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Analysis of the Numeric Water Quality Criteria Adopted by the Ten States That Border Directly on the Mississippi River

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Overview

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The findings presented in this document are based only on what was found in final, state WQS regulations as of June 1, 2009. Hence, though the existence of proposed changes to state water quality standards may be acknowledged, typically in footnotes, the contents of such potential modifications are not reflected in the various analyses contained in the report. Likewise, associated guidance documents, policy memoranda, and other state publications related to the state's WQS are not reflected in this report. As such, one limitation of this report is that it does not fully describe a given state's water quality standards program or how WQS are applied in other water quality programs.

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Analysis of the Numeric Water Quality Criteria Adopted by the Ten States That Border Directly on the Mississippi River

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List of Acronyms

AWS	Agricultural Water Supply
BATEA (or BAT)	Best Available Treatment Economically Achievable
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CALM	Consolidated Assessment and Listing Methodology
CSO	Combined Sewer Overflows
CWA	Clean Water Act
DDT	Dichloro-dephenyl-trichloroethane
DO	Dissolved Oxygen
DU	Designated Use
DW	Drinking Water Standards
DWS	Drinking Water Supply
FC	Fish Consumption
GLI	Great Lakes Initiative
HHO	Human Health Organism
HHWO	Human Health: Water and Organism
IWS	Industrial Water Supply
LA	Load Allocation
MCL	Maximum Contaminant Level
MS4	Separate Sewage System
NPDES	National Pollution Discharge Elimination System
NTU	Nephelometric Turbidity Unit
PAH	Polycyclic Aromatic Hydrocarbons
PBT	Persistent, Bioaccumulative and Toxic (EPA Program)
PCB	Polychlorinated biphenyl
PWS	Public Water System
SDWA	Safe Drinking Water Act
SRF	State Revolving Fund
SSM	Single Sample Maximum
STP	Sewage Treatment Plant
TBA	Technology-Based Approach
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TRI	Toxics Release Inventory
TSS	Total Suspended Solids
WLA	Wasteload Allocation
WQ	Water Quality
WQBA	Water Quality Based Approach
WQBEL	Water Quality Based Effluent Limits
WQC	Water Quality Criteria
WQS	Water Quality Standards

A. Introduction

This document is one of a number of state-specific reports resulting from an Environmental Law Institute (ELI) analysis of the numeric water quality criteria (WQC[1]) component of the water quality standards (WQS) of the ten states that border directly on the Mississippi River. In this report ELI compares the State of Minnesota's numeric water quality criteria to recommended criteria and related standards[2] issued by the US Environmental Protection Agency. The findings presented in the documents produced for this report are based on the most recent version of the state's WQS regulations as of June 1, 2009; hence, contents of associated guidance documents, policy memoranda and other state publications related to the state's WQS are not reflected in this report. As such, one limitation of this report is that it does not fully describe a given state's water quality standards program or how standards are applied in other water quality programs. This report addresses only WQC applicable to waters that drain into the Mississippi River and does not cover WQC applicable to the Great Lakes Basin.

This work was funded by a grant from the Mississippi River Water Quality Collaborative, a group of state, regional and national non-profit organizations working together to improve water quality in the Mississippi River basin.

B. Summary of Findings

The water quality criteria (WQC) specified in Minnesota's water quality standards (WQS) regulations[3] present a mixed picture when compared to the criteria published[4] by EPA, in terms of: 1) pollutant /use combinations[5] covered, 2) the degree to which all key elements of

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[1] The terms "water quality criteria," "WQC," and "criteria" are used interchangeably in this report. Water quality criteria are closely associated with another key element of water quality standards established under state law and the federal Clean Water Act—designated uses. Criteria describe waterbody conditions, primarily pollutant levels, associated with full support of one or more of the designated uses (e.g., aquatic life, fish consumption, water contact recreation, drinking water supply) assigned to specific waters by a state's water quality standards regulations.

[2] The "recommended EPA criteria" referred to in this report are water quality criteria (WQC) issued as guidance to states, territories, and authorized tribes by the EPA under authority of the federal Clean Water Act. The "related EPA standards" are federal regulatory requirements applicable to finished (post treatment) drinking water that is delivered to homes and businesses by a public drinking water system. These standards are established by EPA under authority of the Safe Drinking Water Act (SDWA).

[3] *State Register*, Volume 32, Number 4, pages 87-217, July 23, 2007 (32 SR 87); *State Register*, Volume 32, Number 5, pages 250-255, July 30, 2007 (32 SR 250); and *State Register*, Volume 32, Number 37, pages 1699-1728, March, 2008 (32 SR 1699)

[4] Throughout this report, the water quality criteria (WQC) recommended by EPA under the Clean Water Act will be referred to as the EPA's "issued" or "published" criteria, interchangeably. Unlike Primary Drinking Water Standards promulgated by the Agency according to the federal Safe Drinking Water Act, EPA WQC are not regulatory requirements; rather, they are guidance.

[5] As used in this report, "pollutant/use combination" and "pollutant/use pair" refer to designated use and a particular pollutant or other water quality parameter (e.g., dissolved oxygen, pH, temperature). Often a states have just one WQC for a given pollutant and use; however, in the case of aquatic life criteria, more than one WQC per pollutant/use combination is common. This is usually due to: 1) having both acute and chronic criteria; 2) breaking aquatic life down into a number of sub-categories (e.g., cold and warm water habitat); 3) establishment of different criteria for different ecoregions within the state; and/or 4) setting waterbody-specific WQC.

criteria are clearly articulated, 3) criterion-concentrations, and 4) level of protection likely afforded to applicable designated uses.

Minnesota has adopted numeric water quality criteria (WQC) for a substantial array of pollutant/use combinations, though there are a number of instances in which the state has not established criteria for pollutant/use pairs for which EPA has issued WQC under authority of Section 304(a) of the Clean Water Act.

The state has adopted criteria for a majority of the traditional pollutants[6] for which EPA has issued criteria. Recently, it added criteria for the nutrient phosphorous and the algal density indicator chlorophyll a. The excessive algal densities that often result from overloading of waterbodies with nitrogen and/or phosphorous can adversely impact not only aquatic life, but also public water supply and water-based recreational uses. As these new criteria apply to only lakes and reservoirs, Minnesota's streams, rivers, and wetlands still are missing[7] numeric criteria of any kind related to nutrient over-enrichment.

At the same time it adopted the above WQC for phosphorous and chlorophyll a, Minnesota established criteria for turbidity of lakes and reservoirs, measured in terms of the depth of visibility of a Secchi disk. The state already had turbidity criteria for aquatic life—expressed in NTUs—that apply to a wide array of waters, including rivers and streams.

There are, however, gaps. For example, whereas EPA has published three criteria for ammonia, with criterion-durations of one hour, four days, and 30 days, Minnesota has only a four-day criterion for ammonia. The state also lacks an acute criterion for dissolved oxygen, though it has a chronic criterion. EPA, by contrast, has an acute, but no chronic WQC for this parameter. Also, there are no WQC for total nitrogen aimed at preventing excessive eutrophication, though the state does have a criterion for nitrates plus nitrates that is applicable to drinking water supply ("Domestic Consumption").

On the other hand, the state has several aquatic life WQC for traditional parameters for which there are not corresponding EPA criteria. Among Minnesota's "extra"[8] criteria are acute and chronic temperature criteria, as well as chronic criteria for oxygen, pH, color and oil and grease. The state also has wetland-specific criteria for dissolved oxygen, pH, and temperature. Similarly, Minnesota's WQS regulations contain criteria for a large number of toxic[9] pollutants, including: 1) acute aquatic life criteria for more than two dozen pollutants, and 2) chronic aquatic life criteria for more than one dozen pollutants for which EPA has not published corresponding

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[6] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance, which includes: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. Also considered "traditional" in this document are several other non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen, oil and grease, total phosphorus, and turbidity, which are sometimes called "non-conventional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

[7] For the purposes of this review, "missing" criteria are those pollutant/use combinations for which the state has not officially adopted WQC, whereas EPA has published recommended WQC of the type specified.

[8] For the purposes of this report, "extra" criteria are those pollutant/use pairs for which the state has officially adopted criteria, but for which EPA has not issued corresponding criteria.

[9] In this report, the term "toxic pollutant" includes not only EPA's "priority" toxic pollutants but also all those toxics called, for CWA purposes, "non-priority" pollutants, as well as all toxic chemicals falling into neither of these two EPA classifications. The one exception is ammonia, which is addressed under "traditional pollutants" in this report.

criteria. However, Minnesota lacks acute and/or chronic aquatic life criteria for a number of toxic pollutants for which EPA has published corresponding recommended criteria, including several that fall into categories that are frequently mentioned as possible endocrine disruptors.[10]

The state has "Domestic Consumption" WQC for all of the eight traditional contaminants/parameters[11] for which EPA has published somewhat related[12] Safe Drinking Water Act (SDWA) standards.[13] Minnesota also has adopted Domestic Consumption criteria for a large majority of the toxics for which EPA has promulgated standards under the SDWA.[14] These criteria apply to Subcategories 1A, 1B, and 1C of the state's Domestic Consumption (Class 1) use classification. There also is a Subcategory 1D, for which there are water quality criteria for only a handful of toxic substances.

On the other hand, the state lacks human health-related WQC for a substantial fraction of the toxic pollutants for which EPA has issued criteria to address risks from consumption of: 1) water and fish/other aquatic organisms combined, and 2) aquatic organisms alone. For the first category, which EPA calls "human health: water and organisms" criteria (HHWO) and Minnesota calls "Human Health-Based aquatic organisms" (for Classes 2A and 2Bd), the state has adopted criteria for only one-third of the toxic substances for which EPA has published criteria. And, the state's set of "Human health-based aquatic life WQC" applicable to Classes 2B, 2C, and 2D also is missing a large number of WQC for toxics addressing consumption of aquatic organisms ("fish" consumption) alone—comparable to EPA Human Health: Organisms

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[10] Actually, Minnesota may not be missing any aquatic life WQC for toxics. Part 7050.0218, Subp.4A and Subp. 4B appear to incorporate all of EPA's section 304(a) WQC into the state's WQS regulations, by reference. On the other hand, the criteria tables in 7050.0220, Subp.3a, Subp 4a, and Subp 5a include WQC for some of the pollutants for which there are EPA aquatic life WQC, but not for others.

[11] The situation regarding bacterial criteria for Domestic Consumption is somewhat unclear. Part 7050.0221, Subp. 2 says that all of EPA's Primary and Secondary Drinking Water Standards issued under the Safe Drinking Water Act are incorporated, by reference as criteria applicable to Domestic Consumption Subclass 1A, whereas Subp. 3, 4, and 5 specify that EPA's bacterial drinking water standards do not apply to Subclasses 1B, 1C, or 1D. Taken together, these provisions of 7050.0221 indicate that the EPA primary drinking water standard for total coliform bacteria applies only to Subclass 1A. However, the version of 7050.0221 included in the set of changes to the state's WQS adopted in March 2008 includes a Subpart 1.B, the last sentence of which indicates that the Primary Drinking Water Standards for "microbiological organisms" do not apply to any Class 1 waters., which puts the applicability of the total coliform standard to Class 1A in doubt.

[12] The term "somewhat corresponding" has been used because water quality criteria and drinking water standards apply to different endpoints. WQC apply to surface waters within the jurisdiction of the Clean Water Act. Some of these waters are, or might be, used as a source of "raw" water by public and private drinking water systems. When a waterbody in Minnesota is designated "Domestic Water Supply," then a certain set of WQC apply, per the CWA. There also is another set of standards that apply to the "finished" water that results from "raw" water being run through treatment processes aimed at removing contaminants.

[13] EPA has not issued drinking water supply criteria for either traditionals or toxics; that is, EPA has not published anything that specifies acceptable levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards that address levels of contaminants and indicator parameters (e.g., pH) in drinking water alone apply to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable.
Also, it should be noted that, with the exception of total coliforms, the EPA Safe Drinking Water Act (SDWA) standards for the eight traditional parameters addressed in this section are "secondary" standards (related to taste, odor, and appearance of drinking water), rather than "primary" drinking water standards (related to health). Like the water quality criteria that EPA publishes pursuant to the CWA, Secondary Drinking Water Standards are guidance. By contrast, Primary Drinking Water Standards are federal regulatory requirements.

[14] The recently adopted subsection B of Part 7050.0221, Subp. 1 specifies that federal Primary Drinking Water standards for acrylamide, chloramines, chlorine, chlorine dioxide, epichlorohydrin, copper, and lead are not incorporated into Minnesota's WQS regulations as WQC for Domestic Consumption, for surface waters.

Only (HHO) WQC. Among the pollutants without state equivalents to EPA HHWO and/or HHO criteria are a number of carcinogens, potential endocrine disruptors, and highly bioaccumulative substances.

As for water-contact recreation, the state has recently adopted *E. coli* criteria to replace its long-standing fecal coliform bacteria criteria. *E. coli* is a more reliable indicator of the potential presence of pathogenic organisms that can affect humans. Like EPA, the state has no WQC for toxic chemicals for this category of uses.

Unlike EPA and most states, Minnesota has adopted criteria for a total of seven traditional pollutants/parameters for protection of irrigation water used in agriculture. It also has industrial water supply criteria for chlorides, pH, and hardness.

