APPENDIX E

An Approach for Evaluating Numeric Water Quality Criteria for Wetlands Protection

WATER QUALITY STANDARDS HANDBOOK

SECOND EDITION

AN APPROACH FOR EVALUATING NUMERIC WATER QUALITY CRITERIA FOR WETLANDS PROTECTION

by

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ABSTRACT

Extension of the national numeric aquatic life criteria to wetlands has been recommended as part of a program to develop standards and criteria for wetlands. This report provides an overview of the need for standards and criteria for wetlands and a description of the numeric aquatic life criteria. The numeric aquatic life criteria are designed to be protective of aquatic life and their uses for surface waters, and are probably applicable to most wetland types. This report provides a possible approach, based on the site-specific guidelines, for detecting wetland types that might not be protected by direct application of national numeric criteria. The evaluation can be simple and inexpensive for those wetland types for which sufficient water chemistry and species assemblage data are available, but will be less useful for wetland types for which these data are not readily available. The site-specific approach is described and recommended for wetlands for which modifications to the numeric criteria are considered necessary. The results of this type of evaluation, combined with information on local or regional environmental threats, can be used to prioritize wetland types (and individual criteria) for further site-specific evaluations and/or additional data collection. Close coordination among regulatory agencies, wetland scientists, and criteria experts will be required.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
WATER

MEMORANDUM

SUBJECT: Numeric Water Quality Criteria for Wetlands

FROM: William R. Diamond, Director
Standards and Applied Science Division
Office of Science and Technology

TO: Water Management Division Directors (Regions I-X)
Environmental Services Division Directors (Regions I-X)

State Water Pollution Control Agency Directors

The purpose of this memorandum is to provide you with a copy of a report entitled "An Approach for Evaluation of Numeric Water Quality Criteria for Wetlands Protection", prepared by EPA's Environmental Research Laboratory in Duluth, Minnesota. This report was requested in the early stages of planning for wetland water quality standards to assess the applicability of EPA's existing numeric aquatic life criteria methodology for wetlands. This report was prepared by the Wetlands Research Program and is part of the Agency's activities to assist States with developing water quality standards for wetlands.

The report evaluates EPA's numeric aquatic life criteria to determine how they can be applied to wetlands. Numeric aquatic life criteria are designed to be protective of aquatic life for a wide range of surface water types. The report suggests that most numeric aquatic life criteria are applicable to most wetland types.

However, there are some wetland types where EPA's criteria are not appropriate. This report presents an approach that States may use as a screening tool to detect those wetland types that may be under- or overprotected by EPA's criteria. The proposed approach relies on data readily available from EPA's 304(a) criteria documents, as well as species assemblages and water quality data from individual wetland types. The results of this type of simple evaluation can be used to prioritize wetland types where further evaluation may be needed prior to setting criteria. Two example analyses of the approach are included in the report. EPA's site-specific criteria development guidelines can then be used to modify criteria if appropriate.

This report compiles existing information from EPA's 304(a) criteria guidance documents and site-specific criteria methodologies and does not contain new guidance or policy. The report has been peer reviewed by ERL/Duluth scientists who develop EPA's 304 criteria. The report also has been reviewed by the Standards and Applied Science Division and the Wetlands Division.

If you have additional questions on the information contained in this report or its applications, contact the following persons: David Sabock, Water Quality Standards Branch, at 202-475-7315 regarding designated uses and water quality standards policies; Bob April, Ecological Risk Assessment Branch, at 202-475-7315, regarding EPA's aquatic life criteria; or Bill Sanville, Environmental Research Laboratory/Duluth, at 218-720-5500, regarding the research for this report.

Attachment

cc: Water Quality Branch Chiefs (Regions I-X)
Water Quality Standards Coordinators (Regions I-X)
Wetlands Coordinators (Regions I-X)
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ACKNOWLEDGEMENTS

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SECTION 1

INTRODUCTION

NEED FOR STANDARDS FOR WETLANDS

Wetlands have been studied and appreciated for a relatively short time in relation to other types of aquatic systems. The extent of their value in the landscape has only recently been recognized; in fact, a few decades ago government policies encouraged wetland drainage and conversion. Wetlands traditionally have been recognized as important fish and wildlife habitats, and it is estimated that over one-third of U.S. endangered species require wetland habitat for their continued existence. Some of their many other values, however, have become apparent only recently. These include attenuation of flood flows, groundwater recharge, shoreline and stream bank stabilization, filtering of pollutants from point and nonpoint sources, unique habitats for both flora and fauna, and recreational and educational opportunities.[1]

Impacts to Wetlands

Despite new appreciation of the valuable functions that wetlands perform in the landscape, they continue to be destroyed and altered at a rapid pace. Since pre-settlement times over half of the wetlands in the continental U.S. have been destroyed, and losses over the last few decades have remained high.[2] These figures only represent actual loss of acreage and do not account for alterations to or contamination of still-extant wetlands. The causes of wetland destruction and degradation include:[3]

* Urbanization - Resulting in drainage and filling, contamination, and ecological isolation of wetlands.

* Agriculture Conversion - Drainage, cropping, and grazing which change or destroy wetland structure and ecological function.

* Water Resource Development - Water flow alterations to wetlands from diking, irrigation diversions, alterations to rivers for navigation, diversions for

water supply, and groundwater pumping. These result in changes in the hydrology that sustains the wetland system.

* Chemical Pollution - From point and nonpoint sources, hazardous waste sites, mining, and other activities. These can overwhelm the assimilative capacity of wetlands or be toxic to wetland organisms.

* Biological Disturbances - Introduction or elimination of plant and animal species that affect ecosystem processes.

Gaps in Federal Regulatory Programs

Existing Federal regulatory programs intended to reduce some of the impacts described above leave major gaps in the protection of wetlands. Section 404 of the Clean Water Act (CWA) requires a permit to be obtained from the Army Corps of Engineers, in cooperation with the U.S. Environmental Protection Agency (EPA), before dredged material or fill can be discharged into waters of the United States. Alterations such as drainage, water diversion, and chemical contamination are not covered by Section 404 unless material will be discharged into the wetland in association with such alterations. The Resource Conservation and Recovery Act, which regulates the disposal of hazardous wastes, and the CWA, which regulates contamination from waste-water discharges and nonpoint-source pollution, could provide protection from certain impacts, but they have not been used consistently to regulate impacts to wetlands. Programs designed to protect endangered species, migratory birds, and marine mammals have also been used to reduce impacts to wetlands, but "the application of these programs also has been uneven."[4]

Gaps in State Regulatory Programs

Wetland regulations vary greatly among States. Some States are now developing narrative standards for wetlands (e.g. Wisconsin, Rhode Island, and others). On the other hand, although wetlands are included in the Federal definition of "waters of the United States" and are protected by Section 101(a) of the CWA, not all States include them as "waters of the State" in their definitions. A review conducted in 1989 by the EPA Office of Wetlands Protection and the Office of Water Regulations and Standards found that only 27 of 50 States mentioned wetlands in definitions of State waters. The review verified that there generally is a lack of consideration given to water quality standards for wetlands.[5]

Effective Use of Existing Regulatory Options

Although some impacts (e.g. excavation, most drainage, and destruction of vegetation) are not addressed by the current implementation of existing regulations and programs, much of the chemical contamination of wetlands could be controlled through existing Federal and State water pollution control laws.[4] The National Wetlands Policy Forum recommended that EPA and State water pollution control agencies review the implementation of their water quality programs to ensure that the chemical integrity of wetlands is adequately protected. The Forum stressed the need to develop water quality standards designed to protect sensitive wetlands.[5]

Under Section 401 of the CWA, States have authority to authorize, condition, or deny all Federal permits or licenses in order to comply with State water quality standards, including, but not limited to, Sections 402 and 404 of the CWA, Sections 9 and 10 of the Rivers and Harbors Act, and Federal Energy Regulatory Commission licenses. States with water quality standards that apply to or are specifically designed for wetlands can use 401 certification much more effectively as a regulatory tool.

