cycle toxicity test using *Micropterus dolomieu*. Although the authors did not find any statistical differences in growth between control and the 250 µg/L treatment, they did note that the fish embryos showed overt signs of Al toxicity, which included scoliosis and lordosis. Therefore, an undefined value of >250 µg/L was added to the database.

4.3 Potential Relationships Between Aluminum Toxicity and Water Quality Parameters

An inverse Al toxicity and hardness relationship (within the pH range of 6.5 to 9.0) was identified during the literature review and subsequent database update that was not reported in the 1988 Aluminum Document. To evaluate the relationship between acute toxicity of aluminum and hardness, guidelines from the USEPA (Stephan et al. 1985) and the example calculations provided in the 2001 USEPA cadmium criteria document (USEPA 2001) were followed. USEPA (2001) explicitly states that species acute values should only be used for pooled-hardness slope derivation if data are available for a range of hardnesses such that the highest hardness value is at least three times the lowest and the highest is at least 100 mg/L higher than the lowest.

Pooled-hardness slopes can be derived following guidance by Stephan et al. (1985). First, toxicity and hardness (or other appropriate water quality characteristics) data are normalized (by dividing the toxicity value and the hardness value for a study by the geometric mean toxicity and hardness values of all studies for that species). These normalized values are then log-transformed. Next, a least squares regression of log-transformed normalized acute values on normalized hardness values is performed to obtain the acute hardness slope for that species. This is done for all species and the regression lines are compared (either by visually looking at slopes and intercepts or mathematically with covariance analysis). If they are considered similar enough, data for all species are pooled and the regression is run again to develop the "pooled-hardness" slope used in the final equation.

Appropriate acute values with relevant test media hardness measurements were regressed within and among three species: *Ceriodaphnia dubia*, *Pimephales promelas*, and *D. magna*. These species were chosen because respective hardness treatments fell within a wide range of values and each had many acute endpoints to regress (Stephen et al. 1985). Regression analysis for each species (excluding *D. magna*) resulted in a statistically significant positive relationship between effect measurement and test media hardness (two-sided test, to test that slope term equals zero, both p-values < 0.02). Discussion of data used or not used in this analysis is provided below.

D. magna was used in this evaluation, even though only two data points are available. Stephan et al. (1985) states that it is acceptable to use only two data points if "the two points cover a broad enough range of the water quality characteristic." The two hardness values used in the hardness regression analysis, 220 and 45.3 mg/L, cover a significant range. In addition, a clear relationship was observed between these hardness values and associated LC_{50} values; at a hardness of 220 mg/L the *D. magna* LC_{50} was 38,200 µg/L, and at hardness of 45.3 mg/L the LC_{50} was 3,900 µg/L (Kimball, manuscript; Biesinger and Christensen 1972).

C. dubia data were included in the hardness regression analysis because while the hardness values for the seven usable data points for this species technically do not have a wide enough range, the overall database does represent a sufficient hardness range. While an additional data point is available which would broaden the hardness range, it was reported as a "greater than" value, and thus cannot be used in hardness slope derivation (ENSR 1992a). Thus, the hardness values for usable *C. dubia* data ranged from 26-98.5 mg/L $CaCO_2$ (Soucek et al. 2001).

The Al database contains three data points for *I. punctatus*. However, all three of these values are "greater than" values (i.e., not definitive), and thus are not appropriate for use in regression analyses.

A water hardness versus Al toxicity equation was derived with this subset of data, which included values for *C. dubia*, *P. promelas*, and *D. magna*, that minimized the residual standard error ($r^2 = 0.87$) and resulted in a pooled slope of 1.3695 (Table 3). Figure 1 is a plot of the acute values versus the hardness values used to derive this Al hardness slope.

Table 3: Derivation of acute Al hardness slope.

