3/2/09
Proposed Chloride Criteria Update

Based on new toxicity test data submitted to Chuck Stephan on February 3, 2009, the Department has updated its proposed Chloride criteria as follows:

Acute chloride criterion:

$287.8(\text{Hardness})^{0.205797}(\text{Sulfate})^{-0.07452}$

Chronic chloride criterion:

$177.87(\text{Hardness})^{0.205797}(\text{Sulfate})^{-0.07452}$

Statewide default values for hardness and sulfate will be used unless site specific data is available.

Background documents attached:

1. 09FebChlorideAcute.wpd
2. 09FebChlorideCriteria.wpd

C. Stephan

Summary of Data Concerning the Acute Toxicity of Sodium Chloride to Aquatic Animals

This summary is based on "Results of Literature Search concerning the Toxicity of Chloride to Aquatic Animals" dated 1-15-09, but acute values from Environ (2009) have been added. Except as noted, this summary is consistent with the 1985 Guidelines.

Acute Values and Normalized Acute Values are expressed as mg chloride/L. Normalized Acute Values were calculated by normalizing the Acute Values to hardness = 300 mg/L and sulfate = 65 mg/L using the following equation:

$$NAV = (AV)\,(300/Hardness)^{0.205797}\,(65/Sulfate)^{-0.07452}$$

This equation is based on the equation presented in "Multiple Regression Equation for Chloride" dated 1-15-09. The hardness of 300 mg/L and the sulfate concentration of 65 mg/L are arbitrary; any other values for hardness and sulfate would have worked equally well. NAVs could not be calculated for all AVs because assumed values were not used for hardness or sulfate. Some of the values of hardness and sulfate are nominal, not measured, values.

Species	Method	Test Material	Hardness (mg/L)	Sulfate (mg/L)	Acute Value	Normalized Acute Value	Reference
Tubificid worm, Limnodrilus hoffmeisteri	S,U	Sodium chloride	100	----	3761	------	Wurtz and Bridges 1961
Tubificid worm, Tubifex tubifex	S,M	Sodium chloride	52 220	57.9 58.9	4278 6008	6083.2 6357.1	GLEC and INHS 2008
Aquatic worm, Lumbriculus variegatus	R,M	Sodium chloride	296	68.5	5408	5444	Environ 2009
Leech, Erpobdella punctata	S,U	Sodium chloride	100	----	4550	------	Wurtz and Bridges 1961
Leech, Nephelopsis obscura	R,M	Sodium chloride	290	71	4310	4369	Environ 2009

Mussel, juvenile Villosa delumbis	S,M	Sodium chloride	169.5	162.7	3173	3821.1	Bringolf et al. 2007
Mussel, juvenile Villosa iris	R,M	Sodium chloride	169.5	162.7	2069	2491.6	Wang 2007
Mussel, juvenile Lampsilis fasciola	S,M	Sodium chloride	169.5	162.7	2414	2907.1	Bringolf et al. 2007
Mussel, juvenile Lampsilis siliquoidea	R,M	Sodium chloride	169.5	162.7	1905	2294.1	Wang 2007
Mussel, juvenile Lampsilis siliquoidea	S,M	Sodium chloride	169.5	162.7	2766	3331.0	Bringolf et al. 2007
Fingernail clam, Sphaerium simile	S,M	Sodium chloride	51 192	59.9 61.7	740 1100	1059.2 1201.1	GLEC and INHS 2008
Fingernail clam, Sphaerium tenue	S,U	Sodium chloride	100 20	---- ----	667 698	------ ------	Wurtz and Bridges 1961
Snail, Physa gyrina	F,M	Sodium chloride	84.8	81.4	2540	3350.0	Birge et al. 1985
Snail, Physa heterostropha	S,U	Sodium chloride	100 100 100 20	---- ---- ---- ----	2123 3094 3761 2487	------ ------ ------ ------	Wurtz and Bridges 1961
Snail, Physa sp.	S,M	Sodium chloride	22	15	3247hp	4983.6	Clemens and Jones 1954
Snail,	S,U	Sodium	----	----	>3000p	------	Williams et al. 2000