As wetlands receive more recognition as important components of State water resources, the need for testing the applicability of some existing guidelines and standards to wetlands regulation becomes more apparent.

PROPOSED APPROACH TO DEVELOPMENT OF WETLAND STANDARDS

The EPA Office of Water Regulations and Standards and Office of Wetlands Protection recently completed a document entitled, "National Guidance: Water Quality Standards for Wetlands."[6] It recommends a two-phased approach for the development of water quality standards for wetlands. In the first 3-year phase of this program, standards for wetlands would be developed using existing information in order to provide protection to wetlands consistent with the protection afforded other State waters. Technical support for this initial phase will be provided through documents such as this one, which focuses on the application of existing numeric criteria to wetlands. These criteria are widely used. Applying them to wetlands requires a small amount of effort and can be accomplished quickly.

The development of narrative biocriteria is also required in the initial phase of standards development. The long-term goal (3-10 years) of this program is to develop numeric biocriteria for wetlands. It is anticipated that both narrative and numeric biocriteria can provide a more integrative estimate of whole-wetland health and better identification of impacts and trends than can be attained by traditional numeric chemical criteria. Field-based, community-level biosurveys can be implemented to complement, and help validate, laboratory-based conclusions. Results of such surveys can be used to monitor wetlands for degradation and establish narrative or numeric biocriteria or guidance which take into account "real world" biological interactions and the interactions of multiple stressors.

More information on the development of numeric biocriteria will be available in a guidance document in coming years. Technical guidance to support the development of biological criteria for wetlands has also been prepared.[7] This guidance provides a synthesis of technical information on field studies of inland wetland biological communities.

PURPOSE OF THIS DOCUMENT

A number of steps are needed to develop wetland standards. The document, "National Guidance: Water Quality Standards for Wetlands," mentioned above, provides general guidelines to the States for each of the following steps: the inclusion of wetlands in definitions of State waters, the relationship between wetland standards and other water-related programs, use classification systems for wetlands, the definition of wetland functions and values, the applicability of existing narrative and numeric water quality criteria to wetlands, and the application of antidegradation policies to wetlands.

The technical document for biological criteria[7] and this report are companions to the guidance document described above. This report is directed primarily toward wetland scientists unfamiliar with water quality regulation and is intended to provide a basis for dialogue between wetland scientists and criteria experts regarding adapting numeric aquatic life criteria to wetlands. More specifically:

1) It provides background information and an overview of water quality standards and numeric chemical criteria, including application to wetlands.

2) The need for evaluating numeric water quality criteria is discussed. The site-specific guidelines are introduced and discussed in two contexts: a) as an initial screening tool to ensure that water quality in extreme wetland types is adequately protected by criteria, and b) in terms of using the site-specific guidelines to modify criteria for wetlands where criteria might be over or underprotective.

3) An approach is described that uses information available from criteria documents and is designed to: a) detect wetland types where water quality is not clearly protected by existing criteria, and b) help prioritize further evaluations and research efforts.

4) A simple test of the approach is presented with two examples. Results are not considered conclusive and are presented only as an example of the procedure.

Most of the data and examples are based on the freshwater acute criteria. A similar approach should be equally applicable to the saltwater acute criteria and to both saltwater and freshwater chronic criteria.

SECTION 2

CURRENT SURFACE WATER STANDARDS AND CRITERIA

This section describes how criteria are used in State standards, how national numeric criteria are derived, and what options are currently available for modifying national aquatic life criteria.

DESCRIPTION OF STANDARDS AND CRITERIA

Surface waters are protected by Section 101(a) of the CWA with the goal: "to restore and maintain the chemical, physical, and biological integrity of the nation's waters." State water quality standards are developed to meet this goal.

State Standards

There are two main components to establishing a standard: 1) The level of water quality attainable for a particular waterbody, or the designated use of that waterbody (e.g. recreational, fishery, etc.) is determined; 2) Water quality criteria (usually a combination of narrative and numeric) are established to protect that designated use. Water quality standards also contain an antidegradation policy "to maintain and protect existing uses and water quality, to provide protection for higher quality waters, and to provide protection for outstanding national resource waters."[8] State standards for a particular waterbody must be met when discharging wastewaters. The "National Guidance: Water Quality Standards for Wetlands"[6] outlines a basic program to achieve these goals for wetlands.

Aquatic Criteria

Narrative Criteria--

Narrative criteria are statements, usually expressed in a "free from ..." format. For example, all States have a narrative statement in their water quality standards which requires that their waters not contain "toxic substances in toxic amounts." Narrative criteria are typically applied at the State level when combinations of pollutants must be controlled or when pollutants are present which are not listed in State water quality standards.[8] States must document the process by which they propose to implement these narrative criteria in their standards.

Numeric Criteria--

Pollutant-specific numeric criteria are used by the States when it is necessary to control individual pollutants in order to protect the designated use of a waterbody. Fate and transpor models commonly are used to translate these criteria into permit limits for individual dischargers. Some criteria apply State-wide and others are specific to particular designated uses or waterbodies.

National numeric criteria are developed by EPA based on best available scientific information. They serve as recommendations to assist States in developing their own criteria and to assist in interpreting narrative criteria.[9] These include human health and aquatic life pollutant-specific criteria and whole effluent toxicity criteria. Sediment criteria are now being developed. States can adopt national numeric criteria directly. Alternatively, site-specific criteria may be developed using EPA-specified guidelines, and State-specific criteria can be derived using procedures developed by the State.[8]

DEVELOPMENT OF NATIONAL AQUATIC LIFE NUMERIC CRITERIA

National aquatic life criteria are usually derived using single-species laboratory toxicity tests. Tests are repeated with a wide variety of aquatic organisms for each chemical. The criteria are designed to protect against unacceptable effects to aquatic organisms or their uses caused by exposures to high concentrations for short periods of time (acute effects), to lower concentrations for longer periods of time (chronic effects), and to combinations of both.[9] EPA criteria are composed of 1) magnitude (what concentration of a pollutant is allowable); 2) duration of exposure (the period of time over which the in-stream concentration is averaged for comparison with criteria concentrations); and 3) frequency (how often the criterion can be exceeded without unacceptably affecting the community).[10] Separate criteria are determined for fresh water and salt water. Field data are used when appropriate.

All acceptable data regarding toxicity to fish and invertebrates are evaluated for inclusion in the criteria. Data on toxicity to aquatic plants are evaluated to determine whether concentrations of the chemical that do not cause unacceptable effects to aquatic animals will cause unacceptable effects to plants. Bioaccumulation data are examined to determine if residues in the organisms might exceed FDA action levels or cause known effects on the wildlife that consume them. For a complete description of the procedures for deriving ambient criteria, consult the "National Guidelines" (1985).[9]

Numeric water quality criteria are designed to protect most of the species inhabiting a site.[9] A wide variety of taxa with a range of sensitivities are required for deriving criteria. Guidelines are followed to determine the availability of sufficient experimental data from enough appropriate taxa to derive a criterion. For example, to derive a freshwater Final Acute Value for a chemical, results of acute tests with at least one species of freshwater animal in at least eight different families are required. Acute and chronic values can be made to be a function of a water quality characteristic such as Ph, salinity, or hardness, when it is determined that these characteristics impact toxicity, and enough data exist to establish the relationship. Table 1 lists the chemicals for which freshwater aquatic life criteria have been developed and indicates which of those criteria are pH, hardness, or temperature dependent.