Species	N	Species Mean Acute Slope	R^2
Ceriodaphnia dubia	7	0.8699	0.73
Daphnia magna	2	1.4439	--
Pimephales promelas	5	1.5298	0.90
Pooled Hardness Slope =		**1.3695**	**0.87**

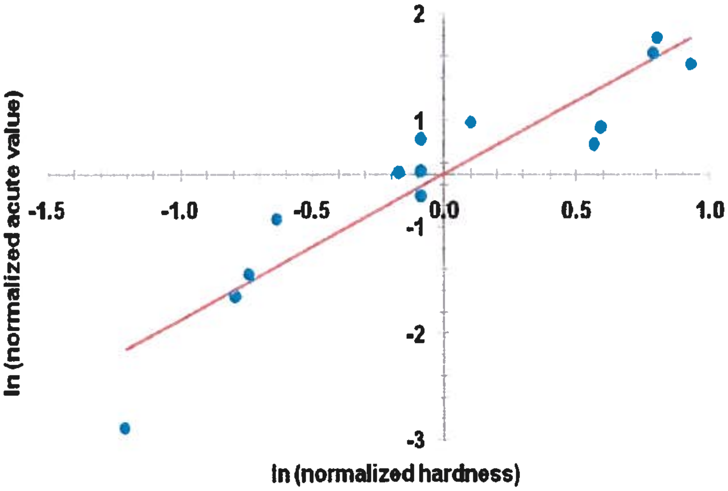

Figure 1:
Scatter plot of Al toxicity and water hardness values used to derive the Al hardness slope.

The Al toxicity data in both acute and chronic databases were subsequently normalized to hardness 50 mg/L $CaCO_3$ concentration using this slope, using USEPA criteria derivation methods (Stephan et al. 1985). The acute water quality standard equation was thus developed to incorporate the protective effect of hardness, which is likely a proxy for calcium, as discussed earlier.

Additional water quality parameters such as pH also affect aquatic organism Al toxicity. The pH of a solution is a major driver of Al speciation. Over the range of USEPA acceptable circumneutral pH values, we could expect that the fraction of monomeric Al in solution will change, most notably at lower (approximately 6.5) and higher pH values (approximately 9). Freeman and Everhart (1971) demonstrated an increase of Al toxicity in rainbow trout from a pH of 7 to 9 using the same concentration and experimental methods. They reported that test organisms showed immediate shock and heavy mortalities within the first 48 hours at a test solution pH of 9.0, effectively terminating the 45-day test after 113 hours. Although there was an apparent pH relationship within the USEPA range, we could not develop a significant toxicity relationship with pH. Attempts to develop such an equation were hindered by limited studies conducted for any species at an acceptable range of pH values (6.5-9.0). In fact, the greatest pH value in the database is 8.29, at which no increased toxicity was apparent. Available data points at lower pH values approximately 6.5 for some taxa indicate that increased toxicity occurs at the lower end of the USEPA recommended range. This trend provided qualitative evidence of a water quality toxicity relationship in some organisms. However, this relationship is not significant within, or consistent between, an acceptable sample of organisms in the updated database.

Preliminary review of published reports that tested aquatic organism toxicity over a wider range of acidic pH values did indicate a strong relationship between measured Al toxicity and pH, with more acidic waters having greater Al toxicity. However, this relationship reached an asymptote at approximately pH = 6, again with no observable pH versus Al toxicity relationship found in the required pH range of 6.5-9.0. As such, no pH factor is included in this update to Al standards.

5.0 Phase III – Recalculation of Acute and Chronic Standards for Aluminum

Data discovered and screened during phase II of this project were used to update and revise the Al acute and chronic database. The revised database was then used to derive potentially updated acute and chronic standards for Al to protect freshwater aquatic organisms.

5.1 Updated Acute Database

Not all of the new acute data added to the database contained enough water quality information to use in derivation of the recommended updated Al standards. Effects data without reported hardness water quality parameters of test water were not used to generate a revised FAV since data values could not be normalized to a hardness of 50 mg/L. In addition, data from Palmer et al. (1988 and 1989) were not included in the final updated acute toxicity database because all LC_{50} values from this study were undefined (i.e., reported as >400 µg/L). When compared to other appropriate values in the database for both *P. promelas* and *I. punctatus*, these undefined values are considerably lower. Thus, while the Palmer et al. data are consistent with data used from other studies (i.e., the other values are indeed "greater than 400 µg/L"), the Palmer et al. >400 µg/L values are irrelevant in the context of other reported LC_{50} values for these organisms, which are up to 100 times higher than 400 µg/L. The undefined *Oncorhynchus mykiss* data from Gundersen et al. (1994) were also not included in the final acute database for the same reason.