Physa sp.		chloride					
Snail, Gyraulus circumstriatus	S,U	Sodium chloride	100	----	1941	------	Wurtz and Bridges 1961
Snail, Gyraulus parvus	S,M	Sodium chloride	56 212	60.9 59.7	3078 3009	4326.9 3211.4	GLEC and INHS 2008
Snail, Helisoma campanulata	S,U	Sodium chloride	100	----	3731	------	Wurtz and Bridges 1961
Cladoceran, Ceriodaphnia dubia	S,U	Sodium chloride	84.8	81.4	1189brt 1042brt	1568.2 1374.3	Mount et al. 1997
Cladoceran, Ceriodaphnia dubia	R,U	Sodium chloride	74.1	----	1395	------	Cowgill and Milazzo 1990
Cladoceran, Ceriodaphnia dubia	S,U	Sodium chloride	39.2	4.6	507 447	632.7 557.8	Hoke et al. 1992
Cladoceran, Ceriodaphnia dubia	S,U	Sodium chloride	39.2 39.2 39.2 39.2 339.0	4.6 4.6 4.6 4.6 325.4	1395 1638 1274 1395 1698	1740.8 2044.1 1589.8 1740.8 1867.0	USEPA 1991
Cladoceran, Ceriodaphnia dubia	S,U	Sodium chloride	84.8 169.5	81.4 162.7	1677c 1499c	2211.8 1805.2	WISLOH 2007
Cladoceran, Ceriodaphnia dubia	S,U	Sodium chloride	84.8	81.4	1413e	1863.6	Valenti et al. 2007
Cladoceran,	S,M	Sodium	67.1	64.4q	964	1311.1	Harmon et al. 2003

Ceriodaphnia dubia		chloride					
Cladoceran, Ceriodaphnia dubia	S,M	Sodium chloride	30	78.7	947	1542.9	GLEC and INHS 2008
			44	75.9	955	1434.1	
			96	73.7	1130	1442.1	
			180	67.7	1609	1792.8	
			400	78.7	1491	1425.5	
			570	76.2	1907	1690.9	
			800	75.5	1764	1457.7	
			25	69.9	1007	1688.4	
			49	67.8	767	1117.1	
			95	70.3	1369	1744.7	
			194	69.9	1195	1314.3	
			375	68.9	1687	1618.3	
			560	68.3	1652	1458.2	
			792	70.9	1909	1573.5	
			280	28.1	1400	1334.0	
			280	59.6	1720	1733.4	
			280	117	1394	1477.2	
			280	239	1500	1676.5	
			280	482	1109	1306.0	
			280	729	1206	1464.7	
			279	22.9	1311	1231.2	
			276	49.7	1258	1254.4	
			283	107	1240	1302.5	
			281	229	1214	1351.5	
			290	461	1199	1397.2	
			278	694	1179	1428.8	
Cladoceran, Daphnia ambigua	S,M	Sodium chloride	67.1	64.4q	1213	1649.7	Harmon et al. 2003.
Cladoceran,	S,U	Sodium	84.8	81.4	2893brs	3815.5	Mount et al. 1997

Daphnia magna		chloride					
Cladoceran, Daphnia magna	S,U	Sodium chloride	240	----	621	------	Khangarot and Ray 1989
Cladoceran, Daphnia magna	S,U	Sodium chloride	39.2 39.2 39.2	4.6 4.6 4.6	3038 2726 2053	3791.1 3401.8 2561.9	Hoke et al. 1992
Cladoceran, Daphnia magna	-,-	Sodium chloride	----	----	1008k 3319m	------ ------	Cowgill 1987
Cladoceran, Daphnia magna	S,U	Sodium chloride	108.7	13	<2548	<2785.1	Anderson 1946
Cladoceran, Daphnia magna	S,U	Sodium chloride	108.7	13	2232i	2439.7	Anderson 1948
Cladoceran, Daphnia magna	S,U	Sodium chloride	41.5	31.2	3563	5068.2	Dowden and Bennett 1965
Cladoceran, Daphnia magna	S,M	Sodium chloride	45.3	3.9v	2529a,f 2806b,f	3025.9 3357.4	Biesinger and Christensen 1972
Cladoceran, Daphnia magna	S,U	Sodium chloride	169.5	162.7	>2669 <3943d	>3214.2 <4748.4	Seymour et al. 1997
Cladoceran, Daphnia magna	S,U	Sodium chloride	46	3.9v	1880	2242.3	USEPA 1991
Cladoceran, Daphnia magna	S,U	Sodium chloride	169.5	162.7	3944c	4749.6	WISLOH 2007

Cladoceran, Daphnia magna	S,U	Sodium chloride	84.8	81.4	3009e	3968.5	Valenti et al. 2007
Cladoceran, Daphnia magna	S,U	Sodium chloride	106	102	3136 3222 3137	4017.4 4127.5 4018.6	Davies and Hall 2007
Cladoceran, Daphnia pulex	S,M	Sodium chloride	84.8	81.4	1470	1938.8	Birge et al. 1985
Cladoceran, Daphnia pulex	S,U	Sodium chloride	84.8 84.8 84.8 84.8	81.4 81.4 81.4 81.4	1159 1775 1805 2242	1528.6 2341.0 2380.6 2956.9	Palmer et al. 2004
Copepod, Diaptomus clavipes	S,M	Sodium chloride	22	15	2571h	3946.1	Clemens and Jones 1954
Isopod, Asellus communis	S,U	Sodium chloride	100 20	---- ----	5004 3094	------ ------	Wurtz and Bridges 1961
Isopod, Lirceus fontinalis	F,M	Sodium chloride	84.8	81.4	2950	3890.7	Birge et al. 1985
Amphipod, Hyalella azteca	S,U	Sodium chloride	102.5	98.4	3947	5077.7	Lasier et al. 1997
Amphipod, Gammarus pseudolimnaeus	S,U	Sodium chloride	----	----	>3000	------	Williams et al. 2000
Amphipod, Crangonyx sp.	S,U	Sodium chloride	----	----	>3000	------	Williams et al. 2000