SITE-SPECIFIC GUIDELINES

An option for modifying national aquatic life water quality criteria to reflect local conditions is presented in the site-specific guidelines. States may develop site-specific criteria by modifying the national criteria for sites where 1) water quality characteristics, such as pH, hardness, temperature, etc., that might impact toxicity of the pollutants of concern differ from the laboratory water used in developing the criterion; or 2) the types of organisms at the site differ from, and may be more or less sensitive than, those used to calculate the criterion; or 3) both may be true. Site-specific criteria take local conditions into account to provide an appropriate level of protection. They can also be used to set seasonal criteria when there is high temporal variability.[8]

A testing program can be used to determine whether site-specific modifications to criteria are necessary. This program may include water quality sampling and analysis, a biological survey, and acute and chronic toxicity tests.[11] If site-specific modifications are deemed necessary, 3 separate procedures are available for using site-specific guidelines to modify criteria values, including the recalculation procedure, the indicator species procedure, and the resident species procedure. These will be discussed more fully in the next section.

SECTION 3

THE NEED FOR EVALUATING NUMERIC WATER QUALITY CRITERIA: USE OF THE SITE-SPECIFIC GUIDELINES

OVERALL RELEVANCE OF CRITERIA TO WETLANDS

The national aquatic life criteria have been developed to provide guidance to the States for the protection of aquatic life and their uses in a variety of surface waters. They are designed to be conservative and "... have been developed on the theory that effects which occur on a species in appropriate laboratory tests will generally occur on the same species in comparable field situations. All North American bodies of water and resident aquatic species and their uses are meant to be taken into account, except for a few that may be too atypical ..."[9] A wide variety of taxonomic groups sensitive to many materials are used in testing, including many taxa common to both wetlands and other surface waters. In order to ensure that criteria are appropriately protective, water used for testing is low in particulate matter and organic matter, because these substances can reduce availability and toxicity of some chemicals. For these reasons, the "National Guidance: Water Quality Standards for Wetlands" states that, in most cases, criteria should be protective of wetland biota.[6]

Although the water quality criteria are probably generally protective of wetlands and provide the best currently available tool for regulating contamination from specific pollutants, there are many different types of wetlands with widely variable conditions. There might be some wetland types where the resident biota or chemical and physical conditions are substantially different from what the criteria were designed to protect. These differences could result in underprotection or overprotection of the wetland resource. This section discusses the use of site-specific guidelines for wetland types for which certain criteria might be over or underprotective, but its primary focus is to provide a mechanism to identify wetland types that might be underprotected by certain criteria and that might require further research.

WETLAND VARIABILITY

Wetlands are usually located at the interface between terrestrial systems and truly aquatic systems, and so combine attributes of both.[12] They are intermediate between terrestrial and aquatic systems in the amount of water they store and process and are very sensitive to changes in hydrology.[12] Their chemical and physical properties, such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties, and pH are influenced greatly by hydrologic conditions. Attendees at a Wetlands Water Quality Workshop (held in Easton, Maryland in August, 1988) listed the most common ways in which wetlands differ from "typical" surface waters: higher concentrations of organic carbon and particulate matter, more variable and generally lower pH, more variable and generally lower dissolved oxygen, more variable temperatures, and more transient availability of water.[13]

There is also high variability among wetland types. Wetlands, by definition, share hydrophytic vegetation, hydric soils, and a water table at or near the surface at some time during the growing season. Beyond these shared features, however, there is tremendous hydrological, physical, chemical, and biological variability. For example, an early classification system for wetlands, "Circular 39", listed 20 distinctly different wetland types[14], and the present "Cowardin" system lists 56 classes of wetlands.[15] This variability makes it important to evaluate different wetland types individually.

USE OF THE SITE-SPECIFIC GUIDELINES FOR WETLANDS

The site-specific guidelines outlined in Section 2 are designed to address the chemical and biological variability described above. Determining the need for site-specific modifications to criteria requires a comparison of the aquatic biota and chemical conditions at the site to those used for establishing the criterion. This comparison is useful for identifying wetland types that might require additional evaluation. The three site-specific options are discussed in the context of their general relevance to wetlands and are used in this discussion to provide a framework for evaluating the protectiveness of criteria for wetlands.

In most cases, because of the conservative approach used in the derivation of the criteria, use of the site-specific guidelines to modify criteria results in no change or in their relaxation, provided that an adequate number of species are used in the calculations. However, criteria can also become more restrictive. Newly tested species could be especially sensitive to certain pollutants, or extreme water conditions found in some surface waters or wetland types might not reduce the toxicity of a chemical. Disease, parasites, predators, other pollutants, contaminated or insufficient food, and fluctuating and extreme conditions might all affect the ability of organisms to withstand toxic pollutants.[9]

<u>Appropriateness of Testing Organisms: Recalculation Procedure</u>

The first option given in the site-specific guidelines is the recalculation procedure.[8,11] This approach is designed to take into account differences between the sensitivity of resident species and those used to calculate a criterion for the material of concern. It involves eliminating data from the criterion database for species that are not resident at that site. It could require additional resident species testing in laboratory water if the number of species remaining for recalculating the criterion drops below the minimum data requirements. "Resident" species include those that seasonally or intermittently exist at a site.[11,16]

Use of the recalculation procedure will not necessarily result in a higher acute criterion value (less restrictive), even if sensitive species are eliminated from the dataset and minimum family requirements are met. The number of families used to calculate Final Acute Values is important. If a number of non-wetland species are dropped out of the calculation without adding a sufficient number of new species, a lower (more restrictive) Final Acute Value can result, because data are available for fewer species.[11]

Similarity of Required Taxa and Typical Wetland Species--

The variety of test species required to establish the national numeric criteria was chosen to represent a wide range of taxa having a wide range of habitat requirements and sensitivity to toxicants. Establishment of a freshwater Final Acute Value for a chemical requires a minimum of 8 different types of families to be tested. These include: 1) the family Salmonidae; 2) a second family of fish, preferably a warmwater species; 3) a third family in the phylum Chordata (fish, amphibian, etc.); 4) a planktonic crustacean; 5) a benthic crustacean; 6) an insect; 7) a family in a phylum other than Arthropoda or Chordata; and 8) a family in any order of insect or phylum not already represented.[9]

When a required type of family does not exist at a site, the guidelines for the recalculation procedure specify that substitutes from a sensitive family, resident in the site, should be added to meet the minimum family data requirement. Should it happen that all resident families have been tested and the minimum data requirements still have not been met, the acute toxicity value from the most sensitive resident family that has been tested should be used as the site-specific value.

Most of the required families are probably well-represented in most wetland types. Some types of wetlands, however, seldom or never contain fish, and most wetland types do not support salmonids or aquatic insects requiring flowing water.

General Evaluation of Species Suitability--

Table 2 presents six criterion chemicals chosen as examples and the eight taxonomic groups required to establish criteria. The chemicals include two organochlorines: polychlorinated biphenyls (PCBs - used in industrial applications, environmentally-persistent, bioaccumulate) and pentachlorophenol (widely used fungicide and bactericide); one organophosphate: parathion (insecticide); two metals: zinc and chromium(VI); and cyanide.