Table 4 summarizes the final list of data and ranked GMAV values used for calculation of the recommended updated acute Al water quality standard.

Table 4: Proposed final Al acute database, with species mean acute values (SMAV), normalized to hardness = 50 mg/L, and ranked by genus mean acute value (GMAV).

Rank	Species	Common Name	Method	SMAV (µg/L)	GMAV (µg/L)
17	*Tanytarsus dissimilis*	Midge	S, U	338,321	338,321
16	*Lepomis cyanellus*	Green sunfish	S, M	53,794	53,794
15	*Perca flavescens*	Yellow perch	S, M	53,578	53,578
14	*Ictalurus punctatus*	Channel catfish	S, M	51,534	51,534
13	*Physa* sp.	Snail	S, M	32,922	32,922
12	*Acroneuria* sp.	Stonefly	S, M	24,315	24,315
11	*Gammarus pseudolimnaeus*	Amphipod	S, M	23,669	23,669
10	*Dugesia tigrina*	Flatworm	S, M	17,859	17,859
9	*Hybognathus amarus*	Minnow	S, M	14,428	14,428
8	*Salmo salar*	Atlantic salmon	S, M	9,205	9,205
7	*Crangonyx pseudogracilis*	Amphipod	S, U	9,190	9,190
6	*Oncorhynchus mykiss*	Rainbow trout	F, M	7,547	7,547
	Oncorhynchus tshawytscha	Chinook salmon	S, M	88,495*	
5	*Pimephales promelas*	Fathead minnow	S, M	5,869	5,869
4	*Tubifex tubifex*	Worm	S, U	5,698	5,698
3	*Daphnia magna*	Cladoceran	S, U	4,735	4,735
2	*Asellus aquaticus*	Isopod	S, U	4,370	4,370
1	*Ceriodaphnia dubia*	Cladoceran	S, M	2,164	2,604
	Ceriodaphnia sp.	Cladoceran	S, M	3,134	

NOTES:

S = static renewal test exposure M = test media aluminum concentration was measured

F = flow-through test exposure U = test media aluminum concentration was not measured

* = Value not used in calculation of GMAV because acute value considerably higher than others in the genus

The updated acute database contains values for 17 genera, increased from 14 genera in the existing criteria document, including 11 species of invertebrates and eight species of fish. These 19 species in 14 families satisfy the "eight-family rule" as specified in the 1985 Guidelines. Addition of new species data and normalization of acute values changed the sensitivity ranking of three of the four most sensitive genera when compared to the 1988 Aluminum Document. The rank of the most sensitive genus (*Ceriodaphnia*) in the updated database is unchanged and its reported acute value changed very little after hardness correction. The 1988 Aluminum Document database ranked the genus *Salvelinus* as second. This value was based on one study in which hardness was not measured (Decker and Menendez 1974). Since the effect endpoint could not be normalized for hardness, this value was not included in the updated database. As a result, *Asellus* replaced *Salvelinus* as the second ranked genus in the updated database. The normalized value for *Asellus* was very similar to that reported for *Salvelinus*, so this deletion and addition process was not particularly influential in updating the FAV. The updated 3rd and 4th ranked genera, *Daphnia* and *Tubifex*, replaced *Oncorhynchus* and *Gammarus* of the 1988 Aluminum Document. These updated values were lower with a range closer to the first two genera, resulting in reduced variability between the four most sensitive genera.

5.2 Updated Chronic Database

The revised and updated Al chronic toxicity database presents data for six genera of freshwater organisms, including three species of invertebrates and three species of fish (Table 5). These six species found in five families do not satisfy the "eight-family rule" as specified in the 1985 Guidelines. The chronic database assemblage does, however, satisfy the minimal requirements for calculation of a FACR.

Table 5: Proposed final Al chronic values (SMCV), with hardness normalized (50 µg/L), and ranked by genus mean chronic values (GMCV).

