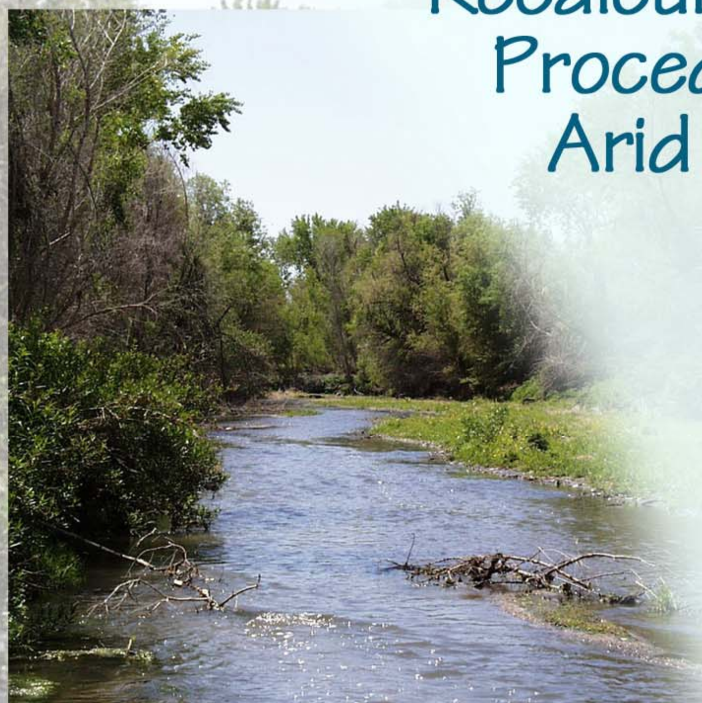
Arid West Water Quality Research Project

Evaluation of the EPA Recalculation Procedure in the Arid West



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May 2006

Executive Summary

Arid West Water Quality Research Project

EVALUATION OF THE EPA

RECALCULATION PROCEDURE

IN THE ARID WEST

Executive Summary

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directed by Pima County Wastewater Management Department

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cover photo: Santa Cruz River, near Tubac, AZ
Linwood Smith, photographer

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ABBREVIATIONS AND ACRONYMS

μg/L	microgram(s) per liter
ACR	acute-to-chronic ratio
ADEQ	Arizona Department of Environmental Quality
AGFD	Arizona Game and Fish Department
Al	aluminum
$AV_{t,8}$	acute value, normalized to pH 8
AW-MDRs	arid West minimum data requirements
AWQC	ambient water quality criteria
AWWQRP	Arid West Water Quality Research Project
BLM	biotic ligand model
Ca	calcium
CCC	criterion continuous concentration
CDOW	Colorado Division of Wildlife
CF	conversion factor for the dissolved metal fraction
CMC	criterion maximum concentration
Cu	copper
$CV_{t,8}$	chronic value, normalized to pH 8
DOC	dissolved organic carbon
DQOs	data quality objectives
EC_{20}	effect concentration, point estimate for specified effect in 20% of organisms
ECE	extant criteria evaluation
EDW	effluent-dependent waters
ELS	sensitive early life
EPA	U.S. Environmental Protection Agency
FACR	final acute-to-chronic ratio
FAV	final acute value
FCV	final chronic value
GMAV	genus mean acute value
GMCV	genus mean chronic value
HCS	habitat characterization study
ITIS	Integrated Taxonomic Information System
LC_{50}	lethal concentration – point estimate for 50% mortality
LOEC	lowest-observed-effect concentration
MDR	minimum data requirement
Mg	magnesium
mg/L	milligram per liter

ABBREVIATIONS AND ACRONYMS (Continued)

N	nitrogen
NCSS	Number Cruncher Statistical System
NH_3	ammonia
NH_4^+	ammonium ion
NOEC	no-observed-effect concentration
OP	organo-phosphate
PCWMD	Pima County Wastewater Management Department
PCWWM	Pima County Wastewater Management
SARDA	Santa Ana River Dischargers Association
SMACR	species mean acute-to-chronic ratio
SMAS	species mean acute slope
SMAV	species mean acute value
SMCV	species mean chronic value
TA-N	total ammonia as nitrogen
T&E	threatened or endangered
TMDL	total maximum daily load
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WET	whole effluent toxicity
WWTP	wastewater treatment plant
Zn	zinc

ES.1 SUMMARY OF PROJECT OBJECTIVES

Although AWQC are intended to protect many aquatic species nation-wide, they may not always represent the contaminant sensitivity of species resident to a particular site. At present, the EPA has provided guidance for the development of site-specific criteria using three primary methods (EPA 1994):

- The recalculation method,
- Water-effect ratios, and
- The resident species procedure.

This study applies and further develops tools for modifying AWQC on a site-specific basis for arid West effluent-dependent waters (EDWs) through an evaluation of the EPA recalculation procedure.

Evaluation of the recalculation procedure has focused on AWQC that represent different modes of toxicity, robustness of toxicological databases, and other recalculation issues. The criteria chosen for evaluation include three initially addressed in the Extant Criteria Evaluation, or ECE (PCWWM 2003) - ammonia, copper, diazinon - as well as two common metals, zinc and aluminum. The selection of AWQC follows the conclusions of both the ECE and the Habitat Characterization Study, or HCS (PCWWM 2002) that the recalculation procedure in the arid West should be based on taxa more representative of communities found in either natural or effluent-dependent, non-perennial streams in the arid West.