Regarding the criterion-concentrations[15] specified by Minnesota's WQC for both traditional parameters and toxic pollutants, most are identical, or very close, to the criterion-concentrations of corresponding EPA water quality criteria or relevant standards issued under the Safe Drinking Water Act. For example, with criteria related to public drinking water supply (called "Domestic Consumption" criteria in the state's WQS regulations), Minnesota has simply adopted the concentrations specified in EPA's Primary Drinking Water Standards (for toxic chemicals and bacteria) or Secondary Drinking Water Standards (for traditional pollutants other than bacteria). [16]

The group of criteria with the largest number of criterion-concentrations that are either higher or lower than those in the corresponding EPA criteria is that addressing the effects of human uptake of toxics substances resulting from combined consumption of: 1) drinking water, and 2) fish and other aquatic organisms – Minnesota's "Human Health (HH)–based aquatic life" criteria applicable to Class 2A and 2Bd waters.[17] For those toxics for which there is one of this type of state WQC as well as a EPA Human Health: Water and Organisms (HHWO) criterion, there are more state criteria with a criterion-concentration higher than that for the corresponding EPA HHWO criterion than state WQC with lower criterion-concentrations. A related category of state criteria are those "Human Health-based aquatic life" criteria applicable to Classes 2B, 2C, and 2D, which are designed to protect persons who consume sport or commercial fish from a given waterbody, but do not obtain drinking water from it. These state criteria are equivalent to EPA's Human Health: Organisms (HHO) criteria. Half of Minnesota's criteria for the 23

[15] According to EPA guidance, numeric water quality criteria (WQC) consist of three components: 1) a criterion-magnitude, 2) a criterion-duration, and 3) a criterion-frequency. The first of these—criterion-magnitude is usually expressed as a concentration; hence, the frequent use of "criterion-concentration" in this report. For some key water quality parameters, such as temperature and pH, quantity is not expressed as a concentration, so EPA employs the broader term "criterion-magnitude".

[16] The criterion-concentrations are identical across all of the three subclasses of Class 1 (Domestic Consumption), despite the fact that there is language in 7050.0221, Subp. 2, 3 and 4 that suggests that the concentrations would vary from one of these subclasses to another. Such differences are implied by the fact that these portions of the state's regulations say that the applicable concentration of parameters and pollutants in raw water are, for each constituent, that level to which specified types of treatment for each subclass can lower to the point that the resulting finished drinking water will meet all SDWA standards.

[17] According to Subpart 6 of Section 7050.0218 of the Minnesota WQS regulations, this group of "Human Health (HH)–based aquatic life" criteria are intended to "protect humans from potential adverse effects of eating fish and edible aquatic organisms…and from the consumption of drinking water..." Hence, these WQC seem equivalent to EPA's "human health: water and organisms" (HHWO) criteria, but not to EPA's "human health: organisms" (HHO) WQC.

chemicals for which there corresponding EPA HHO WQC have criterion-concentration lower than those of EPA's and half have higher criterion-concentrations.[18]

The criterion-concentrations of most of the state's aquatic life criteria for traditional parameters are within the range encompassed by the WQC of EPA and the other states examined for this report. One exception is both of the state' four-day criteria (one warm water/one cold water) applicable to ammonia, which have a criterion-concentration higher than the highest EPA value for WQC with a four-day duration. EPA's equivalent criteria for ammonia vary according to pH and temperature, Minnesota's do not. The range of concentrations specified in Minnesota's chronic criteria for chlorophyll a and phosphorous in lakes and reservoirs found in each of the four ecoregions that the state has identified is slightly higher than the range specified by EPA for the three ecoregions into which the Agency has divided the state. The range of criterion-magnitudes specified for turbidity (measured in Secchi disk depth) for lakes and reservoirs falls within the range of values recommended by EPA. The criterion-magnitudes for the Minnesota chronic aquatic life criteria for turbidity (NTU) applicable in all types of cold and warm waters are higher than the criterion-magnitude of the one turbidity WQC published by EPA for riverine ecosystems within the state.

For toxic chemicals, where the state has adopted aquatic life criteria for toxic chemicals corresponding to EPA's WQC, the state's chronic criterion-concentrations are generally equal to or higher than the criterion-concentrations in the corresponding EPA criteria. On the other hand, the criterion-concentrations in Minnesota's acute aquatic life criteria for toxics are a mix of those that are higher than, lower than, and equal to the criterion-concentrations in EPA's corresponding criteria, with the largest portion being the criterion-concentrations that are higher than those in EPA's corresponding criteria.

The majority of the state's numeric WQC for both traditionals and toxics has fairly clearly-stated criterion-durations[19] (e.g. 24-hour, 30-day); the only category lacking relatively precise criterion-durations is the "Domestic Consumption" (of drinking water) category.

The vast majority of Minnesota's numeric water quality criteria contain no specific reference to a criterion-frequency,[20] with the exception of: 1) one of the criteria for *E. coli* bacteria pertaining to water contact recreation, and 2) the total coliform WQC for Domestic Consumption (drinking water supply). The former has a criterion-frequency of ten percent and

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[18] Dioxin is one of the pollutants for which the state has not adopted Human Health-based aquatic life criteria.

[19] According terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion"—the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as 4 day average concentrations. The occurrence of one or more excursion (e.g. a four-day period in which the instream concentration, for example, of cyanide was higher than the criterion-concentration of 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedence of a water quality criterion occurred

[20] In EPA water quality standard terminology, the criterion-frequency specifies the maximum rate at which "excursions" can occur and the waterbody of concern can still fully support the designated use to which the criterion applies. For instance, EPA guidance specifies a criterion-frequency of once in three years for both its acute and chronic aquatic life WQC for toxic chemicals. This means that only if two or more excursions occur during any 3-year period has there actually been an exceedence of the WQC in question. For example, only if the 4 day average concentration of cyanide in a lake were higher than the chronic criterion-concentration of 5.2 µg/L more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

the latter 5 percent. For those WQC lacking any mention of a criterion-frequency, a default frequency of zero has been assumed for discussion purposes in this report.

As for the level of protection provided by a state WQC for a given pollutant/use combination in comparison to that of EPA (or another state), this cannot be done with any degree of confidence unless all three elements of both WQC are clearly articulated. And, even when the criterion-concentration, criterion-magnitude, and criterion-frequency of each of the two WQC being compared are precisely stated, their comparative degree of protectivity can only be determined, simply by looking at the two WQC and nothing else, with certain combinations of relative criterion-concentration, concentration-duration, and combination-frequency. For instance, if a state and a comparable (same pollutant and same designated use) EPA criterion both have the same criterion-concentration, same criterion-duration, and the same criterion-frequency, they would provide equal levels of protection. If, however, the criterion-concentration of one of the two WQC were lower than the other, and the criterion-duration and criterion-frequency remained identical, then that WQC would provide the higher degree of protection. Likewise, if the criterion-concentrations are the same, the criterion-durations are identical, but one of the WQC has a lower acceptable criterion-frequency, then that criterion with the lower frequency would provide more protection. Also providing a higher level of protection would be a WQC with a shorter criterion-duration than a comparable WQC that had the same criterion-concentration and criterion-frequency. Appendix C provides a set of tables that list all possible combinations, in relative terms, of criterion-concentrations, criterion-durations, and criterion-frequencies, indicating which represent higher, lower, and identical levels of protection.

Unfortunately, the relevance of the tables in Appendix C to Minnesota's WQC is significantly limited by the fact that, though a majority of the state's criteria have a specified criterion-duration, the state's WQS regulations make no mention of a criterion-frequency for most of its water quality criteria. Further complicating comparison of the level of protection afforded to applicable designated uses by a state WQC is the fact that most of EPA's criteria for traditional pollutants lack a clearly-articulated criterion-duration and criterion-frequency.

The absence of explicit criterion-duration and/or criterion-frequency in one or both of two corresponding (same pollutant/use combination) criteria, renders a determination of the absolute or relative level of protection provided by one WQC versus another an exercise fraught with uncertainty. Any such effort would, of necessity, involve making assumptions that may or may not turn out to be consistent with the duration and/or frequency intended, or eventually settled upon, by the entities that established each of the criteria. In turn, the results of attempts to compare the protection provided by a state versus an EPA WQC would be greatly affected by whatever assumptions were made. Assumption of some short-term duration (e.g., one hour), rather than a longer term (e.g., 30 days), would tend to make a criterion more protective. Likewise, assumption of a lower frequency (e.g., once in five years), rather than a higher frequency (e.g., once in two years) would have the same effect, and would be more protective than if the alternative were the case.

As noted previously, only two of Minnesota's numerous WQC articulate a criterion-frequency. And, none of the state's WQC for Domestic Consumption (public drinking water supply), for either traditionals or toxics, mention a criterion-duration. Furthermore, several of EPA's WQC for traditional pollutants/parameters, and all of its human health WQC for toxics, lack clearly stated durations and/or frequencies. Specific examples of the difficulties in estimating comparative levels of protection that arise from such ambiguities are presented later

in this document, in "Discussion: Criteria for Traditional Parameters" and "Discussion: Criteria for Toxic Pollutants."

Further complicating this picture, with regard to aquatic life WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons (differences in water column chemistry, temperature, stream flow patterns, resident species of aquatic life) that a state criterion can have a criterion-concentration higher or lower than that for the corresponding EPA criterion and still provide aquatic life protection equal to that for which the EPA WQC was designed. This would not, however, mean that the two criteria would provide equal levels of protection to the relevant use. If, for example, a state's criterion-concentration were higher than EPA's, while the duration and frequency for the two WQC were identical, then the state's criteria would provide a lower degree of protection relative to that which would be provided by adoption of EPA's criterion as a state WQS for the waterbody in question. Nevertheless, site-specific conditions could have resulted in EPA's WQC providing an even higher level of protection than that for which EPA designed it. The effect of the state's higher criterion-concentration would be to bring the level of protection back down to that intended by EPA. Minnesota's "eutrophication criteria" reflect an attempt to take such factors into effect, in that they vary according to type of waterbody and ecoregion.

Turning from aquatic life to human health, safe levels of pollutants tend to vary less from waterbody to waterbody. The most obvious reason is that, unlike aquatic life WQC, human health criteria address risk to just one species, regardless of the location of the waterbody to which the WQC apply.[21] The most common reason for need for variation in human health criteria from one locale to another is differences in patterns of human use. For example, regarding drinking water use, persons in hotter climates tend to consume more water, on average, than those in cooler areas. Of course, patterns of swimming and other water contact recreation can change considerably depending on differences in the climate in which one waterbody versus another is located, along with the type of waterbody (e.g., river, lake, ocean beach).

Similarly, the amount of fish and other aquatic life from local waters that are caught and eaten by people can differ by an order of magnitude from place to place and/or within subpopulations of humans. Another variable with regard to "fish consumption" use is the type of fish being eaten by people, and the lipid content of the commonly-eaten portions of the organisms in particular. Though Minnesota does not seem to have adopted localized WQC to take into account, for instance, differences in consumption rates among subsistence fisherpersons versus average rates across the state, it has developed two different sets of "Human Health Based-aquatic life" criteria, one reflecting consumption of cold water species (Class 2A waters) and the other reflecting consumption of cool and warm water species (Classes 2B, 2Bd, 2C, and 2D. According to the state, cold water fish tend to have higher lipid content in the relevant parts of their bodies than do species that inhabit warmer waters. Persistent toxic chemicals that tend to bioaccumulate up the food chain will do so to a greater degree in organisms with higher lipid content. Ambient water levels of a given bioaccumulative toxic pollutant would need to be lower in cold water habitats than in warm water, according to this logic, in order to keep the

[21] Of course, within the human population in a given locale, there will be certain sub-populations that are more sensitive to certain pollutants than the average members. Small children, pregnant women, and the elderly are examples of such groups. This fact would not, however, indicate a need for different human health WQC for one waterbody versus another, as the proportion of the total population represented by each of these subgroups would most likely not vary substantially from one location to another.

concentration of said pollutant in fish below levels thought to pose unacceptable risks to human consumers.

With regard to criteria aimed at risks associated with consuming contaminants in drinking water, another confounding factor is the fact that state water quality criteria for public water supply ("Domestic Consumption," in Minnesota's case) apply to the untreated water from a river or lake that is used as a "raw" water supply for a public drinking water system, while EPA's standards established under the Safe Drinking Water Act (SDWA) apply to "finished" drinking water at the tap, which usually has undergone some form of treatment to remove contaminants. Hence, for a given pollutant, a drinking water supply water quality criterion with a concentration higher than that specified in a drinking water standard could actually provide equal, or even greater, protection to consumers of finished drinking water, if the drinking water treatment process to which the raw water is subjected succeeded in removing a substantial percentage of the contaminant found in the raw water.

Returning to the effects of un-addressed or imprecisely-articulated criterion-durations and criterion-frequencies, in addition to making comparison of levels of protection afforded relevant uses difficult, if not impossible, such ambiguities can pose challenges to the implementation of CWA programs driven by WQS—303(d) and 305(b) reporting on the condition of a state's waters, total maximum daily loads (TMDLs), and water-quality based effluent limits in NPDES permits. For instance, if a TMDL were being developed because of exceedences of one of Minnesota's Domestic Consumption WQC, the absence of a clearly-articulated criterion-duration for this category of WQC would create a quandary. What should the time-interval for the maximum loading set forth in the TMDL be? If one assumes, as has been done in this report, a default criterion-duration of an instant in such circumstances, then it would seem logical to express the TMDL as a maximum load over a very short interval, even just a second. On the other hand, if the criterion-duration for the state's Domestic Consumption WQC was 12 months—the averaging period used in determining compliance with SDWA standards—then setting a maximum twelve month total load would seem appropriate.[22]

C. Traditional Pollutants/Water Quality Parameters[23]

1) Coverage

a) **Aquatic Life[24] / "Cold water, etc." [25]**

[22] In *Friends of the Earth v EPA,* 446 F.3d.145 (2006) the federal D.C. Circuit Court ruled that because of the specific reference to "daily" in the portion of Section 303(d) of the CWA that established the Total Maximum Daily Load program, all TMDLs should include, at least, a maximum daily load. Despite this ruling, maximum loads over other time spans would also be needed, in order for the TMDL to consistent with relevant WQC, when such criteria have criterion-durations other than 24 hours.