The species used for acute toxicity testing for each of the six chemicals have been broken down by taxonomic group and evaluated based on the likelihood that those species can be found in wetlands. Except for the unsuitability of the Salmonidae to most wetland types, most of the taxonomic groups are well-represented for the six chemicals used as examples. Wetland species were not present in the list of species used to calculate the Final Acute Value for the "non-arthropod/non-chordate" and "another insect or new phylum" groups for a few of the criteria. This is not because these groups are not represented in wetlands. These are very general classifications. For example, the "non-arthropod/non-chordate" group can include rotifers, annelids, and mollusks among other phyla, all of which should have many representatives in most types of wetlands. There is a large degree of variation in the total number of species tested for the six chemicals used as examples, ranging from 10 fish and invertebrates for polychlorinated biphenyls (PCBs) to 45 for zinc (Table 7). Criteria based on smaller numbers of species are less likely to include a sufficient number of wetland species to fulfill the minimum family requirements. Additional toxicity testing, using laboratory water and wetland species from the missing families, can be done to fill these gaps.

While the general taxonomic groups required for toxicity testing are fairly well represented in wetlands, the similarity between the genera and species inhabiting individual wetland types and those used for criteria testing varies widely among criteria and wetland types. Species chosen for toxicity testing were seldom or never chosen with wetlands in mind. In addition, relatively little is known about species assemblages in some types of wetlands (particularly in those lacking surface waters, such as wet meadows or bogs). Defining typical wetland taxa is difficult. For example, while most types of wetlands do not support salmonids, Coho salmon are highly dependent on wetlands in Alaska, where there is a higher percentage and acreage of wetlands than in any other State. Part of the utility of the evaluation proposed here is in identifying where significant gaps in data exist.

Influence of Cofactors: Indicator Species Procedure

The second of the three site-specific procedures, the indicator species procedure, accounts for differences in biological availability and/or toxicity of a material caused by physical and/or chemical characteristics of the site water, or cofactors. For the acute test, the effect of site water is compared to the effect of laboratory water, using at least two resident species or acceptable non-resident species (one fish and one invertebrate) as indicators. A ratio is determined, which is used to modify the Final Acute Value. See Carlson et al. (1984) for information and guidelines for determination of site-specific chronic values.[11]

Suitability of Standard Testing Conditions--

Standard aquatic toxicity tests are performed using natural or reconstituted dilution water that should not of itself affect the results of toxicity tests. For example, organic carbon and particulate matter are required to be low to avoid sorption or complexation of toxicants, which might lower the toxicity or availability of some criterion chemicals. Recommended acute test conditions for certain water quality characteristics of fresh and salt water are listed in Table 3. Wetlands, as well as some types of surface waters, can have values far outside the ranges used for standard testing for some of these characteristics (most notably total organic carbon, particulate matter, pH, and dissolved oxygen). Wetland types can be evaluated to identify these extremes.

Wetland Cofactors--

Many water quality characteristics can 1) act as cofactors to affect the toxicity of pollutants (e.g. alkalinity/acidity, hardness, ionic strength, organic matter, temperature, dissolved oxygen, suspended solids); 2) can be directly toxic to organisms (e.g. un-ionized ammonia, high or low pH, hydrogen sulfide, low dissolved oxygen); or 3) can interfere mechanically with feeding and reproduction (e.g. suspended solids). The criteria for some of these water quality characteristics can be naturally exceeded in many wetland types, as well as in some lakes and streams.

Hardness, pH, and temperature adjustments built into a few of the criteria account for effects from these cofactors in a few cases, but no other cofactors are now included in the criteria, despite some known effects. For example, alkalinity, salinity, and suspended solids, in addition to pH and hardness, are known to affect the toxicities of heavy metals and ammonia. These cofactors are not included in the criteria primarily because there are insufficient data.[9] For example, most toxicity tests have been performed under conditions of low or high salinity, so that estuaries, where salinity values can vary greatly, may require salinity-dependent site-specific criteria for some metals.[11] An initial evaluation of the adequacy of protection provided to a wetland type by a criterion should take possible cofactor effects into account.

Combination: Resident Species Procedure

The resident species procedure accounts for differences in both species sensitivity and water quality characteristics.[11] This procedure is costly, because it requires that a complete minimum dataset be developed using site water and resident species. It is designed to compensate concurrently for differences in the sensitivity range of species represented in the dataset used to derive the criterion and for site water differences which may markedly affect the biological availability and/or toxicity of the chemical.[11]

AQUATIC PLANTS

One of the most notable differences between wetlands and other types of surface waters is the dominance (and importance) of aquatic macrophytes and other hydrophytic vegetation in wetlands. Aquatic plants probably constitute the majority of the biomass in most wetland types.

Few data concerning toxicity to aquatic plants are currently required for deriving aquatic life criteria. Traditionally, procedures for aquatic toxicity tests on plants have not been as well developed as for animals. Although national numeric criteria development guidelines state that results of a test with a freshwater alga or vascular plant "should be available" for establishing a criterion, they do not require that information.[9] The Final Plant Value is the lowest (most sensitive) result from tests with important aquatic plant species (vascular plant or alga), in which the concentrations of test material were measured and the endpoint was biologically important. Plant values are compared to animal values to determine the relative sensitivities of aquatic plants and animals. If plants are "among the aquatic organisms that are most sensitive to the material," results of a second test with a plant from another phylum are included.[9]

Results of tests with plants usually indicate that criteria which protect aquatic animals and their uses also protect aquatic plants and their uses.[9] As criteria are evaluated for their suitability for wetlands, however, plant values should be examined carefully. Additional plant testing may be advisable in some cases. If site-specific adjustments are made to some criteria, they could result in less restrictive acute and chronic values for animals. Some plant values could then be as sensitive or more sensitive than the animal values. Chemicals with fairly sensitive plant values include: aluminum, arsenic(III), cadmium, chloride, chromium(VI), cyanide, and selenium(VI). For example, fish are generally much more sensitive to cyanide than invertebrates. If the recalculation procedure was used to develop a site-specific cyanide criterion for a wetland type containing no fish, values for these sensitive species would be replaced in the calculation, possibly by less sensitive species. A less restrictive criterion could result, possibly making the plant value more sensitive than the animal value. Therefore, additional consideration should be given to plant toxicity data for wetland systems.

SECTION 4

EVALUATION PROGRAM

The direct application of existing aquatic life criteria to wetlands is assumed to be reasonable in most cases. It provides a practical approach towards protecting the biological integrity of wetlands. The following evaluation program offers a possible strategy to identify extreme wetland types that might be underprotected by some criteria, to prioritize wetland types and criterion chemicals for further testing or research, and to identify gaps in available data. The approach can be helpful for identifying those instances where modifications to existing criteria might be advisable. The proposed evaluation program offers a screening tool to begin to answer the following questions: 1) Are there some wetland types for which certain criteria are underprotective? 2) For criteria in wetland types that cannot be applied directly, can site-specific guidelines be used to modify the criteria to protect the wetland? 3) Will additional toxicity testing under wetland conditions and with wetland species be necessary in some cases in order to establish site-specific criteria?

The proposed approach relates species and water quality characteristics of individual wetland types to species and water quality characteristics important in deriving each criterion. It involves identifying wetland types of concern, identifying cofactors possibly affecting toxicity for the criteria of interest, gathering data on the biota and water quality characteristics of the wetland type, and comparing to data used to derive the criterion.

CLASSIFICATION

The proposed program for the evaluation of the suitability of aquatic life criteria discussed in this section can be done separately for individual wetland types. These can be defined in the classification process, which is the first step in developing standards for wetlands. The classification process requires the identification of the various structural types of wetlands and identification of their functions and values.[6] The classification should provide groups of wetlands that are similar enough structurally and functionally so that they can reasonably be expected to respond in kind to inputs of toxic chemicals.