In the present study, AWQC have been recalculated to better reflect the resident species observed in a number of effluent-dependent study streams in the arid West. Streams chosen for this study include four of the nine streams addressed in the HCS;

- Santa Ana River, California
- Salt/Gila Rivers Arizona,
- Santa Cruz River, Arizona,
- Fountain Creek, Colorado
- South Platte River, Colorado

Waters from most of these sites were also used for water-effect ratio testing for copper and ammonia in two other AWWQRP studies (PCWWM 2005a, 2005b). Resident species lists were developed for these streams for comparison to the toxicity databases as a required step in the recalculation procedure.

Prior to recalculation, we also updated each criteria through: 1) review of the criteria documents for technical accuracy; 2) literature review to update the criteria toxicity databases; and 3) development of revised, updated national criteria. These updated AWQC (Chapters 3 through 7) were subsequently used as the basis for evaluating the recalculation procedure (EPA 1994) in each of our case study EDWs (Chapter 9).

ES.2 OVERVIEW OF STUDY STREAM SEGMENTS, DATA SOURCES, AND RESIDENT SPECIES LIST DEVELOPMENT

Fish and invertebrate taxa lists were compiled from a literature review to determine what taxa currently occur or could potentially occur at the effluent-dependent streams in this analysis. All stream segments were located downstream of wastewater treatment plants (WWTP) that discharge treated effluent into streams that would otherwise have low or no flow during most of the year (i.e., effluent-dependent stream segments).

According to the EPA (1994), the phrase “occur at the site” includes fish or invertebrates that are usually present at the site, either as year-round residents or as seasonal or intermittent residents, or if not currently present, they are expected to reside within the streams when conditions improve (EPA 1994). For our analysis, “occur at this site” is further separated on the basis of whether these organisms are resident (organisms that use the stream reproduction, feeding, and/or refuge) or transient taxa (organisms that are moving through the site, either actively or passively, and do not use the stream for the above functions).

The effluent-dependent stream sites chosen for this study produced a composite fish species list containing a total of 75 taxa (Chapter 2). The number of taxa collected at each stream segment varied from only three non-native fish taxa collected from sites on the Santa Cruz River near Tucson to 40 fish taxa collected from sites on the Salt/Gila Rivers. The native fish species found at each stream grouped by geographic location, as expected due to historic/biogeographical barriers (PCWMD 2002).

The effluent-dependent streams chosen for this study produced a composite invertebrate species list containing a total of 561 taxa (Chapter 2). The total number of taxa collected over the period of record used in this analysis for each stream varied from 41 taxa collected from the Santa Cruz River near Tucson to 282 taxa collected from the Santa Ana River. As with the fish cluster analysis using all fish taxa, the grouping of the invertebrate communities in these streams seems to be highly influenced by the number of studies, the number of years studied, and methods used in those studies. Regardless, the fish and invertebrate taxa lists developed provide a list of resident taxa for the recalculation effort described later in this document.

ES.3 ALUMINUM CRITERIA REVIEW AND UPDATE

The 1988 report entitled *Ambient Water Quality Criteria for Aluminum* (EPA 1988) underwent a technical review and update as the initial step for inclusion in the Arid West Water Quality Research Project AWQC Recalculation Project. The speciation and/or complexation of aluminum (Al) is highly dependent on ambient water quality characteristics and ultimately determines the mechanism of toxicity. Concentration of calcium in the water was shown to decrease toxic effects to fish.

A comprehensive literature review resulted in the addition of 36 acute data points from 15 studies to the updated aluminum acute database (Chapter 3). Additionally, 11 chronic data points from nine studies were added to the updated aluminum chronic database. The updated acute database revealed a statistically significant inverse Al toxicity and hardness relationship with a slope of 0.8327. This was not reported in the 1988 Aluminum AWQC.

The updated acute database contains values for 17 genera, while the updated Al chronic toxicity database presents data for six genera of freshwater organisms. 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. New acute and chronic hardness-based equations were derived from the updated databases (Table ES-1). The updated and revised acute and chronic criteria based on these equations are presented across a wide range of hardness levels (Table ES-1). 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. Given that arid West EDWs can often exhibit hardness values much greater than 220 mg/L, this represents an uncertainty.

Table ES-1
Updated and Revised Acute and Chronic Al Criteria Values (µg Total Aluminum/L) Across Selected Hardness Values

	Mean Hardness (mg/Las $CaCO_3$)									
Updated/Revised National Standards	25	50	75	100	150	200	250	300	350	400
Acute Al Criterion: $e^{(0.8327 [\ln (hardness)]+3.8971)}$	719	1,280	1,794	2,280	3,195	4,060	4,889	5,691	6,470	7,231
Chronic Al Criterion: $e^{(0.8327 [\ln (hardness)]+2.9800)}$	287	512	717	911	1,277	1,623	1,954	2,275	2,586	2,890

NOTE: Current EPA Al criteria: 750 µg/L acute; 87 µg/L chronic

ES.4 AMMONIA CRITERIA REVIEW AND UPDATE

The "1999 Update of Ambient Water Quality Criteria for Ammonia" (EPA 1999) provides current national recommended ammonia criteria and was reviewed and updated in this effort. An extensive review of published and unpublished literature added 23 genera, representing 28 species, to the current national acute/chronic database (Chapter 4). The most noteworthy additions to the database were eight species of freshwater mussels in the Family Unionidae, which appear to be extremely sensitive to ammonia. The updated database also includes four endangered fish species found in the arid West. Additionally, 20 chronic ammonia studies were determined to be useable, which provided toxicity data for 14 species representing 12 genera. The updated chronic database still does not meet the "eight family rule" for the 5th percentile approach for development of national AWQC (Stephan et al. 1985).