Rank	Species	Common Name	SMCV (µg/L)	GMCV (µg/L)
6	*Tanytarsus dissimilis*	Midge	68,021	68,021
5	*Ceriodaphnia dubia*	Cladoceran	4,165	4,165
4	*Pimephales promelas*	Fathead minnow	957	957
3	*Micropterus dolomieu*	Smallmouth bass	777	777
2	*Salvelinus fontinalis*	Brook trout	624*	624*
1	*Daphnia magna*	Cladoceran	274	274

*GMCV was calculated without the undefined chronic value reported by Hunn et al. (1987).

The revised FACR was derived from three species mean ACRs (SMACRs), using the revised and updated chronic toxicity databases. Each ACR was determined from paired acute and chronic values within the same study using similar dilution water (Table 6). The respective SMACRs used to derive the FACR were 0.96 (*C. dubia*), 10.65 (*P. promelas*), and 12.19 (*D. magna*). Including only the Biesinger and Christensen (1972) data in the *D. magna* SMACR calculation (tested at hardness = 45.3) resulted in a substantially lower SMACR for this species than was reported in the 1988 Aluminum Document (12.19 versus 51.47, which was calculated from data from the Kimball manuscript). These data resolved the previous problem noted in the 1988 Aluminum Document associated with taking a geometric mean from a wide range of results.

In general, the inclusion of more available chronic data resulted in a better sample of ACRs, in which values ranged roughly within a factor of 10 from one another. Because the USEPA was lacking data to legitimately generate a FACR using multiple SMACRs, the FACR was set to the lowest organism then defaulted to 2.0. The updated database allows a multiple SMACR approach as an improvement over the EPA's FACR estimate. The revised FCV derived from the revised FACR is expected to be protective of every organism in the chronic database, when corrected for hardness.

Table 6: Updated Al final acute-chronic ratio (FACR).

Species	Hardness ($CaCO_3$ mg/L)	Chronic Value (µg/L)	Acute Value (µg/L)	ACR	SMACR
Daphnia magna	45.3	320[a]	3,900	12.1875	12.1875
Pimephales promelas	220	3,288	35,000	10.6448	10.6448
Ceriodaphnia dubia	50	1,908	1,900	0.9958	0.9590
Ceriodaphnia dubia	50	1,624	1,500	0.9236	
					FACR = 4.9923

NOTES:
[a] 16% decrease in reproduction
SMACR = species mean acute-chronic ratio

5.3 Updated Aluminum Standards Derivation

An updated final acute value (FAV) was derived from the four most sensitive genera in the updated and revised, hardness-normalized acute toxicity database (*Ceriodaphnia, Asellus, Daphnia*, and *Tubifex*), the total number of genera in the updated acute database, and newly derived acute toxicity hardness slope (Table 7). The resulting FAV (2,648 µg/L) is greater than the 1988 FAV of 1,496 µg/L (which was not hardness-modified in the 1988 Aluminum Document), and was used to derive the hardness modified Al standards equation.

Since the revised chronic database did not satisfy the "eight-family rule," the FACR was used to derive a FCV for Al from the acute database. Following the 1985 Guidelines, the acute hardness toxicity relationship was assumed to be similar for chronic toxicity. Therefore, a chronic Al criterion equation was also calculated using this pooled acute-hardness slope (Table 7). Use of the acute-hardness slope in the chronic equation should be applied cautiously given the limited chronic toxicity data, which do not strongly support this assumption. However, the lack of support may be an artifact of difficulties associated with conducting chronic toxicity tests with a poorly soluble compound, rather than a true lack of a hardness relationship.

Table 7: Recalculation of the final acute values for Al using the revised hardness adjusted (50 mg/L $CaCO_3$) acute database.