Crayfish, Cambarus sp.	S,M	Sodium chloride	22	15	10557h	16203.2	Clemens and Jones 1954
Dragonfly, Libellulidae	S,M	Sodium chloride	22	15	9671h	14843.4	Clemens and Jones 1954
Damselfly, Agria sp.	S,U	Sodium chloride	100 20	---- ----	14558 13952	------ ------	Wurtz and Bridges 1961
Stonefly, Nemoura trispinosa	S,U	Sodium chloride	----	----	>3000	------	Williams et al. 2000
Caddisfly, Lepidostoma sp.	S,U	Sodium chloride	----	----	>3000	------	Williams et al. 2000
Caddisfly, Parapsyche sp.	S,U	Sodium chloride	----	----	>3000	------	Williams et al. 2000
Midge, Chironomus attenuatus	S,U	Sodium chloride	----	----	4850	------	Thornton and Sauer 1972
Midge, Chironomus dilutus	R,M	Sodium chloride	296	68.5	6032	6072	Environ 2009
American eel, Anquilla rostrata	S,U	Sodium chloride	42.4	40.7	10846	15667.3	Hinton and Eversole 1978
American eel, Anquilla rostrata	S,U	Sodium chloride	42.4	40.7	13012	18796.2	Hinton and Eversole 1979
Goldfish, Carassius auratus	S,M	Sodium chloride	148.8	----	9465	------	Threader and Houston 1983

Bannerfin shiner, Cyprinella leedsi	R,M	Sodium chloride	296	68.5	6070	6111	Environ 2009
Red shiner, Notropis lutrensis	S,M	Sodium chloride	22	15	5771g 5920g	8857.5 9086.2	Clemens and Jones 1954
Fathead minnow, Pimephales promelas	S,U	Sodium chloride	39.2 39.2 339.0	4.6 4.6 325.4	2790 2123 2244	3481.7 2649.3 2467.3	USEPA 1991
Fathead minnow, Pimephales promelas	F,M	Sodium chloride	84.8	81.4	6570	8665.1	Birge et al. 1985
Fathead minnow, Pimephales promelas	S,M	Sodium chloride	22	15	5288g 5431g	8116.2 8335.7	Clemens and Jones 1954
Fathead minnow, Pimephales promelas	S,U	Sodium chloride	84.8	81.4	3876br	5112.0	Mount et al. 1997
Fathead minnow, Pimephales promelas	S,U	Sodium chloride	84.8 169.5	81.4 162.7	4167c 4127c	5495.8 4970.0	WISLOH 2007
Black bullhead, Ameiurus melas	S,M	Sodium chloride	22	15	4849g	7442.4	Clemens and Jones 1954
Rainbow trout, Oncorhynchus mykiss	S,U	Sodium chloride	22.4	----	>485j	------	Camargo and Tarazona 1991
Rainbow trout, Oncorhynchus mykiss	F,M	Sodium chloride	46	3.9v	6743	8042.6	Spehar 1986,1987
Rainbow trout, Oncorhynchus mykiss	R,U	Sodium chloride	284	----	12363	------	Vosyliene et al. 2006

Brown trout, Salmo trutta	S,U	Sodium chloride	22.4	----	>607j	------	Camargo and Tarazona 1991
Plains killifish, Fundulus kansae	S,M	Sodium chloride	22	15	9706g	14897.1	Clemens and Jones 1954
Mosquitofish, Gambusia affinis	S,M	Sodium chloride	22	15	6472g	9933.4	Clemens and Jones 1954
Mosquitofish, Gambusia affinis	S,U	Sodium chloride	----	14.9	9099	------	Al-Daham and Bhatti 1977
Guppy, Poecilia reticulata	R,M	Sodium chloride	290	71	>11700	>11860	Environ 2009
Threespine stickleback, Gasterosteus aculeatus	R,M	Sodium chloride	84.8	81.4	10200b	13452.6	Garibay and Hall 2004
Green sunfish, Lepomis cyanellus	S,M	Sodium chloride	22	15	6499g	9974.9	Clemens and Jones 1954
Bluegill, Lepomis macrochirus	F,M	Sodium chloride	84.8	81.4	5840	7702.3	Birge et al. 1985
Bluegill (3.7 g), Lepomis macrochirus	S,U	Sodium chloride	44.3	15.5	7853	10461.6	Academy of Natural Sciences 1960; Patrick et al. 1968; Trama 1954
Bullfrog (tadpole), Rana catesbeiana	R,M	Sodium chloride	300	73	5846	5897	Environ 2009
Chorus frog, Pseudacris sp.	R,M	Sodium chloride	84.8	81.4	3553	4686.0	Garibay and Hall 2004