Our analysis of the exisiting criteria led us to not include a temperature component in the acute ammonia relationship. However, uncertainties in the use of "large" rainbow trout data led us to an alternative approach of re-categorizing the updated database into two databases as either cold-water or warm-water species (Chapter 4). The four most sensitive warmwater genera were all mussels from the Unionidae family. Given the uncertainty of the unionid distribution within the arid West (Chapter 2), we also analyzed the warm-water database minus the Unionidae family. Acute equations were then derived for each database (i.e., cold-water, warm-water, warm-water minus Unionidae):

Updated Cold-water Ammonia Acute Criterion:

$$\mathrm{CMC}_{\mathrm{Cold}} = \frac{0.375}{1+10^{7.204\text{-pH}}} + \frac{53.3}{1+10^{\text{pH-}7.204}}$$

Updated Warm-water Ammonia Acute Criterion:

$$\mathrm{CMC}_{\mathrm{Warm}} = \frac{0.081}{1+10^{7.204-\mathrm{pH}}} + \frac{11.5}{1+10^{\mathrm{pH}-7.204}}$$

Updated Warm-water without Unionidae Ammonia Acute Criterion:

$$\mathrm{CMC}_{\text{Warm without Unionidae}} = \frac{0.388}{1+10^{7.204\text{-pH}}} + \frac{55.3}{1+10^{\text{pH-}7.204}}$$

The EPA's development of the chronic equations based on temperature and pH was problematic because: 1) the chronic database does not meet EPA's "eight family rule"; 2) the temperature-dependent chronic equations are based on a single acute toxicity study in which the authors explicitly state no relationship between ammonia toxicity and temperature; 3) the amphipod *Hyalella azteca* was used to develop a temperature-based function to protect early life stage fish; and 4) this *H. azteca* test had significant control mortality.

These major shortcomings of the EPA chronic ammonia criteria led us to re-evaluate the use of acute-chronic ratios (ACR) to adjust the acute equations. A final ACR of 4.9 was derived and the resulting cold-water, warm-water, and warm water without Unionidae chronic equations are listed below. The modifications to the national acute and chronic ammonia water quality criteria are more appropriate for the range of aquatic habitats found in the arid West.

Updated Cold-water Ammonia Chronic Criterion:

$$CCC_{\text{Cold}} = \frac{0.153}{1+10^{7.204\text{-pH}}} + \frac{21.74}{1+10^{\text{pH-}7.204}}$$

Updated Warm-water Ammonia Chronic Criterion:

$$CCC_{\text{Warm}} = \frac{0.033}{1+10^{7.204\text{-pH}}} + \frac{4.69}{1+10^{\text{pH-}7.204}}$$

Updated Warm-water (without Unionidae) Ammonia Chronic Criterion:

$$CCC_{\text{Warm without Unionidae}} = \frac{0.156}{1+10^{7.204\text{-pH}}} + \frac{22.21}{1+10^{\text{pH-}7.204}}$$

ES.5 COPPER CRITERIA REVIEW AND UPDATE

Copper criteria are presently hardness-modified even though copper toxicity does not always exhibit a consistently strong relationship with water hardness (PCWWM 2003, 2005a). The 2003 Copper Draft (EPA 2003) is the first EPA AWQC document to use the biotic ligand model (BLM) to normalize toxicity values for criteria derivation. Unfortunately, requiring such BLM data reduces the database from 43 genera (EPA 1996) to 27 in the 2003 Copper Draft. Since the 2003 Copper Draft is not officially adopted by the EPA, we did not use the BLM to modify the toxicity data or our criteria updates.

The literature review resulted in the addition of 295 acute values (Chapter 5) from 47 different sources to the 1984/1995 acute copper toxicity database, including acute toxicity values for 43 new species, representing 25 new genera. These new data also included toxicity values for many T&E species. In addition to the new acute data, a total of 24 chronic values from ten sources were added to the revised chronic toxicity database.

Updated acute and chronic hardness slopes were developed from the revised and updated toxicity databases.

The revised and updated final acute and chronic dissolved copper equations and a summary of criteria at varying hardness levels are presented below (Table ES-2). *Precautionary Note:* One study in particular, Koivisto et al. (1992), highly influenced the updated final acute value, as it provides the only data for the three most sensitive species in the database - with all values unmeasured. It would not be appropriate to remove these unmeasured values without removing all unmeasured values. However, criteria calculated without acute values from Koivisto et al. (1992) may be more appropriate for revised national criteria.

Table ES-2
Summary of Existing (EPA 1996) and Revised Copper Criteria
(as µg dissolved Cu/L) at Varying Hardness Levels

Equations	Mean Hardness in mg/L $CaCO_3$									
	25	**50**	**75**	**100**	**150**	**200**	**250**	**300**	**350**	**400**
Current EPA Criteria										
Acute = 0.96 $(e^{0.9422 [\ln (hardness)]-1.7000}$	3.640	7.286	10.675	13.999	20.512	26.899	33.192	39.413	45.574	51.684
Chronic = 0.96 $(e^{0.8545 [\ln (hardness)]-1.7020}$	2.739	4.953	7.004	8.956	12.664	16.193	19.595	22.898	26.122	29.279
Updated Criteria (all data)										
Acute = 0.96 $(e^{0.9801 [\ln (hardness)]-2.2608}$	2.380	4.709	7.018	9.316	13.886	18.431	22.969	27.472	31.974	36.466
Chronic = 0.96 $(e^{0.5897 [\ln (hardness)]-1.1054}$	2.121	3.192	4.054	4.804	6.102	7.230	8.246	9.182	10.056	10.880
Updated Criteria (w/o Koivisto *et al*. 1992)										
Acute = 0.96 $(e^{0.9801[\ln(hardness)]-2.2835}$	4.082	8.077	12.039	15.980	23.818	31.615	39.382	47.124	54.846	62.551
Chronic = 0.96 $(e^{0.5897[(\ln(hardness)-1.1281}$	3.638	5.476	6.955	8.240	10.466	12.401	14.145	15.751	17.250	18.663

ES.6 DIAZINON CRITERIA REVIEW AND UPDATE

The EPA has not established national aquatic life criteria for diazinon, but has produced a *Draft Ambient Aquatic Life Water Quality Criteria Diazinon* (EPA 2000. Environmental conditions, such as site-specific channel characteristics and water quality parameters of arid West streams, may differentially affect diazinon degradation and, therefore, exposure to aquatic organisms.