Rank	Genus	GMAV (µg/L)	ln GMAV	(ln GMAV)^2	P = R/(N+1)	√P
4	*Tubifex*	5,698	8.6479	74.7863	0.2222	0.4714
3	*Daphnia*	4,735	8.4627	71.6178	0.1667	0.4082
2	*Asellus*	4,370	8.3825	70.2666	0.1111	0.3333
1	*Ceriodaphnia*	2,604	7.8650	61.8577	0.0556	0.2357
		Sum	33.3581	278.5284	0.5556	1.4487

NOTES:
N = 17 genera, R = sensitivity rank in database, P = rank / (N+1)

Calculations:

Acute Criterion

$$S^2 = \frac{\Sigma(\ln GMAV)^2 - (\Sigma \ln GMAV)^2/4}{\Sigma P - (\Sigma\sqrt{P})^2/4} = \frac{278.5284 - (33.3581)^2/4}{0.5556 - (1.4487)^2/4} = 10.9238 \qquad S = 3.3051$$

$L = [\Sigma \ln GMAV - S(\Sigma\sqrt{P})]/4 = [33.3581 - 3.3051\,(1.4487)]/4 = 7.1425$

$A = S\,(\sqrt{0.05}) + L = (3.3051)(0.2236) + 7.1425 = 7.8816$

Final Acute Value = FAV = e^{A} = 2,647.9903 µg/L

CMC = ½ FAV = 1,323.9952 µg/L

Pooled Slope = 1.3695

ln (Criterion Maximum Intercept) = ln CMC - [pooled slope × ln (standardized hardness level)]
= ln (1,323.9952) - [1.3695 × ln (50)]
= 1.8308

Acute Aluminum Criterion = $e^{(1.3695\,[\ln(\text{hardness})] + 1.8308)}$

Chronic Criterion

Chronic Slope = 1.3695

Final Acute-Chronic ratio (FACR) = 4.9923 (recalculated)

Final Chronic Value (FCV) = FAV / ACR = 2,647.9903 ÷ 4.9923 = 530.4149 µg/L

ln (Final Chronic Intercept) = ln FCV - [chronic slope × ln(standardized hardness level)]
= ln (530.4149) - [1.3695 × ln (50)]
= 0.9161

Chronic Aluminum Criterion = $e^{(1.3695\,[\ln(\text{hardness})] + 0.9161)}$

This review and update to the 1988 Aluminum Criteria Document resulted in new standards using hardness-based equations, similar to other metals standards. We recommend use of these updated standards as the appropriate Al standards for New Mexico, with values calculated as µg/L dissolved Al.

$$\text{Recommended Acute Al Criterion} = e^{(1.3695\,[\ln(\text{hardness})] + 1.8308)}$$

$$\text{Recommended Chronic Al Criterion} = e^{(1.3695\,[\ln(\text{hardness})] + 0.9161)}$$

Updated and revised Al standards based on these equations are presented across a wide range of hardness levels (Table 8). It is important to understand the boundaries of the reported equation. Since the equation models hardness values that ranged from 1 mg to 220 mg of $CaCO_3$/L, estimations made outside of this range should be treated with caution.

Table 8: Updated and revised acute and chronic Al criterion value across selected hardness values.

Aluminum Equations	**Mean Hardness (mg/L as $CaCO_3$)**						
	25	50	75	100	150	200	250
Updated/Revised Aluminum Standards							
Acute= $e^{(1.3695\,[\ln(\text{hardness})]+1.8308)}$	512	1,324	2,307	3,421	5,961	8,839	11,999
Chronic= $e^{(1.3695\,[\ln(\text{hardness})]+0.9161)}$	205	530	924	1,370	2,388	3,541	4,807

NOTE: All values are as µg Dissolved Aluminum/L.

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**GENSEMER TESTIMONY
EXHIBIT 5**

I am submitting this testimony on behalf of Chevron Mining Inc. (CMI), in response to the direct testimony presented by the New Mexico Environment Department (NMED) and other parties on August 28, 2009. In their technical testimony, NMED expressed concern over outside party proposals, reflected in comments issued by EPA on July 30, 2009 in a document titled "*Technical Comments on the Chevron Mining, Inc. Criteria Proposals*". CMI did not receive these comments until August 24, 2009, and thus was unable to fully respond in their technical testimony in time for the August submittals.

It is important to note that the EPA review appears to have been performed on a much earlier version of CMI's proposal (early drafts submitted during the initial comment period September 2008). As such, it turns out many of the issues that were raised by EPA had already been addressed and are reflected in CMI's current proposal, submitted on August 28, 2009.