[23] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance, which includes: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. Also considered "traditional" in this document are several other non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen, oil and grease, total phosphorus, and turbidity, which are sometimes called "non-conventional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

Minnesota lacks an acute and/or chronic WQC for a number of traditional pollutants for which EPA has published criteria. For instance, though it has a four-day WQC for ammonia, it doesn't have a criterion for either a 1 hour average or a 30-day exposure period. Also missing[26] are 1) acute criterion for dissolved oxygen and pH, and 2) chronic values for total dissolved gases, hydrogen sulfide, and total nitrogen.

The state has recently adopted a number of WQC dealing with hypereutrophication, for lakes and reservoirs, though not other types of waterbodies. Among the parameters having new criteria are the nutrient phosphorous, and the response indicator chlorophyll a, which reflects algal levels in a waterbody. Another effect of excessive algal blooms is increased turbidity, and Minnesota has just adopted a criterion for that parameter using visibility of a Secchi disk at various depths as an indicator. The state has developed such "eutrophication criteria" specific to different combinations of: 1) waterbody types (lakes, shallow lakes, and reservoirs); designated use categories (Classes 2A, 2Bd and 2B) and ecoregions within the state.[27] Since these criteria only apply to lakes and reservoirs, other waterbody types – rivers/streams and wetlands – are still without nutrient criteria.

The state has a number of "extra"[28] aquatic life criteria, for the pollutants/water quality parameters color, oil and grease, and temperature. Minnesota also has criteria applicable to wetlands for three traditional pollutants. (The State does not have true numeric criteria for acute exposures to high temperatures. However, it does have, for both cold waters and wetlands "quasi-numeric" acute/chronic criteria, which say, basically "no change in temperature.")

Like EPA, Minnesota has no chronic WQC that is applicable to dissolved oxygen. Both the state and EPA have acute WQC for this parameter.

b) Human Health: Consumption of Fish and Other Aquatic Organisms

Minnesota lacks fecal coliform criteria for shellfish waters.[29]

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[24] Throughout this document, generic names (e.g., "aquatic life," and "human health: drinking water supply," and "human health: water contact recreation") are used in reference to certain categories of uses. When a state uses different wording to refer to one of the generic uses, the name the state employs is listed in quotation marks, following the generic title. Wisconsin has several sub-categories under its "fish and other aquatic life" use category: cold water communities, warm water sport fish communities, warm water forage fish communities, limited forage fish communities, and limited aquatic life. With regard to its ammonia criteria, there are sub-groupings under "cold water communities," each with a different criterion-concentration. The other traditional parameters for which Wisconsin has aquatic life criteria that vary from one of these subcategories to another are temperature and dissolved oxygen, for which there are different criteria just for the cold water and warm water categories.

[25] Minnesota actually has four different subcategories of aquatic life uses: 1) Cold Water (Class 2A, 2) Cool or Warm Water Sport or Commercial Fish and Associated Aquatic Life (Class 2B and 2Bd), 3) Indigenous fish and associated aquatic life (Class 2C), and 4) Aquatic and Terrestrial Species Indigenous to Wetlands (Class 2D).

[26] For the purposes of this review, "missing " criteria are those pollutant/use pairs for which the state has not officially adopted WQC, whereas EPA has published recommended WQC of the type specified

[27] The four ecoregions are: 1) northern lakes and forest, 2) north central hardwood forest, 3) western corn belt plains, and 4) northern glaciated plains.

[28] For the purposes of this report, "extra" criteria are those pollutant/designated use combinations for which the state has officially adopted criteria, but for which EPA has not issued corresponding criteria.

[29] The importance of the absence of bacterial WQC related to shellfish harvesting and consumption depends upon whether or not there are any waters in the state that harbor beds of shellfish that are harvested and consumed for either recreational, subsistence, or commercial purposes.

c) Human Health: Drinking Water Supply/ "Domestic Consumption"[30]

The state has "Domestic Consumption" WQC for all seven of the traditional pollutants/parameters (chlorides, color, foaming agents, odor, pH, sulfates, and total dissolved solids) for which EPA has issued Secondary Drinking Water Standards under authority of the federal Safe Drinking Water Act (SDWA).[31] Recent changes to the WQS regulations deleted a NTU criterion applicable to this use. There is no Safe Drinking Water Act standard for turbidity/NTU.

The situation regarding bacterial criteria for Domestic Consumption is somewhat unclear. Part 7050.0221, Subp. 2 says that all of EPA's Primary and Secondary Drinking Water Standards issued under the Safe Drinking Water Act are incorporated, by reference as criteria applicable to Domestic Consumption Subclass 1A, whereas Subp. 3 and 4 specify that EPA's bacterial drinking water standards do not apply to Subclasses 1B, and 1C. According to these provisions of state law, EPA's bacterial drinking water standards apply only to Class 1 A, but not to Subclasses 1B, 1C, and 1D. However, the version of 7050.0221 included in the set of changes to the state's WQS adopted in March 2008 includes a Subpart 1.B, the last sentence of which indicates that the federal drinking water standards for "microbiological organisms" do not apply to any of the four subclasses in Class 1 (Domestic Consumption).

d) Human Health: Water-contact Recreation[32]

Like EPA, Minnesota has a chronic (30 day duration) WQC for *E. coli* bacteria. There is no EPA WQC directly equivalent to Minnesota's other *E. coli* criterion, which is stated as "nor shall more than ten percent of the samples[33] taken during any calendar month individually exceed 1260 organisms per 100 milliliters."

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[30] Minnesota divides its Domestic Consumption use into four subcategories: a) Domestic consumption-no treatment (Class 1A), b) Domestic consumption—with disinfection (Class 1B), and c) Domestic consumption—after typical drinking water treatment (Class 1 C), and d) Domestic Consumption—after Class C-level treatment plus additional steps. The WQC that apply to these subclasses are, with a few exceptions, exactly the same.

[31] Unlike the water quality criteria that the Agency issues for CWA purposes, the drinking water standards EPA promulgates, via formal rulemaking, under authority of the Safe Drinking Water Act are regulatory requirements, not just recommendations. EPA lacks actual drinking water supply criteria; that is, EPA has not published anything that specifies acceptable levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards that are related to ensuring safe levels of contaminants in drinking water apply to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable.

Also, it should be noted that, with the exception of total coliforms, the EPA Safe Drinking Water Act (SDWA) standards for the eight traditional/nontraditional parameters addressed in this section are "secondary" standards (related to taste, odor, and appearance of drinking water), rather than "primary" drinking water standards (related to health).

[32] The state has two subcategories of water-based recreational uses: 1) Aquatic recreation of all kinds, including bathing (Class 2A and Class 2B), and 2) Boating and other forms of aquatic recreation (Class 2C and Class 2D)

[33] Technically, this is not a water quality criterion because it describes the characteristics of a set of samples taken from a waterbody, rather than the desired condition of the waterbody itself. A true WQC would state something along the line of: "The density of E.coli in surface waters shall be higher than 1260 organisms/100 mL. no more than 10% of the time." What is presented as a WQC appears to be more like a waterbody assessment methodology—a proscribed means of interpreting data collected from a waterbody in order to infer the true (but never completely knowable, with current technology) condition of the waterbody over time and space.

e) Agricultural Water Supply

Minnesota has adopted WQC for protecting use of surface waters for irrigation for a number of pollutants for which there are not corresponding EPA criteria:

bicarbonates (HCO_3)
pH
salts (total dissolved)
sodium
specific conductance (applicable to wild rice areas)

The state has also adopted criteria for pH and total salinity that are applicable to use of waterbodies for livestock watering. Both Minnesota and EPA each have a criterion for boron/borates for this use, but the state's criterion is apparently intended to be an acute criterion (instantaneous concentration) while EPA's is a chronic criterion (long term average concentration).

f) Industrial Water Supply

Minnesota has adopted acute WQC regarding industrial water supply for the parameters calcium carbonate and pH. There are no corresponding EPA criteria for pH for this particular use, though there is a one for calcium carbonate.

2) Criterion-Concentration[34]

In those instances of traditional parameter/designated use combinations where both Minnesota and EPA have criteria, the majority of the state's criterion-concentrations are identical to EPA's. This is particularly true for Minnesota's "Domestic Consumption" criteria – the state has adopted EPA's Secondary (or Primary, in the case of the total coliform criteria) Drinking Water Standards as its water quality criteria for traditional pollutants.

a) Aquatic Life – "Cold water, etc"[35]

The state's acute and chronic chloride criteria for aquatic life protection have the same criterion-concentration as EPA's criteria. The criterion-concentration for Minnesota's chronic (one day duration) cool/warm water aquatic life criterion for dissolved oxygen is identical to EPA's acute (instantaneous) aquatic life criterion. EPA does not distinguish between cold and warm water habitats in its single DO criterion, which has a criterion-concentration of 5.0 mg/L. The state's cold water criterion-concentration (7.0 mg/L) is well within the range of that adopted

[34] According to EPA guidance, numeric water quality criteria (WQC) consist of three components: 1) a criterion-magnitude, 2) a criterion-duration, and 3) a criterion-frequency. The first of these—criterion-magnitude is usually expressed as a concentration; hence, the frequent use of "criterion-concentration" in this report. For some key water quality parameters, such as temperature and pH, quantity is not expressed as a concentration, so EPA employs the broader term "criterion-magnitude."

[35] Minnesota actually has four different subcategories of aquatic life uses: 1) Cold Water, 2) Cool or Warm Water Sport or Commercial Fish and Associated Aquatic Life, 3) Indigenous Fish and Associated Aquatic Life, and 4) Aquatic and Terrestrial Species Indigenous to Wetlands.

for this type of aquatic habitat by other states. Likewise, Minnesota's aquatic life criteria for pH are similar or identical to those issued by EPA and adopted by other states, for comparable types of aquatic ecosystems.

The criterion-concentration of Minnesota's WQC for boron for agricultural-irrigation uses is one-third lower than EPA's. Likewise, its industrial water supply (without pre-treatment) WQC for calcium carbonate has a lower criterion-concentration (50 mg/L) than any of EPA's, which range from 120 mg/L to 5,000 mg/L depending on the type of industry.

The criterion-concentrations of the state's chronic (four day duration) WQC for ammonia for cold water aquatic life (16 µg/L) is somewhat higher than the range of concentrations (over various temperature and pH levels) for both of EPA's early life stages absent (0.44 µg/L to 10.8 µg/L) criteria and early life stages present (0.18 µg/L to 6.7 µg/L) criteria. The state's criterion-concentration for cool/warm water aquatic life for ammonia is 40 µg/L. The criterion-concentrations for both the state's cold water and cool/warm water chronic (four day duration) criteria are within the respective ranges (over various pH readings) of EPA's criterion-concentrations for acute exposures (one hour duration) for: a) salmonids present—0.90 µg/L to 32.6 µg/L, and b) salmonids absent—1.32 µg/L to 48.8 µg/L.

Comparison of Minnesota's eutrophication criteria (total phosphorous, chlorophyll a, and turbidity measured by visibility depth of a Secchi disk) to those issued by EPA for these three water quality parameters is difficult because the state's WQS regulations break the state down into four different ecoregions while EPA's ecosystem map has designated only three ecoregions present in Minnesota. And though the names of some of the ecoregions used by the state and EPA are similar,[36] none are exactly the same. Nevertheless, comparison of the range of concentrations specified by Minnesota and EPA for lakes and reservoirs across all ecoregions and uses[37] within Minnesota may be of interest.

The range of criterion-concentrations specified for phosphorous for lakes and reservoirs in all use categories and all ecoregions is 12 µg/L to 90µg/L, while the span of concentrations specified by EPA is somewhat narrower: 8 µg/L to 37 µg/L. The corresponding ranges for the state's chlorophyll a WQC (in µg/L) are 3 to 30 and 2.43 to 8.59 for EPA's. And, for turbidity, expressed as the minimum depth at which a Secchi disk is still visible, Minnesota's criterion-magnitudes range (0.7 meters to 6.0 meters) has wider variation than the comparable EPA values (1.4 µg/L to 4.9 µg/L).

Minnesota did not revise its WQC for turbidity (NTUs) when it adopted its eutrophication criteria, even though EPA included such criteria applicable to rivers and streams in its package of recommended nutrient criteria. The state's chronic (4 day duration) WQC for cold water aquatic life has a criterion-magnitude of 10 NTU, while the corresponding WQC for cool and warm water aquatic life has a concentration of 25 NTUs. The criterion-concentration for EPA's chronic (growing season average) WQC for turbidity that is applicable to rivers and streams in its Ecoregion VII (Mostly Glaciated Dairy Region) is 1.7 NTU.