The literature review contributed 25 new acute data points from 19 studies to the revised acute. Ten new freshwater chronic data points from eight studies were added to the revised chronic database. The revised and updated diazinon acute toxicity database contains data for 22 genera, satisfing the "eight-family rule" as specified in the 1985 Guidelines. The revised and updated diazinon chronic toxicity database presents data for nine genera of freshwater organisms.

The resulting updated acute criterion for diazinon is 0.11 µg/L. The updated chronic criterion is also 0.11 µg/L - equal to the acute criterion, since the FACR and acute criterion division factor that estimates an LC-low for full protection of the most sensitive species are both equal to 2. Due to diazinon behavior, mechanisms of toxicity, organism's excretion, and exposure patterns in aquatic environments, these results are not surprising and should be appropriate for the protection of aquatic life.

ES.7 ZINC CRITERIA REVIEW AND UPDATE

Over 120 data points from 35 sources were added to an updated acute zinc database. In addition to the new acute data, a total of 23 data points from 12 sources were added to the chronic database, resulting in addition of 12 new genera and 11 new species. An updated acute hardness slope was used to normalize acute values to a hardness of 50 mg/L and to develop a hardness-based final acute equation. The new acute database contains 61 genera and 78 species (previously 36 genera and 44 species). An updated final acute-chronic ratio (FACR) was also determined for chronic criteria derivation. Table ES-3 presents a summary of these revised and updated acute and chronic zinc criteria at varying hardness levels.

Table ES-3
Summary of Existing and Revised Zinc Criteria
(as µg dissolved Zn/L) at Varying Hardness Levels

Equations	Mean Hardness in mg/L $CaCO_3$									
	25	**50**	**75**	**100**	**150**	**200**	**250**	**300**	**350**	**400**
Current EPA Criteria										
Acute = 0.978 $(e^{0.8473\,[\ln(\text{hardness})]+0.8840}$	36.20	65.13	91.83	117.18	165.22	210.82	254.70	297.25	338.72	379.30
Chronic = 0.986 $(e^{0.8473\,[\ln(\text{hardness})]+0.8840}$	36.50	65.66	92.58	118.14	166.57	212.55	256.78	299.68	341.49	382.40
Updated Criteria										
Acute = 0.978 $(e^{0.8537\,[\ln(\text{hardness})]+1.1182}$	46.71	74.41	119.32	152.53	215.62	275.65	333.49	389.66	444.47	498.13
Chronic = 0.986 $(e^{0.8537\,[\ln(\text{hardness})]+0.9473}$	39.69	71.73	101.40	129.62	183.24	234.25	283.40	331.13	377.71	423.31

ES.8 AMBIENT WATER QUALITY CRITERIA RECALCULATION ARID WEST EFFLUENT-DOMINATED STREAMS

ES.8.1 Overview of the EPA Recalculation Procedure

National ambient water quality criteria (AWQC) are to be derived from the most up-to-date toxicity databases for species resident to North America. Established methods for data selection and national criteria derivation are published in Stephan et al. (1985), as well as "Appendix B:

The Recalculation Procedure" in EPA (1994). The basic steps involved with EPA's recalculation procedure include (EPA 1994):

a) Corrections to the national database (Chapters 3-7);
b) Updating the national database (Chapters 3-7);
c) Deletions of taxa that do not occur at the site (Chapter 9 and Appendix 3);
d) If new database does not meet MDRs, generating the data necessary to meet MDRs;
e) Recalculating new acute and chronic criteria based on the revised and updated databases (Chapters 9 and 10); and
f) Presenting results in a report (present study).

ES.8.2 Resident vs. Transient Species

A key component of the recalculation procedure, specifically with regard to deletion of non-resident taxa from the database, is the definition of the phrase "occur at the site." For this analysis, we have taken this *occur at site* phrase a step further by delineating the organisms that occur at the site into "resident" and "transient" species. A resident species is an organism using the habitat located at the site for reproduction, foraging, and/or refuge, which can include migratory species. A transient species, on the other hand, is a species that may *occur at the site*, but does not utilize the habitat for these functions, and is only passively moving through the site.

ES.8.3 Deletion Process

Resident species lists generated in Chapter 2 were used to screen the corrected and updated national toxicity databases for each criterion. When reviewing the EPA (1994) deletion process, we identified a possible conflict between 1) the stepwise process they describe, 2) their accompanying figure that shows an example of the deletion process using three Phyla, and 3) the stated goal of deriving a site-specific database that contains *the most closely related taxa* to taxa found at the site. To resolve these conflicts, we refined the EPA step-wise process with the goal of generating a site-specific toxicity dataset more representative of the species that occur at the site than what would be derived using the standard process (Chapter 8).