Thus, this rebuttal testimony focuses primarily on issues mentioned in the EPA review related to CMI's aluminum, cadmium, molybdenum, and zinc criteria proposals. NMED expressed support for CMI's proposed manganese criteria. In addition, I am responding to proposals put forth by other parties to the triennial hearing.

EPA Comments to NMED Regarding CMI's Proposals

Aluminum

1) **EPA Comment:** To maintain accuracy revise the number of genera depicted in page 16. In Table 4 the number of genera is 18 not the 17 written in the text.

Response: This typo was found and has already been corrected, as presented in the August submittal (GEI 2009a).

2) **EPA Comment:** Check Table 7 Probability calculations. Rank 1 & 2 have errors in the calculated probability. The probability associated to Rank 1 is 0.053 NOT 0.059. The probability associated to Rank 2 is 0.105 NOT 0.118.

Response: These typos were found and have already been corrected, as presented in the August submittal (GEI 2009a).

3) **EPA Comment:** GEI provided an explanation in Sect.3.1 for the decision to use the lower value of 16,600 ug/L for Girardia instead of 1988 value of 23,000 ug/L (which was estimated using the geometric mean) based on more recent data suggesting the lower value may be more appropriate. In this explanation, the authors suggest that Charles Stephan (personal communication to David Moon, 2004) indicated that the 23,000 ug/L value is the "real" value that should be used. In fact, Stephan's comment was that it is inappropriate to use a GMAV of 16,600 ug/L for Dugesia in the calculation of the FAV. EPA concluded that the LC50 must be greater than 23,000 ug/L because, on the average, acute LC50s are about a factor of 2 higher than concentrations that cause a low level of acute mortality. Because 16,600 ug/L resulted in no adverse effects, EPA concluded that the LC50 must be greater than 23,000 ug/L, and therefore set the GMAV at > 23,000.

Response: CMI has decided to retain the more conservative value of 16,600 µg/L given other published data on this organism (GEI 2009a). However, because *Girardia* is not in the top four most sensitive genera, this decision has no effect on calculations and either value could be used.

4) **EPA Comment:** Development of the hardness relationship equation appears to be appropriate. The application of hardness normalization to the revised dataset had a substantial effect resulting in revised final acute (GEI FAV=2559.98 ug/L vs. EPA 1988 FAV=1496 ug/L)

and chronic values (GEI FCV=511.6 vs. EPA 1988 FCV= 750 ug/L) since hardness was not considered in the 1988 criteria. Some have indicated concerns with the 1988 criteria since it did not take into consideration the pH relationship and to a lesser extent the hardness effect on Al toxicity. It would be preferable to see an equation for the pH relationship to toxicity; however, GEI determined they could not develop a significant toxicity relationship with pH due to insufficient data at the upper end of the pH range recommended by EPA.

Response: I agree pH can have a strong influence on aluminum solubility and toxicity. The key issue with regard to our finding of no pH relationships, however, is the restriction to studies that were conducted in the appropriate pH range of 6.5-9.0, based on EPA guidance. Within this range of pH, we could find no relationship to aluminum toxicity patterns (GEI 2009a).

It is also important to note that since the version EPA reviewed, we have conducted additional analysis and had discussions with other parties' consultants. As a result, in the latest version of our proposal, the hardness slope has been further updated from 0.8327 to 1.3695 (GEI 2009a).

5) **EPA Comment:** GEI discussed the total versus dissolved form of Al and the relative toxicity at circumneutral pH. As a result, it's unclear if GEI was recommending that the criteria be expressed in the dissolved form to reflect the non-monomeric Al species. The State's supporting documentation and proposal should provide clarification.

Response: The current version of the supporting technical document (GEI 2009a) provides a detailed discussion on this issue. Consistent with New Mexico's current water quality standards, the proposed updated aluminum hardness-based standards are based on the dissolved portion.

6) **EPA Comment:** GEI reviewed the data that was and was not included in the 1988 document and in updating their dataset they added back in some data that EPA rejected and vice versa – the State's proposal/submission should provide a scientifically defensible rationale for each exclusion of EPA data or inclusion of new data.