EVALUATING THE APPROPRIATENESS OF DIRECT APPLICATION OF CRITERIA

Information Needed

1. Identification of cofactors. Cofactors potentially affecting mobility and biological availability for each criterion chemical should be identified. Cofactors known to affect each criterion chemical are listed in individual national criteria documents and are summarized in Table 4. The absence of a relationship between a cofactor and a chemical on Table 4 does not ensure that no relationship exists, merely that none was discussed in the criteria document. The chemistry of the effects of the cofactors on the chemicals is often very complicated, and limited data are available regarding some of the relationships. The approach presented here is simplistic and is geared toward directing further efforts. Other sources of information, in addition to the criteria documents, should be consulted when actually applying this approach. Criteria that include hardness- or pH-dependent correction factors (Table 1) should apply directly to wetlands unless the wetland type has extremes of pH or hardness well outside the ranges used in toxicity testing. For example, the pH of acid bogs can be as low as 3.5, well below the 6.5 lower limit for toxicity testing (Table 3).

2. Comparison to wetland water chemistry. Natural levels and variability of those cofactors should be identified as well as possible for each major wetland type of interest. Wetlands-related information can be accumulated through consultation with wetland researchers, through literature searches, and from monitoring agencies.

3. Comparison of species lists. Species lists of fish, invertebrates, and plants should be compiled for each wetland type and compared to lists of species used for testing each criterion. Lists should be evaluated on two levels: a) Species level - Are the species used for toxicity testing representative (the same species or genera, or "similar" in terms of sensitivity to toxicants) of the species found in the wetland type? b) Family level - Does the wetland contain suitable representatives for each of the families listed in the minimum family requirements?[8,11] Consultation with fish and invertebrate specialists, plant ecologists, and wetlands expe -s will be necessary to do this comparison.

Adoption of Existing Water Quality Criterion

The existing water quality criterion should be suitable for that wetland type if the following are true:

1. Important cofactor levels are not naturally exceeded in the wetland to a degree that might seriously affect toxicity or availability of the chemical. Would toxicity likely be higher, lower, or not influenced by typical levels or extremes of a particular cofactor in a particular wetland type?

2. Sufficient species or genera used for aquatic toxicity testing are found in the wetland type so that the minimum family requirements can be met by resident wetland species. Consultation between wetland scientists and criteria experts will be necessary in many cases to make judgements on how well-represented some wetland types are.

3. The criterion itself is not naturally exceeded in the wetland.

DEVELOPING SITE-SPECIFIC CRITERIA

When one or more of these stipulations is not true or when insufficient data are available, more evaluation is advisable. Again, consultation between wetland scientists and criteria experts might be helpful in prioritizing those wetland types for which additional protection, or additional research, might be needed for some chemicals. Once a priority list for further evaluation is established, an approach to obtaining the additional required data can be determined. It might be possible to group wetlands by type, and possibly by designated use, and then develop site-specific criteria for all wetlands of that type in the State.

SECTION 5

EXAMPLE ANALYSES

Evaluations of the applicability of the six criteria listed in Table 2 will be made for two sets of wetland data, including shallow marshes and prairie potholes. The analyses in these examples were made with limited data for each wetland type and are preliminary. They have been compiled to be used only as illustrations of the usefulness of this approach.

EXAMPLE 1

The first example is based on a wetland study taking place in southcentral Minnesota. The wetlands are being studied to evaluate the effects of disturbance on water quality, as well as the effects of pesticides on wetland communities. Therefore chemical and biological data have been collected.[18]

Classification

The wetland study sites are primarily shallow marshes (freshwater palustrine, persistent emergent, semi-permanently or seasonally-flooded, according to Cowardin[15]), dominated by *Phalaris* (reed canary grass) and *Typha* (cattails), but also include a small number of wet meadow/seasonally-flooded wetlands, deep marsh, shrub/scrub + woody wetlands, and ponds.

Steps 1 and 2: Identification of Cofactors and Comparison to Wetland Water Chemistry

Cofactors are identified for criteria chemicals in Table 4. Some water quality characteristics averaged for 5 seasons for the Minnesota wetlands are summarized in Table 5.

Although some water chemistry conditions in the shallow marshes were within the ranges of the aquatic toxicity testing conditions, others were exceeded (Table 3). Wetland values for pH were well within the 6.5-9.0 range allowed for testing, so criteria having pH as a possible cofactor affecting toxicity and/or biological availability should not be underprotective because of pH effects. As Table 4 shows, PCP, chromium(VI), zinc, and cyanide can be more toxic at low pH values, so a very acidic wetland might require additional evaluation in regard to pH. The PCP criterion has an adjustment factor for pH, which indicates that enough suitable data are available to allow this relationship to be incorporated into the criterion.

Hardness values were not available for these marshes, but were probably fairly low since alkalinity was low. Table 4 lists hardness as a cofactor for zinc and chromium(VI). Table 1 reveals that the zinc criterion has an adjustment factor for hardness, so any effect of hardness on zinc toxicity and/or biological availability is already included in the criterion and does not have to be considered further. Chromium(VI) is more toxic at low alkalinity and hardness, but the criterion was derived using soft water and should be protective for the wetlands.

Total organic carbon (TOC) was highly variable in the wetlands and generally well above the 5 mg/L limit for toxicity testing. However parathion and zinc, the two criteria with TOC cofactor effects, have reduced toxicity and/or biological availability at high levels of organic matter (Table 4), so criteria should be protective.

Dissolved oxygen (DO) was highly variable in the wetlands and reached very low levels in late summer. The shallow waters of the marshes were extremely warm on hot summer days. Toxicity and/or biological availability is increased by low DO and high temperatures for PCBs, PCP, and cyanide. These relationships will require further evaluation.

Step 3: Comparisons of Species Lists

In Step 3, fish, invertebrates, and plants inhabiting the wetlands are compared to species used in testing each criterion. For these examples, only the acute toxicity lists have been consulted. A list of genera common to both the marshes and to the toxicity tests was compiled for each criterion. When identical species were not found, species from the same genus were compared to determine whether habitat requirements are suitable enough to include them as representative species for these wetlands. The shortened list of marsh species the same as, or similar to, species used for toxicity testing was examined to determine whether the minimum family requirements for acute toxicity tests could be met for each criterion. Table 6 contains a list of marsh genera that could be used to fulfill minimum family requirements for each criterion. Appendix A contains a list of the sources that have been consulted in making this comparison.

The aquatic species found in the Minnesota wetlands were fairly well-represented by the acute toxicity test species for the six chemicals used in this example. The percentages of total species tested that have not been found in these wetlands were below 50% for all six criteria (Table 7). Except for PCBs, for which no plant value is available, plant species tested overlapped with species occurring in the wetlands. The absence of salmonids in wetlands was the only consistent omission.

Of all the species tested, the salmonids are the most sensitive to PCP and cyanide and are much more sensitive than most invertebrate species. The inclusion of highly sensitive salmonid data in the criteria calculations probably ensures that these two criteria are adequately protective when applied to wetlands not containing this sensitive family (not considering cofactor effects). It would perhaps be more important to consider the effects of the absence of salmonids in Minnesota marshes for criteria where salmonids are among the least sensitive species, including parathion and chromium(VI). In this case, the presence of salmonid toxicity data in the criterion calculation, despite their absence from the wetlands, could possibly cause the criterion to be less restrictive than is appropriate for the wetland.

Salmonids do not occur in the wetlands included in this example. Three criteria were missing an additional required taxonomic group (from Table 6: PCBs, chromium(VI), and cyanide). There are certainly representatives of this taxonomic group (nonarthropod/nonchordate) inhabiting the wetlands, but the genera used for toxicity tests did not correspond to the wetland genera. These three criteria have the least species on the acute toxicity list, so there are less species to compare to, in relation to the other criteria (Table 7). Toxicity experts and wetland biologists might be able to fill some of these data gaps by reaching conclusions on the suitability of wetland species to fulfill the minimum family requirements.