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[36] Examples of similar ecosystem names employed by the state of Minnesota and EPA: 1) Western Corn Belt Plains (MN) versus Corn Belt/Northern Great Plains (EPA), and 2) Northern Glaciated Plains (MN) versus both Mostly Glaciated Dairy Region (EPA) and Nutrient Poor, Largely Glaciated Upper Midwest (EPA).

[37] EPA does not distinguish between cold and warm water habitats in the WQC it has published for total phosphorous, total nitrogen, chlorophyll a or turbidity, in its set of "nutrient criteria." That is, within an ecoregion, the WQC for a given pollutant is the same, regardless of the natural temperature regime from one waterbody to the next. Minnesota, on the other hand, has two cold water life categories applicable to lakes and reservoirs within its Class A: 1) designated trout lakes; and 2) designated trout lakes (except lakes harboring lake trout). It also has Class 2B and 2Bd waters, both of which provide habitat for cool and warm water species.

b) Human Health: Consumption of Fish and Other Aquatic Organisms

Not applicable. Minnesota has not adopted human health fish consumption criteria for any traditional pollutants/parameters.

c) Human Health: Drinking Water Supply/ "Domestic Consumption"

The criterion-concentration in seven of the state's "Domestic Consumption" criteria that are applicable to traditional pollutants are the same as the corresponding EPA Secondary Drinking Water standards (per the Safe Drinking Water Act). This is the case for all of Minnesota's subclasses for Domestic Consumption use—1A, 1B, 1C, and 1D. That is, the criterion-concentration does not change from one subclass to another.

d) Human Health: Water-contact Recreation

The state's chronic (30 day duration) WQC for *E. coli* bacteria has the same criterion-concentration as EPA's 30-day WQC for *E. coli* bacteria —126 organisms per 100 mL.

There is no EPA WQC directly equivalent to Minnesota's criterion stated as "nor shall more than ten percent of the samples taken during any calendar month individually exceed 1260 organisms per 100 milliliters." The most closely related value that EPA has would seem to be its Single Sample Maximum Value for an upper 90% confidence level – 409 organisms/100 mL.[38]

e) Agricultural Water Supply

Not Applicable. There are no traditional parameters for which both EPA and Minnesota have WQC for agricultural water supply.

f) Industrial Water Supply

Not Applicable. There are no traditional parameters for which both EPA and Minnesota have WQC for industrial water supply.

[38] There is considerable confusion about EPA's "Single Sample Maximum" (SSM) values. Many take these to be bacterial densities that should never be surpassed. This reading of the EPA criterion document and associated guidance leads one to consider the SSM values as acute criteria with a criterion-duration of an instant and a criterion-frequency of zero.
In fact, the SSM values published by EPA are components of an assessment methodology, and address only those situations in which just one single grab sample has been collected in a 30 day period.
In essence, EPA's SSM values were derived by constructing a bell-shaped distribution with a log standard deviation of 0.4 centered on the criterion-concentration (126 organisms/100 mL for *E. coli*) for the EPA (chronic—30 day duration) WQC and marking the points on the concentration distribution curve above which only 25%, 18%, 10% and 5% of the *E. coli* or enterococci levels in the distribution fall. EPA refers to these as the upper 75%, 82%, 90% and 95% confidence levels. This means, for instance, that if just one grab sample of *E. coli* were taken from a waterbody, and it had an *E. coli* concentration equal to the 75 percentile SSM value (235 organisms/100 ml), there would be a 75% probability that the true waterbody 30-day geometric mean concentration would be equal to or greater than the criterion-concentration of 126 organisms/100 ml.

3) Articulation of Criterion-Duration[39]

Most of Minnesota's WQC for traditional pollutants have a clearly-stated criterion-duration, though there are exceptions with regard to water supply uses for drinking, agricultural, and industrial uses.

a) Aquatic Life/"Cold Water, etc."

The criteria for most traditional parameters have the same durations as applied to toxic pollutants, per aquatic life uses. Acute criteria are expressed as "one day average." (Section 7050.0222 Subpart 7(C) of the Minnesota's WQS regulations). There is some ambiguity as to whether "one day average" means: 1) one calendar day, or 2) any consecutive 24-hour period. A calendar day would be presumed to be the period between 12:00 AM (midnight) and 11:59 PM. The latter interpretation might also be characterized "rolling 24-hour average." For the same reason, the exact meaning of the duration for the state's chronic criteria ("four-day average") is also not entirely clear.

Minnesota's eutrophication criteria for total phosphorous and chlorophyll a have a criterion-duration of four calendar months, June through September.

Minnesota's criteria for temperature pertaining to cold water aquatic life and for aquatic and terrestrial species indigenous to wetlands employ language such as "no material increase," "maintain background," and "no heat shall be added…that would cause an increase of more than ___^{o}C." These are what this report refers to as "quasi-numeric" criteria—that is, they are expressed in terms of a certain change from background conditions. Unlike the case of typical numeric WQC, determination of whether such criteria have been exceeded requires knowledge of water quality: a) currently in other parts of the waterbody, and/or b) at times in the past. Also, there is no indication as to what duration(s) of time the "no change" standard is intended to apply. It would presumably apply to the overall natural background pattern of temperature, over time and space. If so, attention should be paid not only to the instantaneous temperature levels, but also average temperatures over various periods of time.

The dissolved oxygen criteria for wetlands are stated as "If background is less than 5.0 mg/L as a daily minimum, maintain background." Here, as with other D.O. criteria, the term "daily minimum" apparently means "minimum average concentration over a day" (rather than "lowest instantaneous concentration on any day").

b) Human Health: Consumption of Fish and Other Aquatic Organisms

Not Applicable. Minnesota has no criteria for traditional parameters for this use.

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[39] According terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion"—the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as four day average concentrations. The occurrence of one or more excursion (e.g., a four-day period in which the instream concentration of, for example, cyanide was higher than the criterion-concentration of 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedence of a water quality criterion occurred.

c) Human Health: Drinking Water Supply/ "Domestic Consumption"

The Minnesota WQS regulations do not clearly assign a duration to the criterion-concentrations presented in the column labeled "DC" (for Domestic Consumption) in the tables found in Section 7050.0220, Subparts 3a, 4a, 5a and 6a. Hence, a criterion-duration of an instant has been assumed for purposes of this report.

It is worth noting that Section 7050.0221, Subparts 2 and 3 adopt into the State's regulation, by reference, "…the primary (Maximum Contaminant Levels) and secondary drinking water standards issued by the United States Environmental Protection Agency…" Though these Safe Drinking Water Act standards are not directly expressed in a concentration-duration-frequency format, EPA regulations stipulate that compliance with the primary drinking water standards be determined by taking the average of at least four individual samples of finished drinking water collected over a twelve month period, with at least one sample taken in each of four calendar quarters. Another way to describe this methodology is to say that compliance is measured in terms of a "rolling" four calendar quarter average; that is, "rolling" means that attainment is determined by taking the average of all samples taken over any twelve month period starting with January 1, April 1, July 1, or October 1 of any year.

Nevertheless, given that most of the state's numeric WQC do specify a criterion-duration, the lack of a reference to a duration (or averaging period) in the portions of the regulations dealing with Domestic Consumption criteria makes the assumption of an instantaneous duration seem more appropriate than a 4-calendar quarter rolling average.

d) Human Health: Water-contact Recreation

One of Minnesota's criteria for *E. coli* bacteria states, "nor shall more than 10% of all samples collected in any calendar month individually exceed 1,260 organisms/100 mL." [40]

The criterion-duration for this WQC appears to be a second or instant. This is because of the reference to a percentage of samples. Most ambient monitoring for bacteria takes the form of "grab" sampling—collecting a series of single aliquots of water, by manual or mechanical means. It takes only a second to reach into the water and grab each of these individual samples; hence, the assumption that the duration of concern is an instant/second.

Both Minnesota's and EPA's chronic criteria for E.coli bacteria that are applicable to recreational use have a criterion-duration of 30 days.

e) Industrial Water Supply (with various levels of pre-treatment)

Minnesota's WQS regulations do not specify a criterion-duration applicable to the criterion-concentrations presented in the column labeled "IC" (for Industrial Consumption) in the tables found in Section 7050.0220, Subparts 3a, 4a, 5a and 6a.

[40] This is not a water quality criterion because it describes the characteristics of a set of samples taken from a waterbody, rather than the desired condition of the waterbody itself. A true WQC would state something along the line of: "The density of E.coli in surface waters shall be higher than 1260 organisms/100 mL. no more than 10% of the time." What is presented as a WQC appears to be more like a waterbody assessment methodology—a proscribed means of interpreting data collected from a waterbody in order to infer the true (but never completely knowable, with current technology) condition of the waterbody over time and space.

Absent a clear articulation of a criterion-duration, the criterion-duration for WQC for Industrial Water Supply is presumed to be an instant for the purposes of this analysis. Given that the state has articulated criterion-durations for most of its WQC, by not including any specific duration for IC criteria, the State would seem to imply that there is no applicable duration (i.e., duration is zero). We have chosen to characterize this presumed intent by listing the duration for these WQC as "instant" or "instantaneous."

f) Agricultural Water Supply (for irrigation and/or livestock watering)

Minnesota's WQS regulations do not specify a criterion-duration applicable to the criterion-concentrations presented in the column labeled "IR" and "LS" (for Irrigation and Livestock respectively) in the tables found in Section 7050.0220, Subparts 3a, 4a, 5a and 6a.

Absence a clear articulation of a criterion-duration, the criterion-duration for WQC for these two instances of Agricultural Water Supply is presumed to be an instant for the purposes of this analysis. Given that the state has articulated criterion-durations for most of its WQC, by not including any specific duration for IR and LS criteria, the State would seem to imply that there is no applicable duration for these criteria (i.e., duration is zero). We have chosen to characterize this presumed intent by listing the duration for these WQC as "instant" or "instantaneous."

4) Articulation of Criterion-Frequency[41]

Virtually all of the WQC for traditional pollutants/parameters appearing in the State's WQC regulations lack any mention of a criterion-frequency. (Exceptions: 1) the acute water contact recreation criterion for *E. coli* bacteria (criterion-frequency of ten percent) and 2) the acute total coliform WQC for Domestic Consumption (criterion-frequency of 5 percent).

A criterion-frequency of once in ten years applicable to all the state's WQC could possibly be inferred from the discussion of "Minimum Stream Flow" in Section 7050.0210, Subpart 7 of the Minnesota's WQS regulations, which states, "Point and nonpoint sources of water pollution shall be controlled so that the water quality standards will be maintained at all stream flows that are equal to or greater than the $7Q_{10}$ for the critical month or months..." [42] The validity of such a presumption could be called into question because: 1) no direct reference to such a criterion-frequency is made anywhere in the regulations; and 2) the criterion-duration (7

[41] In EPA water quality standard terminology, the criterion-frequency specifies the maximum rate at which "excursions" can occur and the waterbody of concern can still fully support the designated use to which the criterion applies. For instance, EPA guidance specifies a criterion-frequency of once in three (3) years for both its acute and chronic aquatic life WQC for toxic chemicals. This means that only if two or more excursions occur during any 3-year period has there actually been an exceedence of the WQC in question. For example, only if the 4 day average concentration of cyanide in a lake were higher than the chronic criterion-concentration of 5.2 µg/L more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

[42] It would be more accurate to refer to this as the "minimum $7Q_{10}$" or the "low $7Q_{10}$" because all riverine systems also have a "maximum $7Q_{10}$" or "high $7Q_{10}$." There is a tendency among those involved in Clean Water Act implementation, particularly persons in the NPDES program, to assume that "$7Q_{10}$" always refers to the low end of a stream's flow regime. This is because the "critical" condition for continuously-discharging point sources, such as municipal sewage treatment plants and non-stormwater discharges from industrial facilities, occurs during low stream flows—when there is less volume in the receiving water to dilute the pollutants in the effluent. By contrast, for precipitation-dependent sources, such as nonpoint sources or "wet weather" point sources, the critical stream condition is often at the high end of a river's flow distribution.

days) that would be inferred using the same logic is different from all the criterion-durations that are specified in the WQS regulations.

5) Discussion: WQC for Traditional Pollutants/Parameters[43]

Until recently, the most significant gap in Minnesota's WQC coverage for traditional pollutants was the absence of numeric criteria for the nutrients phosphorous and nitrogen, and the related response indicator chlorophyll a. Now, the state has a set of criteria for chlorophyll a and phosphorous applicable to lakes and reservoirs for each of the four ecoregions which the state agency has identified as present in Minnesota. Phosphorous and chlorophyll a criteria are still missing for rivers and streams; as are numeric criteria for total nitrogen aimed at the problem of unnatural eutrophication for all types of water bodies.

Despite its past lack of numeric criteria relevant to eutrophication, the state has included 150 waters on its 303(d) impaired waters list, citing nutrients as the key stressor. These listings reflect the willingness of the state to put waters on the 303(d) list based on conditions considered inconsistent with one or more of the state's narrative WQC. The recent adoption of numeric nutrient WQC will likely result in the identification of additional nutrient-impaired waters in Minnesota. "Nutrients" are among the five most frequently mentioned causes of impairment for waters on state 303(d) lists nationwide, along with "sediments/sedimentation," pathogens, mercury, and metals other than mercury.[44]

Also of note is the absence of acute (one-hour duration) and chronic (30-day duration) criteria for ammonia—one of the most commonly discharged pollutants nationwide according to EPA's Toxics Release Inventory. There is a "semi-chronic" criterion for ammonia, which has a criterion-duration of 4 days.