ES.8.4 Minimum Data Requirements

Direct calculation of a criterion requires a toxicity database contain data for eight diverse Families (Stephen et al. 1985), commonly referred to as the "eight-family rule", or minimum data requirements (MDRs). National AWQC derived from a database that meets the MDRs are calculated from a series of formulas using the geometric mean toxicity values of the four most sensitive genera, and the total number of genera represented in the database. The resulting criteria concentrations are expected to protect at least 95% of all aquatic organisms and aquatic habitats (lotic, lentic, cold-water, and warm-water habitats).

ES.8.5 Redefining the Recalculation Procedure for Arid West Streams

The EPA guidelines and MDRs are the foundation for the arid West effluent-dependent stream AWQC recalculations. However, we believe slight modifications of the MDRs and EPA guidelines may be warranted given the habitats present and organisms expected to occur in these habitats.

First, taking into consideration the non-resident taxa in the EPA MDRs and the relative importance of other taxa not included in the EPA MDRs, we propose a revised eight-family rule specific for arid West effluent-dependent streams. These revised arid West MDRs (AW-MDRs) are intended for the protection of warm water aquatic communities residing in arid West effluent-dependent stream habitats, not in lakes and/or ponds.

Arid West Stream Eight-Family Rule [AWS-MDRs]

1) An organism in the Family Centrachidae (*replacing Family Salmonidae*),
2) An organism in the Family Cyprinidae (*replacing Family in Class Osteichthyes*),
3) A Family in the Phylum Chordata,
4) An aquatic insect,
5) A second aquatic insect in a different Order (*replacing Planktonic Crustacean*),
6) A benthic crustacean,
7) A Family in a Phylum other than Arthropoda or Chordata, and
8) A Family in any Order of insect or any Phylum not already represented.

Second, for the analysis presented herein, we are proposing that criteria derived during the recalculation process be calculated from the geometric mean of species mean acute and chronic values (SMAVs and SMCVs) rather than genus mean acute and chronic values (GMAVs and GMCVs) since 1) the deletion process itself is conducted on a species level rather than a genus level; 2) toxicity of a contaminant to different species within the same genus is not always equivalent; and 3) the minimal overlap between arid West resident species lists and species within the various toxicity databases can artificially lower the criterion if derived at the GMAV level (Great Lakes Environmental Center 2005). Calculating criteria at the species level rather than genus can help increase the database sample size to help resolve potential sample size effects, without affecting the protectiveness of the resulting criteria through inclusion of SMAVs for sensitive species.

ES.8.6 Recalculation of Ambient Water Quality Criteria

The step-wise deletion process was conducted using the revised and updated national toxicity databases and resident species list for each river. Regional databases (Southwest and High Plains) were created by compiling the species lists for rivers in each respective region. Once the site-specific databases were created, checking of AWS-MDRs, the ranking process, and final site-specific criteria derivation was performed.

The first step after completion of the site-specific databases was to check for acceptance of the AWS-MDRs. In addition to compliance with the AWS-MDR, we identified threatened, endangered, and/or recreationally economically important species that reside at a site. If the AWS-MDRs were not met for a particular criterion at a particular site, then the regional site-specific criterion could provide an alternative AWQC recommendation.

ES.9 COMPARISONS OF SITE-SPECIFIC STANDARDS TO UPDATED NATIONAL CRITERIA

For comparisons of actual recalculated site-specific standards to national criteria, the equations or CMC and CCC values for each contaminant and each site were solved for mean hardness and pH of each site, as appropriate. Historical ambient water quality data for the study streams were derived using water quality data presented in the arid West HCS (PCWWM 2002) and from the BLM validation study (PCWWM 2005).

Results for the Santa Ana River, both segments of the Santa Cruz River, the Salt/Gila Rivers, Fountain Creek, and the South Platte River, as well as regional recalculated criteria are summarized in Tables ES-4 and ES-5.

Table ES-4
Site-Specific Acute Criterion Concentrations using Mean Hardness and pH when Necessary

	Site-Specific CMC						**Regional CMC**	
	Santa Ana River	**Santa Cruz River**		**Salt/ Gila River**	**Fountain Creek**	**South Platte River**	**Southwest Region**	**High Plains Region**
		Near Nogales	**Near Tucson**					
Hardness (mg/L)	188	170	150	388	218	280	208	247
pH	7.2	7.5	7.2	7.4	7.4	7.4	7.3	7.4
Aluminum (µg total Al/L)	3463 (3856)	4527 (3546)	NA (3195)	7683 (7050)	3609 (4362)	4826 (5373)	3768 (1506)	4005 (4840)
Ammonia (mg TA-N/L)	28.35 (27.52)	18.53 (18.53)	28.47 (27.52)	21.16 (21.40)	22.05 (21.40)	21.62 (21.40)	24.94 (24.42)	21.77 (21.40)
Copper (µg dissolved Cu/L)	29.93 (16.96)	27.84 (15.36)	21.32 (13.59)	63.36 (34.49)	35.18 (19.57)	45.68 (25.05)	36.42 (18.69)	40.56 (22.14)
Diazinon (µg total diazinon/L)	8.56 (0.11)	9.12 (0.11)	12.50 (0.11)	12.72 (0.11)	9.32 (0.11)	9.32 (0.11)	9.32 (0.11)	9.32 (0.11)
Zinc (µg dissolved Zn/L)	470.2 (261.5)	329.9 (239.9)	301.4 (215.6)	565.0 (485.3)	364.2 (296.2)	464.0 (367.4)	308.2 (284.6)	439.4 (329.9)

NOTES:
NA = Data were not available to derive criteria for that site – see Chapter 9 for discussion.
Values in () = updated national acute criterion, given site hardness or pH, for comparison.