a = not fed. (All tests not marked “a” or “b” were unfed tests.)
b = fed.
c = mean of at least 15 LC50s.
d = range of several toxicity tests.
e = mean of 32 tests.
f = not used because there is reason to suspect that the daphnids might have been unhealthy.
g = tables 4, 7, and 9, except for tests at 28C in table 4.
h = tables 8 and 11; Daphnia pulex tests were not used because test duration was 96 hr.
i = test duration was 64 hr.
j = no deaths in 196 hr.
k = selenium deficient.
m = selenium sufficient.
p = not used in calculation of GMAV because the species is unknown and so it is not known how to combine this acute value with the acute values for which the species are known.
q = calculated using the formula for reconstituted water and the reported average measured hardness.
r = concentrations were measured in stock solutions.
s = not acclimated to the dilution water.
t = might not have been acclimated to the dilution water.
v = based on analyses of samples of Lake Superior water taken in the spring and fall of 2008.

Supplementary information concerning the results of toxicity tests on chloride

1. The atomic weights used are those given on the website of the National Institute of Standards and Technology:
   Calcium = 40.078
   Carbon = 12.011
   Chlorine = 35.453
   Hydrogen = 1.008
   Iron = 55.845
   Magnesium = 24.305
   Nitrogen = 14.007
   Oxygen = 15.999
   Potassium = 39.098
   Sodium = 22.990
   Sulfur = 32.065

2. The molecular weights used are:
   $CaCl_2$ = 110.984 (63.89 % chloride) (36.11 % calcium) (Cl/Ca = 1.769)
   $CaCl_2 \cdot 2H_2O$ = 147.014 (27.26 % calcium) (48.23 % chloride)
   $CaCO_3$ = 100.086 (40.04 % calcium)
   CaO = 56.077 (71.47 % calcium)
   $Ca(NO_3)_2$ = 164.086 (24.42 % calcium)
   $Ca(NO_3)_2 \cdot 4H_2O$ = 236.146 (16.97 % calcium)
   $CaSO_4$ = 136.139 (70.56 % sulfate)
   $CaSO_4 \cdot 2H_2O$ = 172.169 (55.79 % sulfate) (23.28 % calcium) (20.93 % water)
   $FeCl_3 \cdot 6H_2O$ = 270.294 (39.35 % chloride)
   H_2O = 18.015
   KCl = 74.551 (47.56 % chloride) (52.44 % potassium) (Cl/K = 0.9068)
   K_2SO_4 = 174.257 (55.13 % sulfate)
   $MgCl_2$ = 95.211 (74.47 % chloride) (25.53 % magnesium) (Cl/Mg = 2.917)
   $MgSO_4$ = 120.366 (79.81 % sulfate) (20.19 % magnesium)
   $MgSO_4 \cdot 7H_20$ = 246.471 (38.97 % sulfate) (9.86 % magnesium)
   NaCl = 58.443 (60.66 % chloride) (39.34 % sodium) (Cl/Na = 1.542)
   Na_2SO_4 = 142.041 (67.63 % sulfate)

$Na_2SO_4 \cdot 10H_2O$ = 322.191 (29.81 % sulfate)
SO_4 = 96.061

3. Hardness (as $CaCO_3$) = (100.086/40.078)(Ca) + (100.086/24.305)(Mg) = 2.497(Ca) + 4.118(Mg)

4. Trama (1954), Cairns and Scheier (1959), Academy of Natural Sciences (1960), and Patrick et al. (1968) all reported results of toxicity tests that were performed at the Academy of Natural Sciences of Philadelphia with the bluegill in dilution waters that were very similar:

	mg/L
KCl	20
Na_2SiO_3	20
$NaHCO_3$	40
$MgSO_4 \cdot 7H_2O$	40
$Ca(NO_3)_2$	30*
$CaCO_3$	10
K_2HPO_4	10 or 2
Fe^{+++} (as ferric citrate)	4 or 0.4

Ca = 11.3 mg/L
Mg = 3.9 mg/L
Hardness = 44.3 mg/L as $CaCO_3$
Chloride = 9.5 mg/L
Sulfate = 15.5 mg/L

*Long after the tests of concern were performed, this was reported to be 40 mg/L of $Ca(NO_3)_2 \cdot 4H_20$.