EXAMPLE 2

This example is based on data for a number of oligosaline prairie pothole wetlands in southcentral North Dakota.[19,20] Oligosaline is defined as ranging from 0.5-5 g/kg salinity, or specific conductance of 800-8,000 μS/cm at 25°C.[15] The chemical types of the majority of wetlands used in this example include magnesium bicarbonate, magnesium sulfate, and sodium sulfate.[20]

Classification

Wetlands included in this example are semipermanent (cover type 4 of the classification system developed by Stewart and Kantrud for the glaciated prairie region)[21], containing wet meadow, shallow marsh, and deep marsh. Classification of these wetlands based on the Cowardin system can be found in Kantrud et al.[20]

Steps 1 and 2: Identification of Cofactors and Comparison to Wetland Water Chemistry

Cofactors are identified for criteria chemicals in Table 4. Water quality data for the prairie pothole wetlands are summarized in Table 8. A comparison of water chemistry conditions for the prairie potholes with standard toxicological testing conditions (Table 3) reveals a number of differences.

These wetlands are extremely alkaline and saline compared to water used for freshwater toxicity testing. Salinity (reported as specific conductance) can vary greatly over the year and is concentrated by the high rates of evaporation and transpiration that take place in the summer. A number of the wetlands have pH values above the 6.5-9.0 range that the criteria are designed to protect. No data were available for total organic carbon (TOC), but dissolved organic carbon values from other prairie pothole systems were generally well above the TOC limit of 5 mg/L used for toxicity testing.[22] As in Example 1, hardness can be eliminated from consideration as a cofactor, because toxicity and/or biological availability is decreased as hardness increases. Similarly, the probable high TOC levels would decrease toxicity and/or biological availability for zinc and chromium(VI). The high pH values should cause decreased toxicity and/or biological availability. Bioavailability of zinc is reduced in high ionic strength waters such as these.

Dissolved oxygen (DO) levels drop in the winter and in middle to late summer, allowing anoxic conditions to develop. Although no aquatic temperature data were available, the Dakotas have moderately hot summers (mean July temperature of 22.3°C).[20] The shallow waters of the prairie potholes probably become very warm in late summer, corresponding with low DO levels. Toxicity and/or biological availability is increased by low DO and high temperatures for PCBs, PCP, and cyanide. These relationships will require further evaluation.

Step 3: Comparisons of Species Lists

Semi-permanent prairie pothole wetlands are generally shallow and eutrophic. Water levels fluctuate greatly, as does salinity. The cold winters can cause some of the wetlands to freeze to the bottom. Both winterkill and summerkill, caused by the effects of lack of oxygen, can occur. Fish can survive only in semipermanent wetlands that have connections to deeper water habitat. The only native fishes known to occur in semi-permanent prairie potholes are fathead minnow (Pimephales promelas) and brook stickleback (Culaea inconstans).[20]

The invertebrate taxa of prairie potholes are typical of other eutrophic, alkaline systems in the United States. Macroinvertebrate species assemblages are highly influenced by hydroperiod and salinity in these systems, and species diversity drops as salinity increases.[20] Care must be taken in aggregating large salinity ranges into one wetland type (i.e. "oligosaline" may be too broad a class in terms of species representativeness). Comparisons of species typical of the wetlands with the criteria species lists reveals some major differences. For example, a large proportion of the aquatic insects tested for each criterion are found in flowing water, and therefore might not be characteristic of prairie pothole aquatic insects. Although many species of aquatic insects are found in these wetlands[20], there are not many suitable aquatic insects on the criteria species lists to compare to resident wetland species. Prairie pothole wetlands do not harbor Decapods (crayfish and shrimp), another common group for testing. Eubranchiopods (fairy, tadpole, and clam shrimp) are commonly found in prairie pothole wetlands[20], but only one representative of this group has been used to establish criteria, and that species was not on the list for any of the criteria used as examples here. Except for PCBs, for which no plant value is available, plant species tested do overlap with species occurring in the wetlands. Appendix B contains sources used in making comparisons.

The above discussion has obvious implications for determining applicability of criteria based on suitability of species. As Table 7 shows, the percentages of species tested for each criterion that have not been found in prairie potholes are rather high (up to 67%). There are more gaps in the minimum family requirements for fish and chordates (Table 9) than were found for the Minnesota marsh example. The lack of fish in these wetlands dictates that amphibians or other chordates be used to fill these family requirements. The paucity of fish in these wetlands again has relevance to the protectiveness of the criteria. Fish are the most sensitive group tested for PCP and cyanide, so these criteria may have an added "buffer" of protection (in relation to the other criteria used as examples) when applied with no modifications to this wetland type.

SUMMARY OF THE EXAMPLE ANALYSES

The conclusions discussed below should be considered as examples only. They should not be considered final for these wetland types.

Cofactor Effects

Based on this simple analysis, the only cofactors that potentially could cause criteria to be underprotective were DO and temperature. The low DO and high temperatures common in both wetland types in mid to late summer could cause increased toxicity and/or biological availability for PCBs, PCP, and cyanide. Cofactor effects for chromium(VI), zinc, and parathion were either not important under the chemical conditions encountered in these wetlands or should result in criteria being more, rather than less, protective for the wetland biota. Based on water quality characteristics, it can be concluded that chromium(VI), zinc, and parathion criteria are probably adequately protective of these wetland types with no acute modification.

The importance of the DO and temperature relationship requires further evaluation for PCBs, PCP, and cyanide. Chemists and wetlands experts should be consulted and further literature reviews should be completed to evaluate the need for additional toxicity tests. If it is determined that a modification to a criterion is warranted, seasonal site-specific criteria might be appropriate in this case. The indicator species procedure could be used, requiring toxicity tests using site water on one fish and one invertebrate. The tests could be done at the high temperatures and low DO found in late summer in the wetlands.

Species Comparisons

The Salmonidae are a required family group for establishing a Final Acute Value and yet are not present in either of the wetland types used as examples. This evaluation is most concerned with ensuring that criteria are adequately protective, so the absence of this family in the wetlands should only be considered a problem if the unmodified criterion (which includes the Salmonidae) might be underprotective. This would most likely be true for parathion and chromium(VI).

For several criteria, some family requirements are not fulfilled because the available toxicity data for that taxonomic group do not include wetland species or genera ("NT" in Tables 6 and 9). While this document made comparisons at the genus level, others have made comparisons at the family level to determine if the species listed in the criteria document is a member of a family that exists at the site.[16] Issues related to species comparisons should be addressed through discussion with criteria experts and wetlands ecologists and through further literature review.

The absence of fish in prairie potholes to fill the "other chordates" category for cyanide, zinc, chromium(VI), and PCBs may warrant additional toxicity tests and site-specific modifications. The only other fish likely to be present in these wetlands is the brook stickleback (Culaea inconstans)[20] which was not tested for any of the six criteria. No non-fish chordates were tested either, so no evaluation of the probable sensitivity of other chordates to these criteria can be made based on the criteria documents.

If it is decided upon more rigorous evaluation that these differences in taxonomic groups warrant additional efforts and development of site-specific criteria, the recalculation procedure can be used. A suitable family, resident in the wetlands, can be added to the list to replace the Salmonidae and/or other missing groups, either through additional toxicity tests or by including additional available data.