Table ES-5
Site-Specific Chronic Criterion Concentrations using Mean Hardness and pH when Necessary

	Site-Specific CCC						Regional CCC	
	Santa Ana River	Santa Cruz River Near Nogales	Santa Cruz River Near Tucson	Salt/Gila Rivers	Fountain Creek	South Platte River	Southwest Region	High Plains Region
Hardness (mg/L)	188	170	150	388	218	280	208	247
pH	7.2	7.5	7.2	7.4	7.4	7.4	7.3	7.4
Aluminum (µg total Al/L)	1384 (1541)	1809 (1417)	NA (1277)	3071 (2818)	1443 (1744)	1929 (2148)	1506 (1677)	1601 (1935)
Ammonia (mg TA-N/L)	11.57 (11.23)	7.56 (7.56)	11.62 (11.23)	8.64 (8.74)	9.00 (8.74)	8.83 (8.74)	10.18 (9.97)	8.89 (8.74)
Copper (µg dissolved Cu/L)	12.31 (6.97)	11.90 (6.57)	9.57 (6.10)	19.63 (10.69)	13.65 (7.61)	16.08 (8.82)	14.39 (7.40)	14.99 (8.19)
Diazinon µg total diazinon/L)	8.56 (0.11)	9.12 (0.11)	12.50 (0.11)	12.72 (0.11)	9.32 (0.11)	9.32 (0.11)	9.32 (0.11)	9.32 (0.11)
Zinc (µg dissolved Zn/L)	399.6 (222.2)	280.4 (203.9)	256.1 (183.2)	480.2 (412.4)	310.1 (252.1)	394.3 (312.2)	262.3 (242.2)	373.6 (280.5)

NOTES:
NA = data was not available to derive criteria for that site – see Chapter 9 for discussion
Values in () = updated national chronic criterion, given site hardness or pH, for comparison.

To quantify the relative numeric implication of applying the arid West recalculation procedure for particular contaminant/site combinations, we compared these site-specific standards with their respective updated national criteria (Table ES-6). A net change of 10% in the site-specific standard vs. national criteria was used to indicate differences that were likely to be substantially different from the national criteria. Results suggest that the recalculation procedure for development of site-specific standards would generally derive substantially different criteria concentrations for all of the case-study streams. The one exception to this is ammonia, which shows no noteworthy change when compared to the updated national criteria following recalculation.

Table ES-6
Calculation Findings Decision Matrix

	Santa Ana River	Santa Cruz near Nogales	Santa Cruz Near Tucson	Salt/Gila Rivers	Fountain Creek	South Platte River	Southwest Region	High Plains Region
Aluminum	-	+	NA	=	-	-	-	-
Ammonia	=	=	=	=	=	=	=	=
Copper	+	+	+	+	+	+	+	+
Diazinon	+	+	+	+	+	+	+	+
Zinc	+	+	+	+	+	+	=	+

NOTES:
"+" = Recalculated criteria are less restrictive than national updated criteria.
"-" = Recalculated criteria are more restrictive than national updated criteria.
"=" = Less than 10% change in recalculated criteria from national updated criteria.
NA = Data were not available to conduct the analysis.

ES.9.1 Criteria-Specific Issues with the Recalculation Procedure

The following discussion provides a summary of the issues that arose during the recalculation evaluation for each criterion, with comments on the mechanics of updating the national criteria, creating site-specific databases, and deriving final site-specific criteria.

ES.9.1.1 Aluminum

Compared to the updated national aluminum criteria, site-specific aluminum criteria were more restrictive or equal to the national criteria, except for the Santa Cruz near Nogales site (Figure ES-1). These counter-intuitive findings resulted from two basic factors.

First, all site-specific databases contained greater variability in the four lowest SMAVs, resulting in less statistically confident FAV calculations and, hence, more restrictive criteria. Second, the site-specific databases resulted in fewer taxa than the updated national databases. Reduction in number of species (N) within the site-specific toxicity databases decreased the degrees of freedom afforded to the four lowest ranked SMAVs.