5. Freeman (1953), Freeman and Fowler (1953), Fairchild (1955), Dowden (1960), Dowden (1962), and Dowden and Bennett (1965) all contained information regarding toxicity tests performed at Louisiana State University in Baton Rouge, but several different dilution waters were used. Dowden and Bennett (1965) tried to clarify the most important dilution waters used, but the citations given for the waters on page 1310 need to be clarified. Reference 4 is the correct citation for "Standard Reference Water" (SRW), but the correct citation for "Reference Dilution Water" (RDW) is reference 6 (not reference 3) and reference 3 should be cited for "glass-wool filtered University Lake Water (ULW). ULW is considered an unacceptable dilution water because it is from "a small drainpipe-fed lake on the campus of Louisiana State University" (Dowden 1960). The compositions of SRW and RDW are:

SRW	mg/L
$MgSO_4 \cdot 7H_2O$	71.

K_2SO_4	6.5
$MnSO_4 \cdot 4H_2O$	0.2
$CaCl_2 \cdot 2H_2O$	18.6
$NaHCO_3$	25.
NH_4NO_3	3.
$K_2HPO_4 \cdot 3H_2O$	1.1
CaO	32.2
$Na_2SiO_3 \cdot 9H_2O$	62.6
$FeCl_3 \cdot 6H_2O$	1.2

Ca = 23.0 mg/L
Mg = 7.0 mg/L
Hardness = 86.2 mg/L as $CaCO_3$
Chloride = 9.4 mg/L
Sulfate = 31.2 mg/L

RDW	mg/L
$CaCl_2$	110
$NaHCO_3$	110
NaCl	100
$MgSO_4 \cdot 7H_2O$	60
KCl	20

Ca = 39.7 mg/L
Mg = 5.9 mg/L
Hardness = 123.4 mg/L as $CaCO_3$
Chloride = 140.4 mg/L
Sulfate = 23.4 mg/L

6. When known, the concentration of chloride in dilution water was negligible in tests on chloride.

7. Karraker (2007) says that “road salt” contains sodium chloride, sodium ferrocyanide, heavy metals, and often sand or cinder. Results of toxicity tests on “road salt” were not used.

8. Hyalella azteca appears to be especially sensitive to some pollutants when the concentration of chloride is low, e.g., lower than 25 mg/L. This should not affect the sensitivity of this species to chloride.

9. Mount et al. (1997) reported that the toxicities of sodium and calcium salts to C. dubia, D. magna, and the fathead minnow are primarily attributable to the corresponding anion.

10. Some data presented in Table 1 of USEPA (1988) have been changed:
    a. Several values differ because of roundoff differences.
    b. USEPA (1988) used results of short acute tests for the reasons given on pages 2 and 3 (see also Lowell et al. 1995), but results of short tests are not used here because short acute tests sometimes give higher LC50s than standard tests.
    c. Data from Dowden (1961, which should be 1960) and Kostecki and Jones (1983) are not used here because of the dilution water used in the tests.
    d. The test results from Trama (1954) are also given in Academy of Natural Sciences (1960) and Patrick et al. (1968).
    e. Hamilton et al. (1975) did not adequately acclimate the midges.
    f. Fed acute tests were not used in USEPA (1988), but fed acute tests are used here and are given preference over unfed acute tests when the test organisms are cladocerans.

Calculation of Aquatic Life Criteria for Chloride

These calculations are based on "Summary of Data Concerning the Acute Toxicity of Sodium Chloride to Aquatic Animals" dated 2-10-09 and "Summary of Data Concerning the Chronic Toxicity of Sodium Chloride to Aquatic Animals" dated 1-15-09. Except as noted (for example, see footnote a), these calculations are consistent with the 1985 Guidelines. GMAVs and SMAVs are normalized to hardness = 300 mg/L and sulfate = 65 mg/L. GMAVs and SMAVs are expressed as mg chloride/L.

Rank*	GMAV	Genus	Species	SMAV	SMACR
	-----	Agria	Damselfly, Agria sp.	-----	
29	17161	Anquilla	American eel, Anquilla rostrata	17160.6	
	16203	Cambarus	Crayfish, Cambarus sp.	16203.2	
	14897	Fundulus	Plains killifish, Fundulus kansae	14897.1	
	14843	Libellulidae**	Dragonfly, Libellulidae	14843.4	
	13453	Gasterosteus	Threespine stickleback, Gasterosteus aculeatus	13452.6	
	>11860	Poecilia	Guppy, Poecilia reticulata	>11860	

-----	Carassius	Goldfish, Carassius auratus	-----	
9933	Gambusia	Mosquitofish, Gambusia affinis	9933.4	
9157	Lepomis	Green sunfish, Lepomis cyanellus	9974.9	
		Bluegill, Lepomis macrochirus	8406.5e	
8971	Notropis	Red shiner, Notropis lutrensis	8971.1	
8043	Oncorhynchus	Rainbow trout, Oncorhynchus mykiss	8042.6	7.308
7442	Ameiurus	Black bullhead, Ameiurus melas	7442.4	
-----	Erpobdella	Leech, Erpobdella punctata	----	
6515	Pimephales	Fathead minnow, Pimephales promelas	6515.3f	15.17h
6219	Tubifex	Tubificid worm, Tubifex tubifex	6218.6	
6111	Cyprinella	Bannerfin shiner, Cyprinella leedsi	6111	