Further Evaluation

This approach helps to prioritize wetland types and criteria for further evaluation. It was concluded that zinc, chromium(VI), and parathion criteria require no modification with regard to cofactor effects. PCBs, PCP, and cyanide, however, should be evaluated further in regard to the effects of high temperatures and low DO on toxicity, for both wetland types. The absence of salmonids may be most important for parathion and chromium(VI) in both wetland types. Further consideration should be given to the need for additional tests with chordates from prairie pothole wetlands for cyanide, zinc, chromium(VI) and PCBs, although there is no evidence to suggest that the absence of representative wetland chordates from the test species will result in underprotective criteria.

This type of evaluation, done for a number of wetland types and criteria, can be combined with information on the types of pollutants that threaten particular wetland types. In this way wetland types requiring additional evaluation and perhaps eventually some additional toxicity testing for particular pollutants can be prioritized based on adequacy of existing criteria, potential threats to the system, and resources available for testing. These examples illustrate the need for wetland scientists to work closely with criteria experts. Expert judgement is needed to evaluate the significance of the gaps in the available data.

SECTION 6

CONCLUSIONS

The efficient use of limited resources dictates that criteria and standards for wetlands be developed by making good use of the wealth of data that has been accumulated for other surface waters. This report focused on the application of numeric aquatic life criteria to wetlands. The numeric aquatic life criteria are designed to protect aquatic life and their uses. The criteria are conservative, and for most wetland types are probably protective or overprotective.

A simple, inexpensive evaluation technique has been proposed in this document for detecting wetland types that might be underprotected for some chemicals by existing criteria. The approach relies on information contained in criteria documents, data regarding species composition and water quality characteristics for the wetland types of interest, and consultation with experts. It is intended to be used as a screening tool for prioritizing those wetland types that require additional evaluations and research.

Two tests of the approach demonstrated that it can be used to identify cases in which criteria might be underprotective, but further evaluation and close coordination among regulatory agencies, wetland scientists, and criteria experts are needed to determine when actual modifications to the criteria are necessary.

Site-specific guidelines for modifying the numeric criteria should be appropriate for use on wetlands in cases where additional evaluations reveal that modifications are needed. The approach described in this document can be used to compile lists of the most commonly under-represented species and the most frequently encountered chemicals. Aquatic toxicity tests can then be conducted which would apply to a number of wetland types.

Information obtained with this approach can be used to prioritize further evaluations and research, identify gaps in data, and make further testing more efficient, but has some limitations. It does not adequately address the importance of plants in wetland systems and applies only to the aquatic component of wetlands. It relies on species assemblage and water quality data that are not available for some wetland types. For these reasons, a meeting of wetland scientists and criteria experts is recommended to discuss the need for this type of evaluation, the utility of this approach, and possible alternative approaches.

The application of numeric criteria to wetlands is just one part of a large effort to develop wetland standards and criteria. The development of biocriteria, sediment criteria, and wildlife criteria will help to ensure that all components of the wetland resource are adequately protected.

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APPENDIX A

SOURCES USED IN SPECIES HABITAT IDENTIFICATION FOR MINNESOTA MARSHES

Fishes:

Eddy, S., and J.C. Underhill. 1974. Northern Fishes. 3rd edition. University of Minnesota, Minneapolis.

Nelson, J.S. 1984. Fishes of the World. 2nd edition. New York: John Wiley and Sons.

Niering, W.A. 1987. Wetlands. New York: Alfred A. Knopf.

Personal Communications:
P. DeVore and C. Richards of the Natural Resources Research Institute, Duluth, Minnesota.
G. Montz, Minnesota Dept. of Natural Resources.

Macroinvertebrates:

Niering, W.A. 1987. Wetlands. New York: Alfred A. Knopf.

Pennak, R.W. 1978. Fresh-water Invertebrates of the United States. 2nd edition. New York: John Wiley and Sons.

Williams, W.D. 1976. Freshwater Isopods (Asellidae) of North America. U.S. EPA, Cincinnati.

Personal Communications:
P. DeVore and A. Hershey of the Natural Resources Research Institute, Duluth, Minnesota.
P. Mickelson of the University of Minnesota, Duluth.

APPENDIX B

SOURCES USED IN SPECIES HABITAT IDENTIFICATION FOR PRAIRIE POTHOLES

Fishes:

Kantrud, H.A., G.L. Krapu, and G.A. Swanson. 1989. Prairie Basin Wetlands of the Dakotas: A Community Profile. U.S. Fish and Wildlife Service Biological Report 85(7.28).

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TABLE 1. FRESHWATER NUMERIC AQUATIC LIFE CRITERIA*

Chemical	H, T, or pH** Dependent	Chemical	H, T, or pH** Dependent
Organochlorines:		Metals:	
Aldrin		Aluminum	
Chlordane		Arsenic(III)	
DDT		Cadmium	H
Dieldrin		Chromium(III)	H
Endosulfan		Chromium(VI)	
Endrin		Copper	H
Heptachlor		Lead	H
Lindane		Mercury	
PCBs		Nickel	H
Pentachlorophenol	pH	Selenium	
		Silver	H
Organophosphates:		Zinc	H
Chlorpyrifos			
Parathion		Others:	
		Ammonia	pH, T
		Chloride	
		Chlorine	
		Cyanide	
		Dissolved oxygen	T

* Summarized from individual criteria documents. Chemicals that have adjustment factors built into the criteria are indicated.

** H = Hardness, T = Temperature.

TABLE 2. SUITABILITY OF WETLAND SPECIES TO FILL MINIMUM FAMILY REQUIREMENTS FOR SIX CRITERION CHEMICALS

Required Taxonomic Group	PCBs	Para-thion	PCP	Cyanide	Zinc	Chrom-ium(VI)
Salmonid	NP*	NP	NP	NP	NP	NP
Other Fish	Y**	Y	Y	Y	Y	Y
Other Chordate	Y	Y	Y	Y	Y	Y
Planktonic Crustacean	Y	Y	Y	Y	Y	Y
Benthic Crustacean	Y	Y	Y	Y	Y	Y
Insect	Y	Y	Y	Y	Y	Y
Nonarthropod-Nonchordate	NT***	Y	Y	Y	Y	Y
Another Insect or New Phylum	Y	Y	Y	NT	Y	Y

*NP Not present: Taxonomic group not present in most wetland types.
**Y Wetland genera represented adequately.
***NT Not tested: Available toxicity data does not include sufficient wetland species.

TABLE 3. SOME CONDITIONS RECOMMENDED FOR DILUTION WATER FOR WATER QUALITY CRITERIA TESTING[17]

Characteristic	Freshwater	Saltwater
Total organic carbon	<5 mg/L	<20 mg/L[a]
Particulate matter	<5 mg/L	<20 mg/L[a]
pH	6.5-9.0	Stenohaline 8.0 Euryhaline 7.7 Range <0.2
Hardness (mg/L as $CaCO_3$)	Soft water 40-48 Range <5 mg/L[b]	
Salinity		Stenohaline 34 g/kg Euryhaline 17 g/kg Range <2 g/kg[c]
Dissolved oxygen	60-100% saturation[d]	60-100% saturation[d]
Temperature	+/- 5 °C of water[e] of origin	

[a] <5 mg/L for tests other than saltwater bivalve molluscs.
[b] Or 10% of average, whichever is higher.
[c] Or 20% of average, whichever is higher.
[d] For flow-through tests (40-100% for static tests).
[e] For invertebrates only.