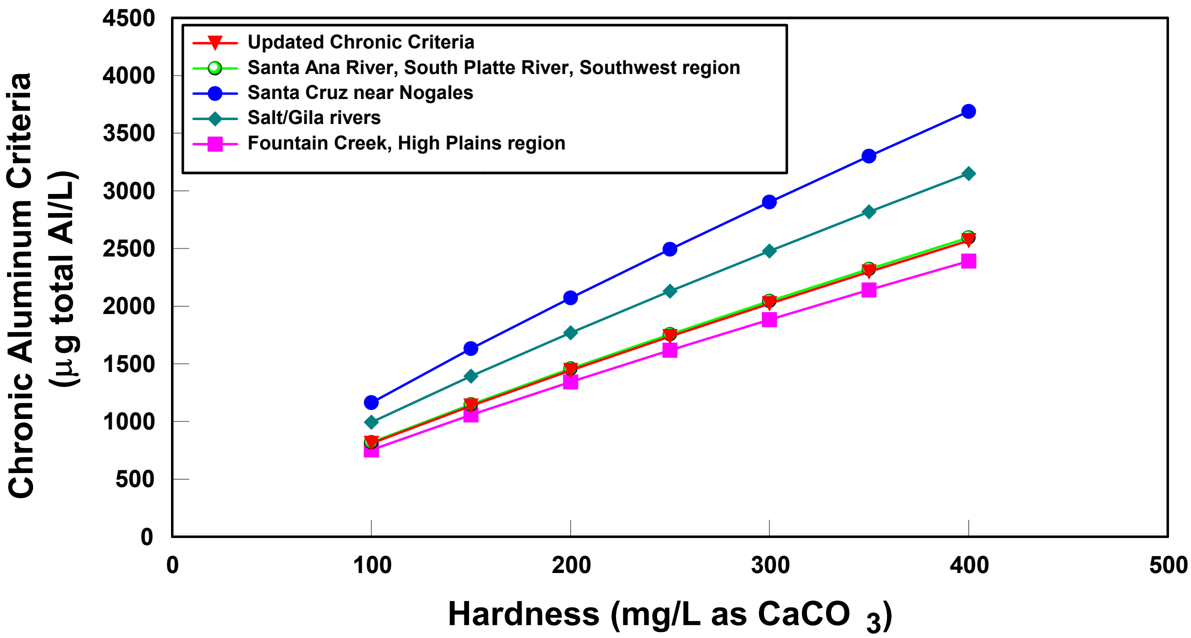

Figure ES-1
Comparison of Site-Specific Chronic Aluminum Criteria to the Updated National Criteria at Varying Hardness

In other words, the lower aluminum criteria resulting from site-specific recalculations relfect a reduction in the size of an already limited toxicity database and are not related to the species richness of the study sites. As such, we would recommend adoption of the updated aluminum AWQC presented in the national review and update (Chapter 3) and continue further investigation into site-specific recalculations when a more robust database becomes available.

ES.9.1.2 Ammonia

With regard to ammonia, there is little variability in site-specific criteria between any of the sites or regions (Figure ES-2). However, regional criteria are less restrictive than all but one site-specific criterion. This is directly associated with using the larger regional toxicity databases when compared to the site-specific databases. The similarity in results for all sites and regions with the updated national criterion suggest that site-specific recalculations for ammonia might not be necessary, as the breakdown of warm and cold water habitats proposed in our national updated ammonia criteria may already account for site-specific differences in arid-west streams, making further species-based recalculation efforts unnecessary.

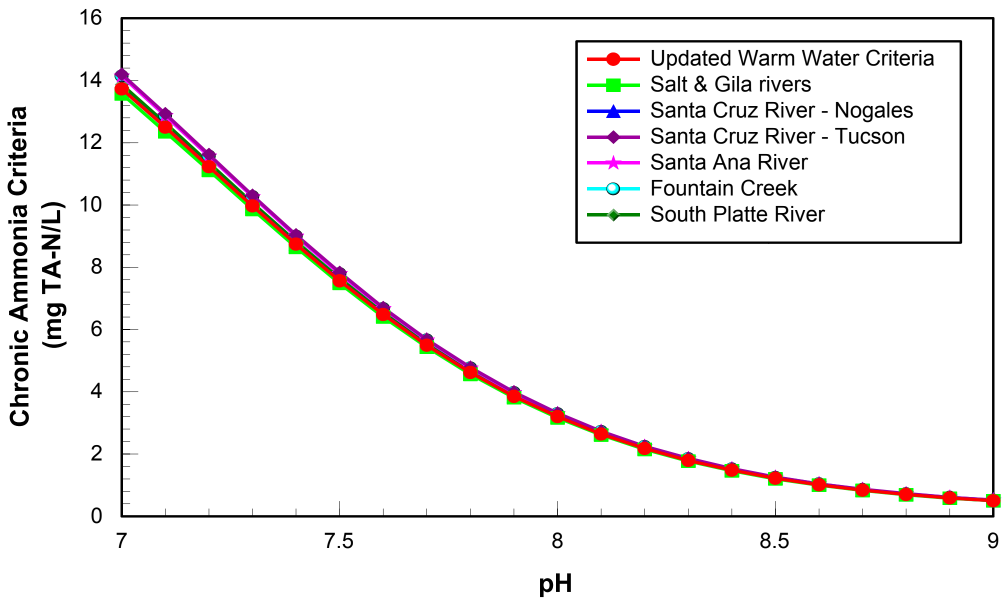

Figure ES-2
Site-Specific Chronic Ammonia Criteria as a Function of pH
(Note: Acute Criteria Distribution is Similar to Chronic)

ES.9.1.3 Copper

The recalculation procedure for copper provided substantial site-specific differences in criteria concentrations in arid West study streams compared to national criteria. Unlike ammonia, we found a substantial increase in all site-specific criteria (i.e., were less restrictive) compared to national or updated national AWQC (Figure ES-3). This was primarily a result of deletion of non-resident cladocerans.