In its recent modifications to is WQS regulations, Minnesota supplemented its statewide aquatic life criteria for turbidity (expressed in terms of NTUs) with a set of four ecoregion-specific WQC for turbidity (expressed as the depth of visibility of a Secchi disk). These new turbidity criteria apply only to lakes and reservoirs, while the previously-established (NTU) turbidity criteria apply not only to lakes and reservoirs but also to rivers and streams. The state has 120 waters on its 303(d) list for which turbidity was the cited causative stressor.

The state apparently[45] has "Domestic Consumption" WQC for all the traditional contaminants/parameters for which EPA has established standards for "finished" drinking water,

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[43] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance, which includes: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. Also considered "traditional" in this document are several other non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen, oil and grease, total phosphorus, and turbidity, which are sometimes called "non-conventional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

[44] EPA National Section 303(d) List Fact Sheet: Causes of Impairment. Available at: http://iaspub.epa.gov/waters/national_rept.control#TOP_IMP.

[45] As noted earlier in this report (Section C.1.c) it is not clear whether the federal drinking water standard for total coliform bacteria applies to Class 1A waters. It clearly does not apply to Classes 1B, 1C, or 1D.

under authority of the federal Safe Drinking Water Act.[46] Recent changes to the WQS regulations deleted a NTU criterion applicable to this use; there is no federal drinking water standard for NTU.

With the exception of the standard for total coliforms, the EPA SDWA standards for the traditional parameters addressed in this section are Secondary Drinking Water Standards, which address problems of taste, odor, and appearance of drinking water. Primary Drinking Water Standards, including that for total coliform bacteria, on the other hand, are aimed at protecting human health. Secondary Drinking Water Standards are like the WQC EPA publishes pursuant to the CWA in that they are guidance, rather than regulatory requirements. Primary Drinking Water Standards, by contrast, are enforceable requirements that public water supplies must achieve in the finished drinking water that they send to their customers through their distribution system of pipes.

The criterion-concentrations in most of the state's WQC for traditionals pollutants are comparable to the criterion-concentrations in corresponding EPA criteria, and to those adopted by other nine states covered by this project. In the case of Minnesota's Domestic Consumption criteria, the criterion-concentrations for traditional parameters are identical to the concentrations specified in EPA's Drinking Water Standards. Some of the aquatic life criteria for phosphorous, turbidity, and ammonia have criterion-concentrations that are slightly higher than those in seemingly comparable EPA WQC.

The criterion-durations for most of the criteria for "traditionals, etc" are clearly stated. Exceptions are all WQC for "domestic consumption" and industrial and agricultural water supply, for which no mention of a duration is made in the regulations. A default duration of instantaneous is, therefore, assumed for purposed of this report.

Several criteria are stated as a "daily average." There is a question as to whether "daily average" is intended to literally mean average concentration over any calendar day, as opposed to average concentration over any rolling consecutive 24 hour period. The latter would seem to be more consistent with biological science, as the concept of a "day" starting at what humans choose to call 12:00 AM and ending at 11:59 PM is unlikely to be relevant to the physiology of aquatic animals and plants.

The vast majority of the state's WQC for traditionals do not have clearly articulated criterion-frequencies. The two exceptions are bacterial WQC, one for water contact recreation, and the other for Domestic Consumption. The former has a criterion-frequency of ten percent and the latter a five percent frequency.

Because of the lack of: 1) a clearly defined criterion-frequency in almost all of the state's WQC for traditionals, and 2) absence of well articulated criterion-durations in some WQC for such pollutants/parameters, it is difficult to make conclusive judgments about the degree of protection provided to applicable designated use(s) by the state's criteria, in an absolute sense or relative to the degree of protection provided by corresponding EPA criteria. Obviously, such comparisons between two WQC can only be done when one knows the concentration, duration, and frequency for both. Unfortunately, most of EPA's criteria for traditionals lack mention of a criterion-duration and criterion-frequency. Comparisons could be made involving most of

[46] EPA has not published any drinking water supply water quality criteria – specifications of levels of contaminants in surface waters consistent with their use as a "raw" water supply by public drinking water systems. For toxic chemicals, it has issued WQC aimed at protecting humans who consume both: 1) drinking water, and 2) aquatic organisms that originate in local surface water. EPA's Safe Drinking Water Act standards apply to "finished" water – that water that results from "raw" water being passed through a treatment system aimed at removing contaminants.

Minnesota's criteria for traditionals only if assumptions were made regarding the criterion-duration and/or criterion-frequency. The results of attempts to compare the protection provided by a state versus an EPA criterion would, of course, be greatly affected by whatever assumptions were made.

For example, one could reasonably assume that both the state and EPA intend that, with the exception of certain WQC for pathogens, all their WQC for traditionals have a criterion-frequency of zero, given that both the state and EPA make no reference to an acceptable rate of excursions (i.e., a criterion-frequency). But, for EPA, a frequency of once in three years for its aquatic life WQC for traditional parameters could be inferred from the fact that the agency has clearly specified such a criterion-frequency for its aquatic life WQC for toxic chemicals. If two WQC for the same pollutant/use combination had identical criterion-concentrations and criterion-durations, then the criterion with the lowest criterion-frequency would be the more protective. For example, if Minnesota's criterion-frequency were zero, and EPA's were once in three years, a state WQC with a concentration and a duration identical to the federal agency's would be somewhat more protective. On the other hand, if the criterion-frequency for both the state and EPA were zero, then these particular two WQC would be equally protective of aquatic life.

Additional uncertainty is created by the fact that, although all of Minnesota's WQC for traditional parameters have fairly clearly stated criterion-durations, EPA's criterion documents for most traditionals make no reference to a criterion-duration. For instance, Minnesota specifies one day as the criterion-duration for its acute aquatic life criteria. If EPA's silence regarding a criterion-duration is taken to infer a duration of an instant, then a Minnesota acute aquatic life WQC with a criterion-concentration identical to that in the corresponding EPA WQC would be less protective, given that its criterion-duration (24 hours, of 86,400 seconds) is significantly longer than the assumed EPA duration of just one instant/second. This statement is predicated on the assumption of the state and EPA criteria having the same criterion-frequency, whatever it might be. A different assumption regarding the criterion-duration (i.e., a longer duration) for the EPA WQC could possibly change the balance of protection.

Minnesota's acute cold water aquatic life WQC for dissolved oxygen (DO) presents a more challenging situation, with regard to determining relative degree of protection compared to the corresponding EPA WQC. The state's criterion-concentration for D.O. for this particular use is 7.0 mg/L, while EPA's generic (no distinction between cold and warm water or other variants) WQC has a concentration of 5.0 mg/L. This differential in criterion-concentrations suggests the state's WQC is more protective. However, the state's criterion-duration (1 day) is substantially longer than the apparent EPA duration (one instant), which taken by itself suggests the state's WQC is less protective. Assuming both criteria have a criterion-frequency of zero, then one is left to ponder to what degree would the more-protective effect of the higher oxygen concentration of the state WQC be offset by the less-protective effect of a longer duration.

Another variant is presented by Minnesota's Domestic Consumption WQC for traditional contaminants. Here, the state and EPA criterion-concentrations are identical, the state's criterion-duration (one instant, assumed) is much shorter than EPA's implicit duration of twelve months for its SDWA standards, and the frequencies for both are assumed to be zero, given that neither the state nor the federal agency mentions a criterion-frequency. The much shorter duration in the state's WQC, compared that in EPA's somewhat corresponding standard, would make the state's criterion considerably more protective. For instance, the Minnesota "Domestic Consumption" criterion for chlorides would limit concentrations to 250 mg/100 mL or less at all

times, whereas EPA's standards would allow numerous instances with concentrations above 250 mg/L, so long as the twelve-month average concentration was 250 mg/L or less.

A further confounding factor pertaining to criteria aimed at risks associated with consuming contaminants in drinking water is the fact that most states' water quality criteria for public water supply ("Domestic Consumption," in Minnesota's case) apply to the untreated water from a river or lake that is used as a "raw" water supply for a public drinking water system, while EPA's standards established under the Safe Drinking Water Act (SDWA) apply to "finished" drinking water at the tap, which usually has undergone some form of treatment to remove contaminants. Hence, for a given pollutant, a drinking water supply WQC with a concentration equal to that specified in a drinking water standard could actually provide greater protection to consumers of finished drinking water. For instance, if the drinking water treatment process to which the raw water is subjected removes 50% of a certain pollutant, then the level of the pollutant in the raw water could be two-times the concentration specified by the SDWA standard, and still meet that standard in the finished drinking water. For example, EPA's Secondary Drinking Water Standard for chloride is 250 mg/L, so a water quality criterion for raw drinking water supply with a criterion-concentration of 500 mg/L should result in finished drinking water with a concentration equal to that of the drinking water standard (250 mg/L). And, if the drinking water treatment system could remove more than 50% of the chloride, e.g., 80%, then a water supply criterion with a concentration of 500 mg/L would lead to finished drinking water with a chloride level of 100 mg/L.

A reading of Part 7050.0221, subparts 3 and 4 of the state regulations gives the impression that Minnesota had taken treatment efficacy into account when establishing its WQC for subclasses 1B, 1C, and 1D of its Domestic Consumption use class. For example, Subpart 4 indicates that WQC for Class 1C waters should be set at such a level "that with treatment consisting of coagulation, sedimentation, filtration, storage, and chlorination, or other equivalent treatment, the treated water will meet…drinking water standards issued by the United States Environmental Protection Agency…." By contrast WQC for Class 1 waters are to be set at levels "such that without treatment of any kind raw waters will meet … (federal drinking water standards). These two bits of regulatory text strongly suggest that, at least for some contaminants, the Domestic Consumption Class 1C WQC would have a considerably higher criterion-concentration than that for Class 1A waters. Yet, for all traditional parameters, they are exactly the same. Hence, it would seem that those persons whose drinking water originated in Class 1C waters would be afforded a higher level of protection from adverse effects of waterborne pathogens than those whose drinking water originated from Class 1A waters. Likewise, it would seem quite possible that the aesthetic quality of finished drinking water that started out as raw water in a Class 1C would be superior to water coming from Class 1A waters. That is, that levels of the traditional parameters that, at levels above Secondary Drinking Water Standards would likely result in unpleasant taste and/or odor, would be at levels well below said Standards in finished drinking water produced by treating water from a Class 1C waterbody.

Returning to problems associated with lack of clearly-stated criterion-durations and criterion-frequencies, these can render considerably more challenging the implementation of CWA programs that are driven largely by WQC (Section 303(d) and 305(b) assessment and reporting, TMDLs, and water quality-based NPDES permitting programs). Clearly, it would be difficult for someone implementing one of these "downstream" CWA programs to deal with a WQC having a criterion-concentration reading "levels no greater than approximately 40 µg/L - 60 µg/L." Though perhaps less immediately obvious, imprecisely-stated criterion-durations and

criterion-frequencies can pose similar challenges to those presented by missing or vaguely-stated criterion-magnitudes. For example, if over some 30 day period, four "grab" samples had been collected from a waterbody, passed quality assurance/quality control screening, and analyzed for levels of a certain pollutant, and one of those samples had a concentration higher than a relevant criterion-concentration, the answer to the question "Has this pollutant exceeded this WQC in the sampled waterbody?" would differ depending on the criterion-duration and criterion-frequency. If the duration were "instantaneous" and the frequency "zero," the WQC would have been exceeded, without question. But, if the duration was 30 days and the frequency remained at zero, the mere fact that one out of four instantaneous measurements surpassed the criterion-concentration would not prove that an exceedence had occurred. Rather, only if the *average* of the concentrations in the four samples were higher than the criterion-concentration would there be strong evidence of an exceedence of WQC in the water from which said samples were collected. And, if the criterion-frequency were "two or more times per year," then the possibility that a WQC exceedence had not occurred should be considered.[47]

D) Toxic Chemicals

1) Coverage

a) Aquatic Life / "Cold water," "Cool and warm water"

Acute Toxicity

The state has acute aquatic life WQC for 57 toxic pollutants. Minnesota has not adopted acute aquatic life criteria for six (6) toxic chemicals for which EPA has issued Section 304(a) criteria (Appendix B, Table 1).

On the other hand, the state has adopted acute aquatic life criteria for 32 pollutants for which EPA has not issued corresponding Section 304(a) criteria. The majority of these are synthetic organic chemicals, including a number of pesticides (Appendix B, Table 3).

Chronic Toxicity

The state has chronic aquatic life WQC for 57 toxic pollutants. Minnesota has not adopted chronic aquatic life criteria for 21 toxic chemicals for which EPA has issued chronic Section 304(a) criteria (Appendix B, Table 1).