TABLE 4. EFFECTS OF COFACTORS ON CRITERION CHEMICAL TOXICITY

	COFACTORS: Effect of Greater Value								
	pH	TOC	TURB	TEMP	DO	H	IONIC	S	NUTR/ORG
Organochlorines:									
Aldrin									
Chlordane									
DDT		+					+	+	
Dieldrin									
Endrin									
Heptachlor									
Lindane									
Endosulfan				+		O			
PCBs				+	-				
Pentachlorophenol	-			+	-				
Toxaphene		-		+					
Organophosphates:									
Parathion		-							
Chlorpyrifos									
Metals:									
Arsenic (III)		-		+	+				
[illegible]ium		-		?	0	-	-	-	?
[illegible]nium (VI)	-					-			
C[illegible]mium (III)						-			
Copper	-	-		+		-			
Lead		-?	-			-			
Mercury	-			+	-	0			
Nickel	-			+		-		-	
Selenium		-		-		-			
Silver		-				-			
Zinc	-	-			+	-	-	+	
Aluminum	-	-							-
Other:									
Chlorine	0					0	?		
Cyanide	-			±	-		0		
Ammonia	+			+	-		-		
Chloride				+?		-?	0		
DO									

+: increased toxicity/mobility
O: no effect on toxicity/mobility
-: decreased toxicity/mobility
TOC: total organic carbon
TURB: turbidity
[illegible]C: ionic strength/cations
?: tested and found inconclusive
: not discussed in criteria document
±: short-term increase/long-term decrease
DO: dissolved oxygen H: hardness
NUTR/ORG: nutrients/organic acids
S: salinity

TABLE 5. WATER CHEMISTRY FOR SELECTED MINNESOTA MARSHES*

Water Quality Characteristic	Mean Value	Range	Comparison with Standard Testing Conditions
pH (pH units)	7.1	6.1 - 7.6	Within range
Total organic carbon (mg/L)	20	5 - 60	High
Dissolved oxygen (mg/L)	8.2	0.4 - 15.4	Seasonally low
Hardness (mg/L as $CaCO_3$)	No data	-	-
Alkalinity (mg/L as $CaCO_3$)	8	4 - 14	-
Temperature (°C)	11.9	0.3 - 31.0	Seasonal extremes
Turbidity (NTU)	33	1 - 412	-

* Data taken from Detenbeck (1990), n=42 wetlands.[18]

TABLE 6. COMPARISON OF TEST SPECIES WITH MINNESOTA MARSH BIOTA FOR SIX CRITERIA

Required Taxonomic Group	PCBs	Parathion	PCP
Salmonid	NP[d]	NP	NP
Other Fish[a]	Micropterus	Lepomis	Micropterus
Other Chordate	Pimephales	Pimephales	Rana
Planktonic Crustacean	Daphnia	Daphnia	Daphnia
Benthic Crustacean	unknown amphipod	Orconectes	Orconectes
Insect	Ishnura[b]	Chironomus	Tanytarsus
Nonarthropod-Nonchordate	NT[e]	unknown[c] nematodes/ annelids	unknown[c] nematodes/ annelids
Another Insect or New Phylum	Tanytarsus	Ishnura	unknown amphipod/ isopod
Aquatic Plant	NT	alga	Lemna

continued

TABLE 6, CONTINUED

Required Taxonomic Group	Cyanide	Zinc	Chromium(VI)
Salmonid	NP	NP	NP
Other Fish[a]	Perca	Lepomis	Lepomis
Other Chordate	Lepomis	Pimephales	Pimephales
Planktonic Crustacean	Daphnia	Daphnia	Daphnia
Benthic Crustacean	unknown[c] amphipod/ isopod	unknown[c] amphipod/ isopod	Orconectes
Insect	Tanytarsus	Argia[b]	Chironomus
Nonarthropod-Nonchordate	Physa	Physa	Physa
Another Insect or New Phylum	NT	unknown[c] annelid/ nematode	NT
Aquatic Plant	Lemna	Lemna	alga

a Fish were sampled in water bodies associated with some of the wetlands, not in the wetlands themselves.
b Probable or seen as an adult.
c Unknown species from these taxa found in wetlands. May or may not be similar in terms of habitat requirements, etc. to species used in toxicity tests.
d Not present: Taxonomic group not present in wetland type.
e Not tested: Available toxicity data does not include sufficient wetland species.

TABLE 7. NUMBER OF SPECIES TESTED FOR ACUTE CRITERIA AND PERCENTAGE OF TEST SPECIES THAT ARE NOT FOUND IN MINNESOTA MARSHES OR OLIGOSALINE PRAIRIE POTHOLES*

Chemical	Species Used to Establish FAV** (Total Number)	Not Present in Marshes (Per cent)	Not Present in Prairie Potholes (Per cent)
PCBs	10	30%	40%
Parathion	37	43%	64%
PCP	37	22%	43%
Cyanide	17	29%	65%
Zinc	45	45%	67%
Chromium(VI)	33	27%	64%

* Remainder of percentage includes both those species that are known to occur in these wetlands and those species that may occur in the wetlands, but insufficient data are available.

** Final Acute Value.

TABLE 8. WATER QUALITY CHARACTERISTICS FOR OLIGOSALINE PRAIRIE POTHOLES[a]

Water Quality Characteristic	Mean Value	Range	Comparison with Standard Testing Conditions
pH (pH units)	8.9	7.4 - 10.3[b]	High
Total organic carbon (mg/L)	No data[c]	-	-
Dissolved oxygen (ppm)	No data[d]	-	-
Hardness (mg/L as $CaCO_3$)	No data[e]	-	-
Alkalinity (mg/L as $CaCO_3$)	650	230 - 1300	High
Temperature (°C)	No data[f]	-	-
Specific conductance (µS/cm at 25°C)	3568	750 - 8000	-

a Data summarized from Swanson et al. (1988).[19]
b N=27 wetlands.
c Dissolved organic carbon data for Manitoba prairie potholes ranged from 0.4-102 mg/L, and for Nebraska, from 20-60 mg/L in one study and 139-440 mg/L in another study.[22]
d Winterkill, caused by low dissolved oxygen under ice, occurs in many of these lakes.
e An estimate of hardness based on alkalinity values gives a mean of 760 mg/L as $CaCO_3$.
f Region is characterized by very cold winters and warm summers.

TABLE 9. COMPARISON OF TEST SPECIES WITH PRAIRIE POTHOLE BIOTA FOR SIX CRITERIA

Required Taxonomic Group	PCBs	Parathion	PCP
Salmonid	NP	NP	NP
Other Fish	Pimephales	Pimephales	Pimephales
Other Chordate	NT	Pseudacris[a]	Rana[a]
Planktonic Crustacean	Daphnia	Daphnia	Daphnia
Benthic Crustacean	Gammarus[a]	Gammarus[a]	Hyalella
Insect	damselfly[b]	Peltodytes	Tanytarsus[b]
Nonarthropod-Nonchordate	NT	tubificid worm[b]	tubificid worm[b]
Another Insect or New Phylum	Tanytarsus[b]	Chironomus	Physa
Aquatic Plant	NT	Microcystis	Lemna

TABLE 9, CONTINUED

Required Taxonomic Group	Cyanide	Zinc	Chromium(VI)
Salmonid	NP	NP	NP
Other Fish	Pimephales	Pimephales	Pimephales
Other Chordate	NT	NT	NT
Planktonic Crustacean	Daphnia	Daphnia	Daphnia
Benthic Crustacean	Gammarus[a]	Gammarus[a]	Hyalella
Insect	Tanytarsus[b]	Argia[b]	Chironomus[a]
Nonarthropod-Nonchordate	Physa[a]	Physa[a]	Physa[a]
Another Insect or New Phylum	NT	tubificid worm[b]	damselfly[b]
Aquatic Plant	Lemna	Lemna	Nitzschia

a Genus is present in the wetlands; may not be same species.
b Species representative of that taxonomic group from criteria testing lists probably present in prairie potholes, but no actual data available.