Response: As stated and supported in the technical report (GEI 2009a), data from three studies published prior to the 1988 Aluminum Criteria Document were added to the acute toxicity database. The studies by McCauley et al. (1986) and Call (1984) provided acceptable data points in addition to those used by EPA in the 1988 Aluminum Criteria Document. Acceptable data for two species from Martin and Holdich (1986) were not mentioned in the 1988 Aluminum Criteria Document, but were added during GEI's updates. Data from seven studies published prior to the 1988 Aluminum Criteria Document were added to the chronic toxicity database (GEI 2009a). Three of these (McCauley et al. [1986], Call [1984], Kane and Rabeni [1987]) were not discussed in the chronic toxicity section of the 1988 Aluminum Criteria Document, but were deemed acceptable during GEI's updates. Data from the other four studies (Biesinger and Christensen [1972], Lamb and Bailey [1981], Cleveland [manuscript], Hunn et al. [1987]), which were unused in the 1988 Aluminum Criteria Document, were re-reviewed by GEI and deemed appropriate for use, as discussed in GEI (2009a).

7) **EPA Comment:** This review and update to the 1988 Aluminum Criteria Document resulted in new proposed criteria using hardness-based equations, similar to other metals criteria. The data used in these updated criteria appear appropriate for developing Al standards for New Mexico:

$$\text{Recommended Acute Al Criterion} = e^{(0.8327\,[\ln(\text{hardness})]+3.8971)}$$

$$\text{Recommended Chronic Al Criterion} = e^{(0.8327\,[\ln(\text{hardness})]+2.9800)}$$

Response: It is important to note that following the additional evaluation noted earlier, including discussions with other parties' consultants, the equations have been further updated reflecting the new hardness slope and normalized toxicity data (GEI 2009a) and are now as follows:

$$\text{Recommended Acute Al Criterion} = e^{(1.3695\,[\ln\,(\text{hardness})]+1.8308)}$$

$$\text{Recommended Chronic Al Criterion} = e^{(1.3695\,[\ln\,(\text{hardness})]+0.9161)}$$

Other Issues

I would like to bring attention to a typo error in CMI's August 28, 2009 technical testimony. The aluminum equations presented in the testimony do not accurately reflect our proposal as presented in GEI (2009a). The correct equations, as shown in GEI (2009a), are provided below.

$$\text{Recommended Acute Al Criterion} = e^{(1.3695\,[\ln\,(\text{hardness})]+1.8308)}$$

$$\text{Recommended Chronic Al Criterion} = e^{(1.3695\,[\ln\,(\text{hardness})]+0.9161)}$$

Cadmium

1) **EPA Comment:** The State's submission should provide a scientifically defensible rationale for inclusion of the studies by Suedel *et al.*, (1997), Davies and Brinkman, (1994) and Buhl and Hamilton, (1991) since these have been previously rejected.

Response: I continue to support inclusion of these studies in development of cadmium criteria for reasons described in our technical document (GEI 2009) and further explained below.

In the study by Suedel et al. (1997), the acute test organisms were fed. EPA guidance states "results of acute tests during which the test organisms were fed should not be used, unless data indicate that the food did not affect the toxicity of the test material" (Stephan et al. 1985). The acute values for *Ceriodaphnia dubia*, *Daphnia magna*, and *Pimephales promelas* from

Suedel et al. (1997) are similar to those reported in other studies, which indicates feeding did not affect the test results. Given the results of this comparison, data from Suedel et al. (1997) for *C. dubia*, *D. magna*, *P. promelas*, *Chironomus tentans*, and *Hyalella azteca* were all added to the acute database.

I was unable to find any reason to remove the Davies and Brinkman (1994) study from the acute and chronic cadmium toxicity databases (GEI 2009). It is important to note that neither the Suedel et al. (1997) nor Davies and Brinkman (1994) were cited, and therefore, were not rejected in the 2001 EPA Cadmium Criteria Document (EPA 2001).