On the other hand, the state has adopted chronic aquatic life criteria for seventeen pollutants for which EPA has not published corresponding criteria (Appendix B, Table 3). Of

[47] Actually, depending on how much data had been collected, there could be a very good chance that more than one excursion had occurred, even if only one had been observed. This is because it would be contrary to the laws of probability to conclude that no additional excursions (30-day periods with average bacterial concentrations about the criterion-concentration) had occurred during any twelve-month period encompassing the 30 days in which the four grab samples had been collected, if these four individual samples were the only ones gathered during a given twelve-month period. The reason for this conclusion is that, given that there are 336 30-day periods in any twelve-month period, the odds of having randomly chosen to collect samples during the only 30-day period in which an excursion occurred are very low. (Several times lower than randomly selecting a card from a well-shuffled deck of 52, and having that card turn out to be one named in advance.)

these, the criteria for two pollutants (acetochlor and methoxychlor) have been recently adopted. EPA has not issued aquatic life criteria for either one of these pollutants.

b) Human Health: Consumption of Fish and Other Aquatic Organisms/ "Human Health-based aquatic life criteria" (Classes 2B, 2C, and 2D)[48]

Minnesota has adopted WQC for 29 toxic chemicals that apply solely to exposure of humans to toxic chemicals via consumption of aquatic organisms ("sport and commercial fish," in the state's case) that correspond to EPA's "human health: organisms only" (HHO) criteria. EPA, by contrast, has HHO WQC for 106 toxic substances.

Of the 29 pollutants for which the state has such WQC, there is one pollutant—1,1,1 trichloroethane—for which there is not a corresponding EPA criterion.

These Minnesota WQC apply to Classes 2B, 2C , and 2D waters, which represent various types of cool and warm water habitats. (Class 2A waters are cold water habitat).

c) Human Health: Drinking Water Supply/ "Domestic Consumption"

Minnesota has two sets of WQC that are relevant to provision of a supply of water to be used as raw (before treatment) water for public drinking water systems: 1) "Domestic Consumption" criteria, and 2) "Human Health-based aquatic life" criteria for Classes 2A and 2Bd. The "Domestic Consumption" criteria are aimed at situations in which people are using a waterbody as a raw water source for their drinking water, but are not consuming fish and/or other aquatic life from the waterbody. These criteria are discussed in this portion of the report. The "Human Health-based aquatic life criteria" for Classes 2A and 2Bd are aimed at waterbodies which people use as a source of both: a) drinking water, and b) a portion of their diet. These criteria are covered in Subsection D(1)(c) of the report, below.

"Domestic Consumption**"** criteria are listed in a column labeled "DC" in the tables found in Subparts 2, 3, and 4 of Section 7050.0220 of the Minnesota WQS regulations. The state has "DC" criteria for 82 toxic pollutants, 77 of which are covered by Primary Drinking Water Standards (often referred to as Maximum Contaminant Levels--MCLs) that EPA has promulgated under the SDWA. The state has adopted <u>all</u> of EPA's SDWA drinking water standards for toxic contaminants as its own "Domestic Consumption**"** criteria, with the exception of the federal Primary Drinking Water standards for acrylamide, chloramines, chlorine, chlorine dioxide, epichlorohydrin, copper, and lead. These exceptions are set forth in the recently adopted (March 2008) subsection B of Part 7050.0221. The state also has "Domestic Consumption**"** criteria for five (5) toxic pollutants for which EPA has not issued SDWA standards – aldicarb, aldicarb sulfoxide, aldicarb sulfone, chloroform,[49] and bromoform.[50]

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[48] Class 2B waters are to support "propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life". Class 2C waters are to support "propagation and maintenance of a healthy community of indigenous fish and associated aquatic life." Class 2D waters are to support "propagation and maintenance of a healthy community of aquatic and terrestrial species indigenous to wetlands." None of these three categories are also protected as drinking water supply. Chronic criteria ("CS") aimed at protecting humans from adverse effects of ingestion of toxic chemicals through the combination of consumption of drinking water and sport or commercial fish are listed as "HH" in the tables appearing in 7050.0220 Subp. 4, Subp. 5 and Subp. 6.

[49] Although EPA has not issued an MCL for chloroform (trochloromethane), the Agency has issued Maximum Contaminant Level Goal (MCLG) for Total Trihalomethanes, a group of pollutants of which chloroform is a member. The MCLG for chloroform is 70 μg/L.

d) Human Health: Water and Organisms (HHWO) / "Human Health (HH)-based aquatic life criteria" (Classes 2A and 2Bd)"[51]

"Human Health-based aquatic life" criteria applicable to Class 2A and 2Bd waters are listed in the column labeled "CS" in the tables found in Subparts 2, and 3 of Section 7050.0220 of the Minnesota WQS regulations. The uses relevant to these "CS-HH criteria" are apparently, according to the opening paragraphs of Subparts 2 and 3 in Section 7050.0222: a) human consumption of drinking water, plus) human consumption of sport-caught fish. These criteria are, therefore, comparable to EPA's Human Health: Water and Organisms (HHWO) criteria.

Minnesota has not adopted criteria for 85 of the 113 pollutants for which EPA has issued HHWO criteria (Appendix B, Table 2). On the other hand, the state has adopted "Human Health (HH)-based aquatic life" for Classes 2A and 2Bd criteria for 7 "extra" pollutants for which EPA has not issued corresponding HHWO criteria (Appendix B, Table 4). Hence, the state has this type of WQC for 31 pollutants.

Note: There are toxic 26 pollutants for which Minnesota has both a "Domestic Consumption**"** and a "consumption of drinking water and sport-caught fish criteria." On the other hand, there is a large number of pollutants for which EPA has issued HHWO criteria but for which Minnesota has neither adopted "domestic consumption" nor "human health" criteria.

e) Agricultural Water Supply

Not Applicable. Minnesota has no WQC for toxic chemicals that are applicable to agricultural water supply.

f) Industrial Water Supply

Not Applicable. Minnesota has no WQC for toxic chemicals that are applicable to industrial water supply.

2) Criterion-Concentration[52]

a) Aquatic Life – "Cold water," "Cool and warm water"

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[50] Although EPA has not issued an MCL for bromoform (tribromomethane), the Agency has issued Maximum Contaminant Level Goal (MCLG) for Total Trihalomethanes, a group of pollutants of which bromooform is a member. The MCLG for bromoform is zero (0) µg/L.

[51] Class 2A waters are to support "propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life. Class 2Bd waters are to support "propagation and maintenance of a healthy community of cool and warm water sport or commercial fish and associated aquatic life. Class 2A and Class 2Bd waters are also protected as a source of drinking water. Chronic criteria ("CS") aimed at protecting humans from adverse effects of ingestion of toxic chemicals through the combination of consumption of drinking water and sport or commercial fish are listed as "HH" in the tables appearing in 7050.0220 Subp. 2 and Subp. 3.

[52] According to EPA guidance, numeric water quality criteria (WQC) consist of three components: 1) a criterion-magnitude, 2) a criterion-duration, and 3) a criterion-frequency. The first of these—criterion-magnitude is usually expressed as a concentration; hence, the frequent use of "criterion-concentration" in this report. For some key water quality parameters, such as temperature and pH, quantity is not expressed as a concentration, so EPA employs the broader term "criterion-magnitude."

Acute Toxicity

Of the 57 toxic pollutants for which Minnesota has adopted acute freshwater aquatic life WQC, 25 pollutants[53] have WQC for which there are corresponding EPA recommended WQC. Within this subset, five pollutants have acute freshwater aquatic life WQC for which the criterion-concentrations are the same as those in the corresponding EPA criteria; eight (8) pollutants have acute freshwater aquatic life WQC for which the criterion-concentrations are lower than those in the corresponding EPA criteria (Appendix B, Table 5); and 12 pollutants have acute freshwater aquatic life WQC for which the criterion-concentrations are higher than those in the corresponding EPA criteria (Appendix B, Table 6).

Chronic Toxicity

Of the 31 toxic pollutants for which Minnesota has adopted chronic freshwater aquatic life WQC, fourteen pollutants[54] have corresponding (i.e., chronic aquatic life) EPA recommended WQC. Within this subset, there are six WQC for which the criterion-concentrations are the same as those in the corresponding EPA criteria; one has a criterion-concentration lower than that in the corresponding EPA criteria (Appendix B, Table 5); and seven have criterion-concentrations higher than those in the corresponding EPA criteria (Appendix B, Table 6).

b) Human Health: Consumption of Fish and Other Aquatic Organisms/"Human Health-based aquatic life criteria" (Classes 2B, 2C, and 2D)

Minnesota has adopted "Human Health (HH)–based aquatic life" criteria applicable to Class 2B, 2C and 2D waters for 29 pollutants. These criteria are aimed at protecting persons who consume sport fish from the designated waters, but the public water supply that serves them does not draw its raw water from said waters. The criterion-concentrations are identical for each of these three classes.

Of the 29 pollutants for which the state has such WQC, 28 are ones for which EPA has corresponding (Human Health: Organisms [HHO]) criteria. Criteria for fourteen of these pollutants have a criterion-concentration higher than that for the EPA criterion, and the remaining fourteen criteria have lower criterion-concentrations than EPA's.

c) Human Health: Drinking Water Supply/ "Domestic Consumption"

The criterion-concentrations in all of the state's "Domestic Consumption" criteria for toxic pollutants are the same as those of the corresponding Primary Drinking Water Standards that EPA issued under the Safe Drinking Water Act, with the exception of the Class 1D criteria for a few substances. Of the latter, the state's Class 1D criteria for barium, fluoride, and selenium have lower criterion-concentrations than the SDWA standard, while the state WQC for arsenic and cadmium have criterion-concentrations that are higher than the concentrations in the EPA drinking water standards.

[53] The remaining 33 pollutants are ones for which EPA has not issued acute aquatic life criteria.
[54] The other seventeen pollutants are those for which EPA has not adopted corresponding criteria.

d) Human Health: Water and Organisms / "Human Health (HH)-based aquatic life criteria" (Classes 2A and 2Bd)

Minnesota has adopted "Human Health (HH)–based aquatic life" criteria applicable to Classes 2A and 2Bd for 35 pollutants. These criteria are aimed at protecting persons who consume both 1) drinking water, and 2) fish and other aquatic organisms from waterbodies to which the criteria apply.

Of the 35 toxic pollutants for which Minnesota has adopted "Human Health (HH)–based aquatic life" criteria that are applicable to class 2A (cold water fishery and drinking water) waters, there are 28 pollutants for which the criteria are comparable to EPA's "human health: water and organisms (HHWO)" criteria. Within this subset, the criterion-concentrations in the criteria for 10 pollutants are lower than those in the corresponding EPA criteria (Appendix B, Table 7). And within this same subset, the criterion-concentrations in the criteria for eighteen pollutants are higher than those in the corresponding EPA criteria (Appendix B, Table 8). Of note is the criterion-concentration for arsenic, which is higher that the corresponding EPA value by two orders of magnitude.

Of the 35 toxic pollutants for which Minnesota has adopted "Human Health (HH)–based aquatic life" criteria that are applicable to Class 2Bd (cool and warm water fishery and drinking water uses), there are 28 pollutants for which there are corresponding HHWO criteria published by EPA. Within this subset, the criterion-concentrations in the criteria for eleven pollutants are lower than those in the corresponding EPA criteria (Appendix B, Table 7). Also within this same subset, the criterion-concentrations in the criteria for seventeen pollutants are higher than those in the corresponding EPA criteria (Appendix B, Table 8).

e) Human Health: Water-based Contact Recreation

Not Applicable. Minnesota has no WQC for toxic chemicals that are applicable to water-based contact recreation.

f) Agricultural Water Supply

Not Applicable. Minnesota has no WQC for toxic chemicals that are applicable to agricultural water supply.

g) Industrial Water Supply

Not Applicable. Minnesota has no WQC for toxic chemicals that are applicable to industrial water supply.

3) Articulation of Criterion-Durations[55]

[55] According terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion"—the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as 4 day

With the exception of those applicable to water supply uses – domestic, industrial, and agricultural uses – the criterion-durations in Minnesota's criteria for toxic chemicals are relatively clear.

a) Aquatic Life – "Cold water," "Cool and warm water"

The durations are specified in Section 7050.0222 Subpart 7 (C) as "1 day" and "4 days," for acute and chronic criteria, respectively, for all categories of aquatic life use. (See discussion of ambiguity associated with the word "daily" in section B(3)(a) of this report, above.)

b) Human Health: Consumption of Fish and Other Aquatic Organisms/ "Human Health-based aquatic life criteria" (Classes 2B, 2C and 2D)

Section 7050.0222 Subpart 7 (C) of the state's WQS regulations specifies that, "…the CS (chronic standard), based on human health or wildlife toxicity, will be a 30-day average." For purposes of this report, this is presumed to mean a rolling 30-day average, as opposed to any 30 day period commencing on the first day of any calendar month because no reference is made to "month(s)" in this specific portion of the regulations.

c) Human Health: Drinking Water Supply/"Domestic Consumption"

The Minnesota WQS regulations do not clearly assign a duration to the criterion-concentrations presented in the column labeled "DC" (for Domestic Consumption) in the tables found in Section 7050.0220, Subparts 3a, 4a, 5a and 6a of the state's WQS regulations. Hence, a criterion-duration of an instant has been assumed for the purposes of this report.

An alternative assumption that could possibly apply only to toxic chemicals would be that the duration applicable to these criteria is the same as that for those criteria for toxics listed in the tables found in Section 7050.0220, Subparts 3a, 4a, 5a and 6a under "CS" (chronic standard), and which are also identified in the tables in 7050.0222, Subparts 2 and 3 as having effects on human health ("HH"), rather than toxicity to aquatic organisms ("Tox"), as their basis. Under this interpretation, the applicable criteria-duration would be 30 days. (Section 7050.0222 Subpart 7 (C) of the state's WQS regulations specifies that, "…the CS (chronic standard), based on human health or wildlife toxicity, will be a 30-day average." For purposes of this report "30 day average" is presumed to mean a rolling 30-day average, as opposed to any 30 day period commencing on the first day of any calendar month, given that the word "month" does not appear in this specific portion of the regulations.