6072	Chironomus	Midge, Chironomus attenuatus	-----
		Midge, Chironomus dilutus	6072
5897	Rana	Bullfrog (tadpole), Rana catesbeiana	5897
5444	Lumbriculus	Aquatic worm, Lumbriculus variegatus	5444
5078	Hyalella	Amphipod, Hyalella azteca	5077.7
-----	Asellus	Isopod, Asellus communis	-----
-----	Limnodrilus	Tubificid worm, Limnodrilus hoffmeisteri	-----
-----	Helisoma	Snail, Helisoma campanulata	-----
4686	Pseudacris	Chorus frog, Pseudacris sp.	4686.0
-----	Gammarus	Amphipod, Gammarus pseudolimnaeus	-----
-----	Crangonyx	Amphipod, Crangonyx sp.	-----

-----	Nemoura	Stonefly, Nemoura trispinosa	-----
-----	Lepidostoma	Caddisfly, Lepidostoma sp.	-----
-----	Parapsyche	Caddisfly, Parapsyche sp.	-----
4369	Nephelopsis	Leech, Nephelopsis obscura	4369
3946	Diaptomus	Copepod, Diaptomus clavipes	3946.1
3891	Lirceus	Isopod, Lirceus fontinalis	3890.7
3728	Gyraulus	Snail, Gyraulus circumstriatus	-----
		Snail, Gyraulus parvus	3727.7
3350	Physa	Snail, Physa gyrina	3350.0
		Snail, Physa heterostropha	-----
3086	Villosa	Mussel, Villosa delumbis	3821.1

			Mussel, Villosa iris	2491.6	
4	2835	Lampsilis	Mussel, Lampsilis fasciola	2907.1	
			Mussel, Lampsilis siliquoidea	2764.4	
3	2326	Daphnia	Cladoceran, Daphnia ambigua	1649.7	4.148
			Cladoceran, Daphnia magna	3773.1d	1.974
			Cladoceran, Daphnia pulex	2020.5g	3.952
2	1542	Ceriodaphnia	Cladoceran, Ceriodaphnia dubia	1542.3c	>2.470i
1	1128	Sphaerium	Fingernail clam, Sphaerium simile	1127.9	
			Fingernail clam, Sphaerium tenue	-----	

* A “greater than” acute value for the brown trout (Salmo trutta) is not in this table because it is too low to be a useful “greater than” value.
** Name of family, not name of genus.

a. Section IV.I of the 1985 Guidelines says: “For each species for which at least one acute value is available, the Species Mean Acute Value should be calculated as the geometric mean of the results of all flow-through tests in which the concentrations of test material were measured. For a species for which no such result is available, the SMAV should be calculated as the geometric mean of all available acute values, i.e., results of flow-through tests in which the concentrations were not measured and results of static and renewal tests based on initial concentrations (nominal concentrations are acceptable for most test materials if measured concentrations are not available) of test material." The guidance presented in section IV.I of the 1985 Guidelines seems inappropriate for chloride because chloride is different from most pollutants for which aquatic life criteria are derived. Chloride is very soluble in water, does not oxidize or reduce, is not volatile, does not degrade, does not sorb to test chambers, test organisms, food, or waste products, is not complexed by materials that commonly occur in water, is not involved in a pH-dependent equilibrium in water, and does not precipitate in waters in which aquatic organisms commonly occur.

i. For chloride, as long as the concentration of dissolved oxygen is sufficiently high, it seems appropriate to give static and renewal acute tests the same weight as flow-through acute tests in the derivation of the SMAV for a species.

ii. For chloride, it seems inappropriate to give measured acute tests a weight of 1 and unmeasured acute tests a weight of 0 when both are available for the derivation of the SMAV for a species. For example, if there is a choice between one measured acute test on chloride and three unmeasured acute tests in three different laboratories, the three tests are probably preferable to the one test, but if the choice is between one measured acute test and two unmeasured acute tests in two different laboratories, the one test is probably preferable. Thus, for a species for which both measured and unmeasured acute tests are available for chloride, it seems appropriate to give measured acute tests a weight of 2.5 and unmeasured acute tests a weight of 1 when the SMAV is calculated.