The data point for the arctic grayling (*Thymallus arcticus*) from Buhl and Hamilton (1991) is listed as unused in the 2001 EPA Cadmium Criteria Document (EPA 2001) because the EPA claims the toxicity test was conducted improperly due to low dissolved oxygen. Yet, dissolved oxygen levels never fell below 40 percent saturation for their cadmium tests. Therefore, this cadmium data point does meet EPA guidelines and is appropriate for use (GEI 2009b).

2) **EPA Comment:** The proposed FAV and FCV values, 2.875 μg/L and 0.273 μg/L are higher than the 2001 values (2.763 μg/L and 0.162 μg/L). The State's submission should provide a scientifically defensible rationale as to their acceptability.

Response: It is important to note that the FAV and FCV mentioned by the EPA have been updated (GEI 2009b). The updated FAV is 2.802 μg/L, which is closer to the 2001 value. The updated FCV is 0.293 μg/L. The scientifically defensible rationale is fully described in the supporting technical document (GEI 2009b). In general, however, the values have changed from the older EPA values simply because the databases used in their development have been expanded considerably through the updates made by GEI's review of new published scientific data.

3) **EPA Comment:** EPA acknowledges the intention to follow the 1985 Guidelines in protecting commercially and recreationally sensitive fish species. Therefore, we recommend using the SMAV of *Salvelinus fontinalis* (1.76) as the FAV in the calculation of the CMC to protect a commercially and recreationally important species.

Response: In CMI's original proposal, the FAV was, in fact, dropped to 1.9146 for *Salvelinus* GMAV, not SMAV. However, we are now lowering the FAV to the rainbow trout SMAV of 1.8805, which is more consistent with EPA guidance. As noted in the August submittal, the *S. fontinalis* SMAV is now <1.8 µg/L, and we did not want to base the equation on a SMAV which is actually an undefined value.

4) **EPA Comment:** A set of minor, but important revisions are recommended to improve the clarity and accuracy of the presented data.

a. Check the revised acute slope value and/or adjusted hardness LC_{50} calculations reported in Table 2 as it is slightly different from the one calculated in Table 8 (0.9207 vs. 0.9151) and used in the FAV calculations (section 4.2).

Response: The acute slope has been further updated in the August submittal (GEI 2009b), thus this comment has been addressed.

b. Also, the addition of test duration data in Table 2 and chemical form of Cd in Table 3 will also contribute to clarity, proof of data accuracy and style of the current document.

Response: I agree this would be useful information and will include this if revisions of the technical document are made in the future.

5) **EPA Comment:** In order to keep data accuracy, and a clear, and consistent style throughout section 3.2 we suggest the:

a. revision of the chronic slope value Table 4 as it is slightly different from the one calculated in Table 10 (0.7432 vs. 0.7998) and used in the FCV calculations (section 4.3) and

Response: The chronic slope has been further updated (GEI 2009b). Thus, this comment has been addressed.

b. update Tables 4 and 5 in such way they present the same data (for example adjusted chronic values).

Response: I agree and will include this additional background data if revisions of the technical document are made in the future.

Molybdenum

1) **EPA Comment:** The current assessment (GEI, Sept 2008) does not contain two additional data points reported in other assessments, one for *Euglena* sp. and one for *Morone* sp., both listed below. However, these values are not in the sensitive 4 genera and would likely have no meaningful effect on the final CMC and CCC values. This data is acceptable. *Absent references*:

Colmano, G. 1973. Molybdenum toxicity: Abnormal cellular division of teratogenic appearance in Euglena gracilis. Bulletin of Environmental Contamination and Toxicology 9(6): 361-364.

Dwyer, F.J., S.A. Burch, C.G. Ingersoll, and J.B. Hunn. 1992. Toxicity of trace element and salinity mixtures to striped bass (*Morone saxatilis*) and *Daphnia magna*. Environmental Toxicology and Chemistry 11: 513-520.

Response: GEI reviewed those studies. I continue to believe that they should not be included in the analysis. Data from the Colmano (1973) study cannot be used in the acute molybdenum database because EPA guidance does not allow the use of data for single-celled organisms in criteria development (Stephan et al. 1985). Data for striped bass from Dwyer et al.