It is also worth noting that Section 7050.0221, Subparts 2 and 3 adopt into the state's regulation, by reference, "…the primary (maximum contaminant levels)… drinking water standards issued by the United States Environmental Protection Agency…" Though these standards are not directly expressed in a concentration-duration-frequency format, EPA

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average concentrations. The occurrence of one or more excursion (e.g., a four-day period in which the instream concentration of, for example, cyanide was higher than the criterion-concentration of 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedence of a water quality criterion occurred

regulations stipulate that compliance with the primary drinking water standard be determined by taking the average of at least four individual samples of finished drinking water collected over a twelve-month period, with at least one sample taken in each of four calendar quarters. Another way to describe this methodology is to say that compliance is measured in terms of a "rolling" four calendar quarter average; that is, rolling" means that attainment is determined by taking the average of all samples taken over any twelve month period starting with January 1, April 1, July 1, or October 1 of any year.

Nevertheless, given that most of the state's numeric WQC do specify a criterion-duration of a day or longer, the lack of a reference to a duration (or averaging period) in the portions of the regulations dealing with its "Domestic Consumption" criteria makes the assumption of an instantaneous duration seem more appropriate than either a 30-day or a four-calendar quarter rolling average.

d) Human Health: Water and Organisms / "Human Health (HH)-based Aquatic life criteria" (Classes 2A and 2Bd)

Section 7050.0222 Subpart 7 (C) of the state's WQS regulations specifies that, "…the CS (chronic standard), based on human health or wildlife toxicity, will be a 30-day average." For purposes of this report, this is presumed to mean a rolling 30-day average, as opposed to "any 30 day period commencing on the first day of any calendar month" because no reference is made to "month(s)" in this specific portion of the regulations.

e) Human Health: Water-based Contact Recreation

Not Applicable. Minnesota has no WQC for toxic chemicals that are applicable to water-based contact recreation.

f) Industrial Water Supply (with various levels of pre-treatment)

Not Applicable. Minnesota has no WQC for toxic chemicals that are applicable to use of waterbodies as a water supply for industrial operations.

g) Agricultural Water Supply (for irrigation and/or livestock watering)

Not Applicable. Minnesota has no WQC for toxic chemicals that are applicable to use of waterbodies as a water supply for agricultural operations.

4) Articulation of Criterion-Frequencies[56]

Criterion-frequencies have not been defined for any of the WQC for toxic chemicals appearing in the state's WQC regulations. In the absence of any mention of an acceptable frequency of excursions (ambient conditions worse than those described by the combination of the criterion-concentration and criterion-duration), assumption of a frequency of zero appears appropriate.

A criterion-frequency of once in ten years applicable to all the state's WQC could possibly be inferred from the discussion of "Minimum Stream Flow" in Section 7050.0210, Subpart 7 of the state's WQS regulations, which include, "Point and nonpoint sources of water pollution shall be controlled so that the water quality standards will be maintained at all stream flows that are equal to or greater than the $7Q_{10}$ for the critical month or months…." In addition, the "Seven-day ten-year low flow or $7Q_{10}$"[57] is defined in Section 7050.0130. Subpart 3 of the state's WQS regulations as "the lowest average seven day-flow with a once in ten-year recurrence interval." The validity of a presumption of a one-in-ten year criterion-frequency is brought into question by two facts: 1) no direct reference to such a criterion-frequency is made anywhere in the regulations; and 2) the criterion-duration—seven days—that would be inferred using the same logic is different from all the criterion-durations that are specified in the WQS regulations.

Hence, a criterion-frequency of zero is assumed to be applicable to all of Minnesota's WQC for toxic chemicals.

5) Discussion: Criteria for Toxic Chemicals

Criteria Related to Aquatic Life Protection

Minnesota has adopted *acute* aquatic life criteria for more than two dozen pollutants and chronic aquatic life criteria for more than one dozen pollutants for which EPA has not published corresponding aquatic life criteria. Conversely, Minnesota has not established acute aquatic life criteria for a half-dozen pollutants. The state also lacks chronic aquatic life criteria for nearly two dozen toxic pollutants for which EPA has adopted chronic aquatic life criteria. Of these "missing" pollutants, several are pesticides that fall into categories frequently mentioned as

[56] In EPA water quality standard terminology, the criterion-frequency specifies the maximum rate at which "*excursions*" can occur and the waterbody of concern can still fully support the designated use to which the criterion applies. For instance, EPA guidance specifies a criterion-frequency of once in three (3) years for both its acute and chronic aquatic life WQC for toxic chemicals. This means that only if two or more excursions occur during any three-year period has there actually been an *exceedence* of the WQC in question. For example, only if the four day average concentration of cyanide in a lake were higher than the chronic criterion-concentration for CN of 5.2 μg/L more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

[57] It would be more accurate to refer to this as the "minimum $7Q_{10}$" or the "low $7Q_{10}$" because all riverine systems also have a "maximum $7Q_{10}$" or "high $7Q_{10}$." There is a tendency among those involved in Clean Water Act implementation, particularly persons in the NPDES program, to assume that "$7Q_{10}$" always refers to the low end of a stream's flow regime. This is because the "critical" condition for continuously-discharging point sources, such as municipal sewage treatment plants and non-stormwater discharges from industrial facilities, occurs during low stream flows—when there is less volume in the receiving water to dilute the pollutants in the effluent. For precipitation-dependent sources, such as nonpoint sources or "wet weather" point sources, on the other hand, the critical stream condition is often at the high end of a river's flow distribution.

possible endocrine disruptors (DDT, chlordane, dieldrin, heptachlor, methoxychlor, toxaphene, and pentachlorophenol).

Where the state has adopted aquatic life criteria corresponding to EPA's WQC, on the other hand, the criterion-concentrations in Minnesota's acute aquatic life criteria are a mix of those that are higher than, lower than, and equal to the criterion-concentrations in EPA's corresponding criteria – with the largest portion being the criterion-concentrations that are higher than those in EPA's corresponding criteria. The state's chronic criterion-concentrations are generally equal to or higher than the criterion-concentrations in the corresponding EPA criteria

The criterion-durations for criteria for toxics applicable to aquatic life are clearly stated in the Minnesota WQS regulations. The applicable criterion-durations are one day and four days for state's acute and chronic aquatic life criteria, respectively.

All the state's aquatic life WQC for toxics criteria lack any specific language regarding a criterion-frequency. Hence, a criterion-frequency of zero is assumed, for purposes of this report.

Criteria Related to Human Health Protection

The state has adopted all of the Primary Drinking Water Standards promulgated by EPA under the Safe Drinking Water Act as its own state "Domestic Consumption" criteria for toxic substances. These state WQC apply to surface waters that currently, or might in the future, serve as a sources of "raw" water for a public drinking water system. By contrast, EPA's Primary Drinking Water Standards apply to "finished' drinking water—the (usually) treated water that a drinking water utility sends out through its distribution lines to its customers.

A significant gap in the Minnesota's array of WQC relates to those criteria intended for addressing human health risks associated with the combined consumption of: 1) water and fish (or other aquatic organisms). Indeed, the state has adopted "Human Health (HH)-based aquatic life" criteria pertaining to Class 2A and 2Bd (designated for both aquatic life and domestic consumption use) for less than 25% of the 112 pollutants for which EPA has published corresponding criteria ("Human Health: Water and Organisms" – HHWO). Though some of the pollutants lacking criteria for combined drinking water and fish consumption are covered by the state's "Domestic Consumption" (of water) criteria, several dozen of the missing pollutants are not.

Likewise, the state has established criteria for a relatively small portion of the 106 toxic substances for which EPA has issued WQC dealing with consumption of fish and other aquatic organisms alone (i.e., not combined with consumption of drinking water). Such EPA criteria are referred to as Human Health: Organisms (HHO) criteria. In the Minnesota WQS regulations, such WQC are those "Human Health (HH)-based aquatic life" criteria pertaining to Classes 2B, 2C, and 2D (designated for various forms aquatic life, but not for domestic consumption use).

Most of the pollutants lacking state equivalents to EPA's HHWO and/or HHO criteria are synthetic organic chemicals, including over two dozen known or suspected carcinogens (e.g., beta-BHC, 1,3-dichloropropene, and 2,4-dinitrotoluene); persistent bioaccumulators (e.g., anthracene, benzo(a)pyrene, hexachlorobutadiene); and a number of potential endocrine disruptors (e.g., aldrin, 2,4-D, and methoxychlor). Also among the pollutants lacking state equivalents to EPA's "Human Health: Water & Organism" and "Human Health: Organisms" criteria are several polycyclic aromatic hydrocarbons, which are not only carcinogenic and bioaccumulative, but are also commonly found in urban stormwater. And, like phthalate esters, for some of which Minnesota also lacks "Human Health (HH)–based aquatic life" criteria

corresponding to EPA's HHWO or HHO criteria, polycyclic aromatic hydrocarbons are among those types of chemicals cited by numerous sources as likely endocrine disruptors. In addition, the state lacks HHWO- and HHO-equivalent criteria for methoxychlor and pentachlorobenzene – pollutants reported to be associated with suspended materials in parts of the Mississippi River.

In theory, the absence of a human health criterion for a pollutant might not be essential to ensuring that people are protected from exposure (via ingestion of drinking water and/or eating aquatic organisms) to levels of that pollutant that pose a significant risk. In particular, if Minnesota has an acute and/or a chronic aquatic life criterion for the pollutant with a criterion-concentration lower than that in EPA's human health criteria for the pollutant of concern, attainment of the aquatic life criterion would ensure that waterbody levels of the pollutant would remain below those specified in EPA's human health criteria. This statement is based upon the assumption that EPA's human health criteria have a criterion-duration equal to or longer than the 96 hour duration of the state's chronic aquatic life WQC. This is a reasonable assumption, given that the EPA methodology for developing human health WQC for toxics specifies an assumed duration of exposure of an average human lifetime—70 years, which strongly suggests a criterion-duration of as long as seven decades. On the other hand, there is language in various parts of EPA guidance documents that can be read in such a way as to imply a criterion-duration of just an instant for the Agency's human health WQC for toxics. If the criterion-duration were just a second—a much shorter period than 96 hours—then it would not follow that any state WQC having a criterion-concentration lower than EPA's would provide greater protection than application of the federal agency's WQC.

Where the state has adopted criteria related to human health, the group of criteria with the largest number of criterion-concentrations that are either higher or lower than those in the corresponding EPA criteria (human health: water and organisms (HHWO)) is that involving the combined human consumption of water and fish (or other aquatic organisms) – Minnesota's "Human Health (HH)–based aquatic life" criteria for Classes 2A and 2Bd. The differences maybe due to the state's use of somewhat different average values for lipids in sport fish than did EPA. This factor also explains why the criterion-concentrations for the "Human Health (HH)–based aquatic life" criteria applicable to cool and warm waters (Classes 2B and 2C) and wetlands (2D) are higher than those for cold waters (Class 2A) – the percent lipid employed for cool/warm water is 1.5%, compared to 6 % for cold water fish. (Another reason the criterion-concentrations for the "Human Health (HH)–based aquatic life" criteria for Class 2A and 2Bd waters tend to be lower than those for Classes 2B, 2C, and 2D is that both drinking water and fish consumption apply to the former group, whereas only fish consumption applies to the latter

Another comparison of interest involves those WQC aimed at protecting humans from adverse effect in ingesting toxics as a result of combined consumption of water and aquatic organisms ("Human Health-based aquatic life" criteria for Classes 2A and 2Bd) to those that address drinking water alone (Domestic Consumption criteria). Of the 26 pollutants for which Minnesota has both "Domestic Consumption" criteria and "Human Health (HH)–based aquatic life" criteria (consumption of drinking water and fish), both criterion-concentrations for selenium are the same, the criterion-concentration in the applicable "Domestic Consumption" criteria for six pollutants are lower than those in the applicable "Human Health (HH)–based aquatic life" criteria, and the criterion-concentrations in the applicable "Domestic Consumption" criteria for nineteen pollutants are higher than those in the applicable "Human Health (HH)–based aquatic life" criteria.

The criterion-duration for the state's "Human Health (HH)-based Aquatic Life Criteria" for Classes 2A and 2Bd are clearly stated in the Minnesota WQS regulations (30 days). The regulations do not mention a criterion-duration for the state's "Domestic Consumption" WQC. For this report, a duration of an instant is assumed, though durations of seven days, 30 days, and 12 months are suggested by language in various parts of the regulations. Unfortunately the EPA literature regarding criterion-duration applicable to is human health WQC is inconsistent. Sometimes the duration seems to be just an instant, but in other places, it seems to be as long as 70 years.

The Minnesota WQS regulations make no mention of criterion-frequencies applicable to WQC for toxics aimed at human health. Consequently, a criterion-frequency of *zero* is assumed in this report.

Degree of Protection

It is often difficult to make conclusive judgments about the degree of protection provided to applicable designated use(s) by a state's criteria, either in absolute or relative terms, compared to corresponding EPA criteria. This is particularly the case when, as has been mentioned above regarding some types of WQC for toxics, the state and/or EPA has not articulated a clear criterion-duration and/or criterion-frequency.