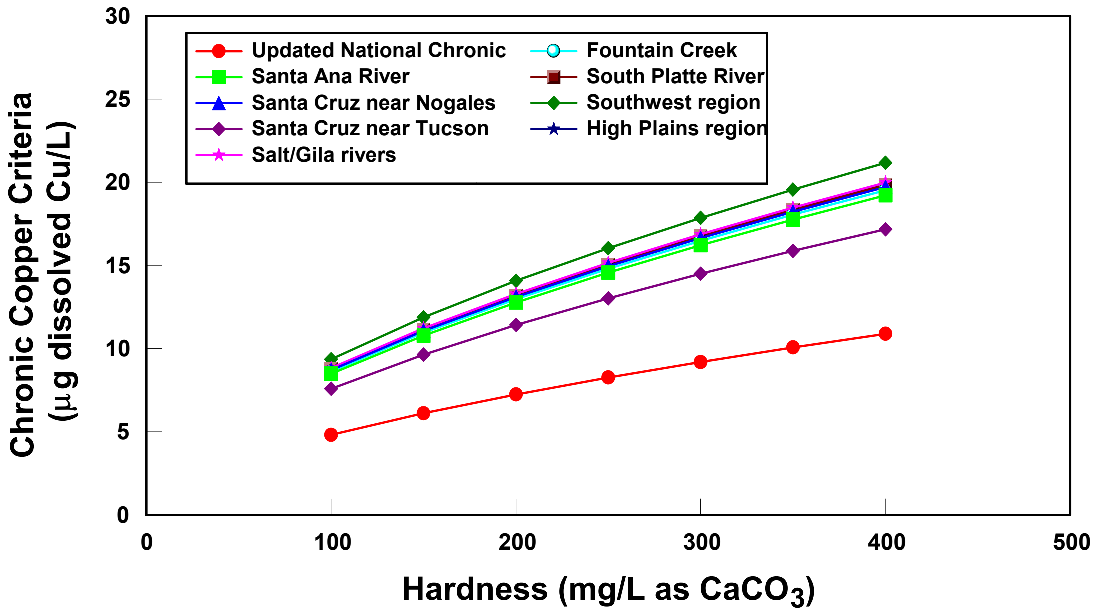

Figure ES-3
Comparison of Site-Specific Chronic Copper Criteria to the Updated National Chronic Copper Criteria at Varying Hardness Values

ES.9.1.4 Diazinon

Resulting site-specific diazinon criteria were substantially greater (i.e., less restrictive) than the updated national criteria. The site-specific databases are half as variable as the national update, which increases confidence in respective estimates and results in greater values. Furthermore, site-specific criteria for diazinon were more variable between sites than other criteria in this analysis. Although the most sensitive organisms are similar between most sites, the variability in database size between sites was substantially different. The significant increase of the recalculated criterion and the variability of criterion between sites provide some evidence that moderately sized databases are uniquely sensitive to the arid West recalculation procedure.

ES.9.1.5 Zinc

In general, the arid West recalculation procedure applied to the updated national zinc database successfully generates site-specific criteria that reflect the relative sensitivity of organisms at the site, rather than criteria that are driven by database size. The species composition of the site-specific databases and ranking were variable among sites, which greatly influenced the numeric outcome of the recalculated criteria (Figure ES-4). Initiating the deletion process with the robust updated database makes it more likely that the site-specific databases will reflect the unique species composition for each arid West site.

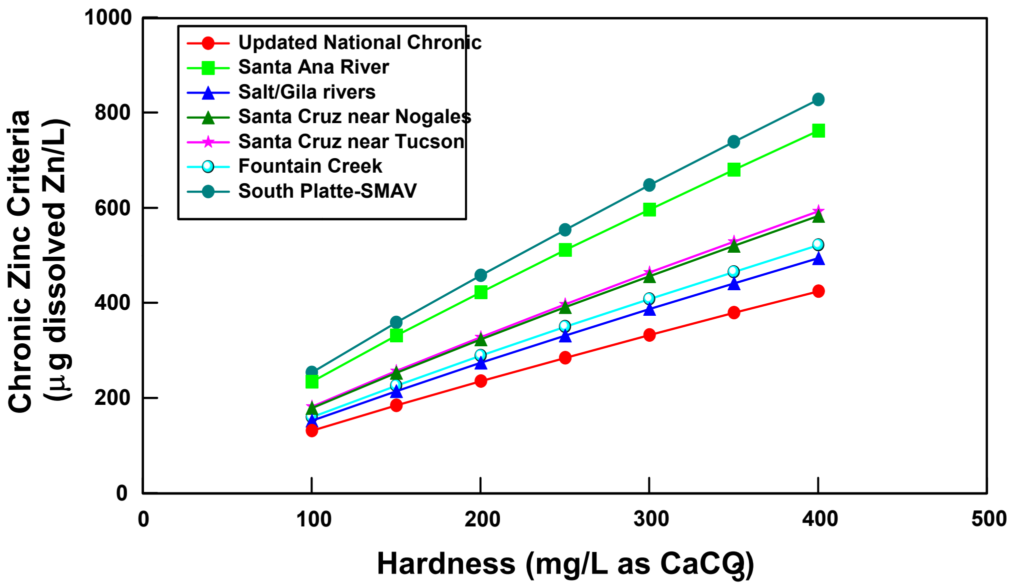

Figure ES-4
Comparison of Site-Specific Chronic Zinc Criteria to the Updated National Chronic Zinc Criteria at Various Hardness Concentrations

ES.10 FACTORS AFFECTING RECALCULATION "SUCCESS"

Based on our analysis, the recalculation procedure can be a useful tool, particularly when modified and applied to arid West streams. The results of recalculated site-specific criteria resulted in significant changes for some, but not all AWQC reviewed in this analysis.

Significant changes in site-specific critera as the result of the recalculation procedure include copper, diazinon and zinc. These toxicants produced universally less restrictive criteria than updated national criteria, while ensuring the same levels of protection for resident fauna for all study streams. It is clear that starting the deletion process for criteria with a more robust toxicity database increases the chance the taxa retained for each site will vary, which then influences the final criteria concentrations. Since ammonia criteria were already partitioned into cold and warm water equations, and many of the most sensitive species in the updated warm water database are resident to the arid West, the resulting site-specific criteria would be expected to be similar. The issues with recalculation for aluminum criteria surfaced due to the relatively limited number of species in the updated national toxicity database. Until more aluminum toxicity data are available for more aquatic organisms common to the arid West, it may be more appropriate to adopt the updated national criterion developed in this study.

Although results from the recalculation procedure could be used to derive scientifically defensible site-specific criteria, the tasks involved require considerable effort. However, the updated toxicity databases developed for this study can be used as a starting point for future updates to these five criteria. Furthermore, relevant invertebrate and fish population data are required for the development of resident species lists. Invertebrate and fish population monitoring plans should be initiated and maintained in the reach of interest. Lastly, there needs to be continued support for more toxicity testing for all AWQC, especially with species resident to arid West streams.

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