The conclusions described above concerning chloride were developed during discussions among Charles Delos, Charles Stephan, and Glen Thursby. For other pollutants, different conclusions concerning the relative merits of static, renewal, and flow-through acute toxicity tests and the relative merits of measured and unmeasured acute toxicity tests are likely to be more appropriate.

b. For Ceriodaphnia dubia, the acute values from Hoke et al. (1992) are considered outliers. The geometric mean is 1468.1 for Mount et al. (1997), 1790.2 for U.S. EPA (1991), 1998.2 for WISLOH (2007), and 1457.3 for GLEC and INHS (2008).
SMAV = antilog ([log 1468.1 + log 1790.2 + log 1998.2 + log 1863.6 + 2.5(log 1311.1) + 2.5(log 1457.3)]/9) = 1542.3.

c. For Daphnia magna, the values of 3815.5 (Mount et al. 1997), <2785.1, (Anderson 1946), 2439.7 (Anderson 1948), and 3025.9 and 3357.4 (Biesinger and Christensen 1972) were not used. A geometric mean of 3906.7 was calculated from the limits given by Seymour et al. (1997). The geometric mean is 3208.8 for Hoke et al. (1992) and is 4054.2 for Davies and Hall (2007). The SMAV is 3773.1, which is the geometric mean of 3208.8, 5068.2, 3906.7, 2242.3, 4749.6, 3968.5, and 4054.2.

d. Bluegill: SMAV = antilog ([2.5(log 7702.3) + log 10461.6]/3.5) = 8406.5.

e. Fathead minnow: SMAV = antilog([log 2833.9 + 2.5(log 8665.1) + 2.5(log 8225.2) + log 5112.0 + log 5226.3]/8) = 6515.3.

f. Daphnia pulex: SMAV = antilog([2.5(log 1938.8) + log 2240.3]/3.5) = 2020.5.

g. Not used in calculations because, even though the acute and chronic tests were in the same document, different dilution waters were used in the tests.

h. The SMACR for Ceriodaphnia dubia is the geometric mean of 1.508, >3.841, and 2.601.

FAV = 1364 mg chloride/L

CMC = FAV/2 = 682.0 mg chloride/L

The five SMACRs (7.308, 4.148, 1.974, 3.952, and >2.438) that are available for use in calculations result in three GMACRs:

7.308	Oncorhynchus
3.187	Daphnia
>2.470	Ceriodaphnia

The 1985 Guidelines require ACRs for species in three different families, but Daphnia and Ceriodaphnia are in the same family. However, even though the ACR for the fathead minnow should not be used in calculations because the acute and chronic tests using the fathead minnow were performed in different dilution waters, the fathead minnow ACR can be considered a qualitative ACR and used to satisfy the MDRs because chloride is not likely to be complexed or sorbed or detoxified by organic or inorganic constituents of the dilution water.

The GMACRs for Oncorhynchus and Daphnia are consistent with the "greater than" GMACR for Ceriodaphnia and the GMACRs are within a factor of ten. Therefore, the Final ACR = 4.826, which is the geometric mean of the GMARCs for Oncorhynchus and Daphnia. This would give FCV = FAV/FACR = (1364 mg chloride/L)/4.826 = 282.6 mg chloride/L. However, this approach is contraindicated because the GMACRs (including the unused GMACR for Pimephales) indicate that the GMACR increases as the GMAV increases.

The GMACR for Daphnia is consistent with the "greater than" GMACR for Ceriodaphnia, so the GMACR for Daphnia can be used as the FACR. Therefore, FACR = 3.187 and FCV = FAV/FACR = (1364 mg chloride/L)/3.187 = 428.0 mg chloride/L.

CCC = FCV = 428.0 mg chloride/L.

The CMC and CCC given above are for hardness = 300 mg/L and sulfate = 65 mg/L. The equation that was used to normalize the acute values can be used to make the CMC and CCC dependent on hardness and sulfate. The resulting equations for the CMC and CCC are:

$$CMC = (682.0 \text{ mg chloride/L}) (\text{hardness}/300)^{0.205797} (\text{sulfate}/65)^{-0.07452}$$
$$= (287.8 \text{ mg chloride/L}) (\text{hardness})^{0.205797} (\text{sulfate})^{-0.07452}$$

At hardness = 300 mg/L and sulfate = 65 mg/L, CMC = 682.0 mg chloride/L.

$$CCC = (428.0 \text{ mg chloride/L}) (\text{hardness}/300)^{0.205797} (\text{sulfate}/65)^{-0.07452}$$
$$= (180.6 \text{ mg chloride/L}) (\text{hardness})^{0.205797} (\text{sulfate})^{-0.07452}$$

At hardness = 300 mg/L and sulfate = 65 mg/L, CCC = 428.0 mg chloride/L.

Derivation of an Alternative FCV

Even though the above derivation of FCV = 378.1 mg chloride /L follows the procedure described in the 1985 Guidelines, there is an alternative approach that is justified on the basis of the "good science" clause in section XII.B of the 1985 Guidelines. This approach is based on the fact that the four low SMACRs for chloride were obtained with invertebrates, whereas the high SMACR was obtained with a vertebrate. This can be interpreted to mean that vertebrates have a higher ACR, on the average, than invertebrates, especially because the qualitative ACR for the fathead minnow is 15.17. Therefore, a vertebrate ACR and an invertebrate ACR can be used with the GMAVs to calculate a predicted Genus Mean Chronic Value for each genus, and then a FCV can be calculated directly from the predicted GMCVs. This approach calculates and uses a predicted chronic value for each genus for which an acute value is available and probably does a better job of taking into account the chronic sensitivities of both vertebrates and invertebrates to chloride. The relevant data and calculations are presented on the next few pages.

The FACR of 3.187 derived above was derived from all of the acceptable ACRs for invertebrates. The only acceptable ACR for a vertebrate is 7.308. A predicted GMCV can be calculated from each GMAV by using 3.187 as the invertebrate ACR and using 7.308 as the vertebrate ACR.

Table of predicted GMCVs for Chloride

(GMAVs and pGMCVs are expressed as mg chloride/L)
(ranked according to predicted GMCVs)

Rank	GMAV	Genus	Species	pGMCV
	-----	Agria	Damselfly, Agria sp.	-----
29	16203	Cambarus	Crayfish, Cambarus sp.	5084
	14843	Libellulidae*	Dragonfly, Libellulidae	4657

17161	Anquilla	American eel, Anquilla rostrata	2348
14897	Fundulus	Plains killifish, Fundulus kansae	2038
6219	Tubifex	Tubificid worm, Tubifex tubifex	1951
6072	Chironomus	Midge, Chironomus attenuatus	1905
		Midge, Chironomus dilutus	
-----	Erpobdella	Leech, Erpobdella punctata	-----
13453	Gasterosteus	Threespine stickleback, Gasterosteus aculeatus	1841
-----	Carassius	Goldfish, Carassius auratus	-----
5444	Lumbriculus	Aquatic worm, Lumbriculus variegatus	1708
>11860	Poecilia	Guppy, Poecilia reticulata	>1663
5078	Hyalella	Amphipod, Hyalella azteca	1593

----	Asellus	Isopod, Asellus communis	-----
-----	Limnodrilus	Tubificid worm, Limnodrilus hoffmeisteri	-----
-----	Helisoma	Snail, Helisoma campanulata	-----
4369	Nephelopsis	Leech, Nephelopsis obscura	1371
9933	Gambusia	Mosquitofish, Gambusia affinis	1359
-----	Gammarus	Amphipod, Gammarus pseudolimnaeus	-----
-----	Crangonyx	Amphipod, Crangonyx sp.	-----
-----	Nemoura	Stonefly, Nemoura trispinosa	-----
-----	Lepidostoma	Caddisfly, Lepidostoma sp.	-----
-----	Parapsyche	Caddisfly, Parapsyche sp.	-----
9157	Lepomis	Green sunfish, Lepomis cyanellus	1253

		Bluegill, Lepomis macrochirus	
3946	Diaptomus	Copepod, Diaptomus clavipes	1238
8971	Notropis	Red shiner, Notropis lutrensis	1228
3891	Lirceus	Isopod, Lirceus fontinalis	1221
3728	Gyraulus	Snail, Gyraulus circumstriatus	1170
		Snail, Guraulus parvus	
8043	Oncorhynchus	Rainbow trout, Oncorhynchus mykiss	1101
3350	Physa	Snail, Physa heterostropha	1051
		Snail, Physa gyrina	
7442	Ameiurus	Black bullhead, Ameiurus melas	1018
3086	Villosa	Mussel, Villosa delumbis	968.3

			Mussel, Villosa iris	
	6515	Pimephales	Fathead minnow, Pimephales promelas	891.5
	2835	Lampsilis	Mussel, Lampsilis fasciola	889.6
			Mussel, Lampsilis siliquoidea	
	6111	Cyprinella	Bannerfin shiner, Cyprinella leedsi	836.2
	5897	Rana	Bullfrog (tadpole), Rana catesbeiana	806.9
4	2326	Daphnia	Cladoceran, Daphnia ambigua	729.8
			Cladoceran, Daphnia magna	
			Cladoceran, Daphnia pulex	
3	4686	Pseudacris	Chorus frog, Pseudacris sp.	641.2
2	1542	Ceriodaphnia	Cladoceran, Ceriodaphnia dubia	483.8

1	1128	Sphaerium	Fingernail clam, Sphaerium simile Fingernail clam, Sphaerium tenue	353.9

* Name of family, not name of genus.

FCV based on predicted GMCVs = 421.5 mg chloride/L at hardness = 300 mg/L and sulfate = 65 mg/L.

$$\text{CCC} = (421.5 \text{ mg chloride/L}) (\text{hardness}/300)^{0.205797} (\text{sulfate}/65)^{-0.07452}$$
$$= (177.87 \text{ mg chloride/L}) (\text{hardness})^{0.205797} (\text{sulfate})^{-0.07452}$$

At hardness = 300 mg/L and sulfate = 65 mg/L, CCC = 421.5 mg chloride/L.