For example, six of Minnesota's chronic aquatic life criteria for toxics have criterion-concentrations equal to the concentrations in corresponding EPA WQC. Like EPA, the criterion-duration for all chronic aquatic life WQC for toxics is equal to 4 days (96 hours). But, unlike EPA, which specifies a criterion-frequency of once in 3 years for all its aquatic life criteria for toxics, Minnesota's WQS regulations make no mention of a criterion-frequency. In this study, whenever a state is silent regarding criterion-frequency, a frequency of zero is assumed. That is, just one excursion[58] would be deemed to impair the relevant designated use. If this assumption were correct, then these six Minnesota chronic aquatic life WQC for toxics would seem to be more protective than the corresponding EPA WQC, given its WQC have a lower criterion-frequency than that of the corresponding EPA WQC. On the other hand, if the state's criterion-frequency were higher than EPA's—once in one year, for example—then these half-dozen WQC would appear to be less protective than EPA's.

Overall, it seems likely that the state's Domestic Consumption WQC,[59] established under the federal CWA and state law, would provide greater protection than the federal SDWA standards. First, the state's criterion-concentrations are identical to the threshold values in the federal drinking water standards. Second, the state WQS regulations regarding its Domestic Consumption WQC imply a default criterion-duration of just an instant; whereas the federal standards for finished drinking water are implemented in such a way as to create a de facto duration of 12 months. Third, both the state's WQC and EPA's drinking water standards make no mention of a frequency, which implies a zero frequency. This combination -- equal

[58] An "excursion" is any period equal in length to the criterion-duration of a WQC when the average waterbody concentration is higher than the criterion-concentration.

[59] Minnesota actually has 4 subclasses of Domestic Consumption Uses—Class 1A, Class 1B, Class 1C and Class 1D. The definitions of these classes appearing in the WQS regulations assumes that raw water drawn from a surface water would undergo different levels of treatment before being sent to customers of a drinking water utility, with Class 1A water getting no treatment, and the remaining 3 subclasses getting increasingly greater treatment. Nevertheless, the criterion-concentrations for Domestic Consumption WQC do not change from one of these subclasses to another.

concentration, same frequency, and an apparently much shorter state duration -- indicates a higher level of protection from the state's WQC. But, if it were eventually determined that the criterion-duration for Minnesota's Domestic Consumption WQC were longer than 12 months, with readily available information, it would seem that state's WQC would be less protective (if criterion-concentrations identical for state and EPA, and criterion-frequencies also the same).[60]

Even if all elements of a state and EPA WQC are clearly articulated, differences in the criterion-duration and criterion-frequencies between one WQC and another can complicate attempts to determine which criteria provide the higher level of protection. For instance, Minnesota's acute aquatic life criteria for toxics have a duration of one day (24 hours), while EPA's acute criteria for toxics and the same use have a considerably shorter duration – 1 hour. Assume, for purposes of discussion, that the state had a clearly stated criterion-frequency of zero. EPA, on the other hand, has a clearly-stated criterion-frequency of once in three years. Even if the state's acute WQC and the acute WQC published by EPA had identical criterion-concentrations, it would be difficult to establish the relative degree of protection provided by the state and corresponding EPA WQC. EPA's shorter criterion-duration would have the effect of making the WQC more protective, as it limits exposure to average ambient levels equal to the criterion-concentration to an hour, while the state's WQC provides for exposure to said average concentration for a period 24 times as long – a full day. But, the state's (apparently) lower criterion frequency (zero versus once in 3 years) would tend to make its WQC more protective. In order to estimate the net effect of these two opposite "vectors," it would be necessary to locate, or perform, studies of the effects of each of these two unique combinations of concentration, duration, and frequency on several species of aquatic life for each toxic substance of interest.

Also, with regard to aquatic life WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons that a state criterion can have a criterion-concentration higher or lower than that for the corresponding EPA criterion and still provide aquatic life protection equal to that for which the EPA WQC was designed. For instance, the level of a given pollutant consistent with a healthy ecosystem can vary significantly from one waterbody to another. If, for example, a waterbody has naturally high iron, the plants and animals inhabiting it will have evolved to live in such conditions, even though organisms living in a river or lake with a lower natural level of iron could be severely stressed by exposure to such higher levels. Differences, from one waterbody to another, in the mix of indigenous species also could explain the need for criteria with different concentrations, as could differences in waterbody chemistry affecting the bioavailability of metals and other chemicals. Such site-specific differences could result in the need for higher or lower criterion-concentrations compared to a statewide or EPA nationwide WQC, in order to provide equal levels of protection. [61]

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[60] This would be the case if the effect of the typical treatment processes which drinking water utilities apply to their raw water supply were ignored. As noted earlier, for those contaminants for which substantial levels of removal is achieved by such treatment, the probability that a drinking water supply WQC set equal to the SDWA standard for the contaminant would most likely provide a higher level of protection.

[61] Of course, if the criterion-duration and criterion-frequency for a state and corresponding EPA criteria are the same (e.g., duration of 96 hours, frequency of once in three years) and the state's criterion-concentration where higher than EPA's, then the state's criterion would indeed provide less protection to aquatic organisms in the waterbody or set of waterbodies than would EPA's. However, due to site-specific or watershed-specific conditions, the state's WQC could provide the same absolute level of protection as that for which the EPA WQC were designed, while use of the recommended EPA WQC in such waters would actually provide greater protection than that which EPA intended.

Of course, if the criterion-duration and criterion-frequency for a state and corresponding EPA criteria are the same (e.g., duration of 96 hours, frequency of once in three years) and the state's criterion-concentration where higher than EPA's, then the state's criterion would indeed provide less protection to aquatic organisms in the waterbody or set of waterbodies than would EPA's, in relative terms. However, due to site-specific or watershed-specific conditions (e.g., water chemistry, indigenous species), the state's WQC could provide the same absolute level of protection as that for which the EPA WQC were designed, while use of the recommended EPA WQC in such waters would actually provide greater protection than that which EPA intended.

Safe levels of toxic chemicals with regard to human health tend to be less variable from one waterbody to another, one reason being that the species of concern—Homo sapiens—is, obviously, the same everywhere.[62] The most common cause of variation in human health criteria from one waterbody to the next is differences in patterns of human use. For example, differences in the rates of human consumption of local aquatic foodstuffs from one waterbody to the next can result in the need for different criterion-concentrations, in order to provide the same level of protection.[63] EPA's human health criteria dealing with fish consumption (alone or in combination with consumption of drinking water) assume a daily intake of 17.5 grams of fish (and other aquatic organisms) per person. This estimate is based on national data, and represents the average rate of fish consumption. However, there are subpopulations that consume locally-caught "fish" at considerably higher rates. Native Americans, Cajuns, immigrants from Southeast Asia, and low income persons of all ethnic racial backgrounds are widely-recognized examples. For such subsistence fisherpersons, the EPA estimates that the fish consumption rate can be as high as ten times the 17.5 g/day national average. If a state simply adopts a EPA "human health: organisms"(HHO) or a "human health: water and organisms" (HHWO) criteria for a waterbody that is used by subsistence fishers, those people will face a higher risk of illness than that upon which EPA's human health criteria are based. In order to compensate for this situation, the criterion-concentrations for these kinds of criteria ("Human Health-based aquatic life" criteria, in Minnesota's case) would need to be set at lower levels than that which has been set by EPA.

There is nothing in Minnesota's WQS regulations that indicates that the state has established site-specific Human Health-based aquatic life criteria, in order to account for differences in rates of fish consumption from one waterbody to another. On the other hand, Minnesota does vary the criterion-concentration for this category of WQC according to the types of sport and commercial fish (cold versus cool/warm) thought to be present in specific waters or groups of waterbodies. According to the state, cold water fish tend to have higher lipid content (averaging 6%) in the relevant parts of their bodies than do species that inhabit warmer waters (average of 1.5% lipid). Persistent toxic chemicals that tend to bioaccumulate up the food chain will do so to a greater degree in organisms with higher lipid content. Ambient water levels of a given bioaccumulative toxic pollutant would need to be lower in cold water habitats than in warm water, according to this logic, in order to keep the concentration of said pollutant in fish below levels thought to pose unacceptable risks to human consumers.

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[62] Of course, within the human population in a given locale, there will be certain sub-populations that are more sensitive to certain pollutants than the average members. Small children, pregnant women, and the elderly are examples of such groups. Other groups worthy of special attention are persons who engage in hard physical labor and those who participate in vigorous outdoor exercise. In most cases, this fact would not, however, indicate a need for different human health WQC for one waterbody versus another, as the proportion of the total population represented by each of these subgroups would most likely not vary substantially from one location to another

[63] Rates of consumption of drinking water and frequency of water contact recreation also can vary from one climate zone to another--being higher in hotter areas.

Finally, returning to the problem of the lack of clearly-stated criterion-durations and criterion-frequencies, this not only complicates efforts to determine relative degree of protection provided by one WQC as compared to another, but also can result in lack of consistency in the application of Clean Water Act programs that are "driven by" water quality criteria. For instance, if one assumes that the criterion-duration for Minnesota's Domestic Consumption criteria is an instant and the criterion-frequency is zero, then any waterbody from which just one valid (meets QA/QC requirements/guidelines) grab sample, out of several such samples, with a concentration of a pollutant higher than the criterion-concentration should be included in the state's Section 303(d) list. On the other hand, if the criterion-duration the criteria were 365 days, then exceedence of WQC would not be indicated by having just one sample out of a number collected over any 365 day period with a concentration above the criterion-concentration. In this latter case, the appropriate determinant of criterion exceedence would be having a set of samples collected over some 365-day periods with an average concentration higher than the criterion-concentration (assuming the criterion-frequency is zero).

Other possible ways in which different outcomes could result from different assumptions regarding the criterion-duration for the state's human health criteria could be manifested in the TMDL and NPDES programs. For instance, it would seem that meeting TMDL wasteload allocation or an NPDES permit limit of "no higher than 10 µg/L for an instant, at any time" would be considerably more difficult, and presumably more expensive, than keeping the 365 day average concentration at or below 10 µg/L.

Appendix A

Missing and Extra Criteria for Conventional Pollutants: MINNESOTA

Table 1 - Aquatic Life

i) MISSING POLLUTANTS[64]

	ACUTE	CHRONIC[65]
Cold/cool/warm water[66]	ammonia $CaCO_3$ (TD) gases oxygen (dissolved)	ammonia (30d) (TD) gases hydrogen sulfide nitrogen (total)
Rivers and streams		chlorophyll a phosphorous

ii) EXTRA POLLUTANTS[67]

	ACUTE	CHRONIC
Cold/cool/warm water Streams	temperature	color oil and grease oxygen (dissolved) pH temperature
Lakes (all)[68]		temperature
Wetlands[69]		chlorides oxygen (dissolved) temperature

[64] For the purposes of this review, "missing pollutants" are those pollutants for which EPA has issued WQC while the state has neither adopted nor officially proposed corresponding criteria. In situations where a state has adopted and submitted to EPA a set of state-adopted changes but EPA has either not acted on the changes or has disapproved the changes, this fact is noted in this document.

[65] Minnesota recently adopted chronic criteria for phosphorous and chlorophyll a. These criteria apply to lakes and reservoirs, but not to rivers and streams. Hence, they are still shown as missing per rivers and streams, because EPA has published WQC for rivers and streams applicable to the ecoregions in Minnesota.

[66] EPA's criteria do not distinguish between warm and cold water habitat.

[67] For the purposes of this review, "extra pollutants" are those pollutants for which the state has established WQC while EPA has not.

[68] Though EPA's criteria apply to all types of aquatic habitats, including presumably lakes and wetlands, the fact that Minnesota has criteria that apply to these two types of habitat is worthy of note.

[69] Id. at 5

Table 2 - Drinking Water Supply[70]

i) MISSING POLLUTANTS

ACUTE	CHRONIC
total coliform	

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
	turbidity (NTU) *(proposed deletions)*

Table 3 - Water-Based Recreation

i) MISSING POLLUTANTS

ACUTE	CHRONIC
	E. coli - *pro* Enterococci

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
hydrogen sulfide	turbidity (NTU)

[70] EPA lacks actual drinking water supply criteria for conventional pollutants – specification of the levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards with regard to ensuring safe levels of contaminants in drinking water apply to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable.

APPENDIX B

Table 1

	Aquatic Life Protection	
	Acute	*Chronic*
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Minnesota Has Not	Aldrin alpha-Endosulfan[71] beta-Endosulfan[71] Diazinon Nonylphenol Tributyltin	4,4'-DDT alpha-Endosulfan[71] Arsenic beta-Endosulfan[71] Chlordane Demeton Diazinon Dieldrin Guthion Heptachlor Heptachlor Epoxide Iron Malathion Mercury Methoxychlor Mirex Nonylphenol Pentachlorophenol PCBs Toxaphene Tributyltin

[71] While the Minnesota WQS regulations do not specify acute and chronic aquatic life criteria for the alpha and beta forms of endosulfan in particular, the regulations do specify such criteria for endosulfan.

Table 2

	"Human Health (HH)-based aquatic life" Criteria	"Domestic Consumption" Criteria
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Minnesota Has Not	1,1,2-Trichloroethane 1,1-Dichloroethylene 1,2,4,5-Tetrachlorobenzene 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,2-Dichloropropane 1,2-Diphenylhydrazine 1,2-Trans-Dichloroethylene 1,3-Dichlorobenzene 1,3-Dichloropropene 1,4-Dichlorobenzene 2,3,7,8-TCDD (Dioxin) 2,4,5-Trichlorophenol 2,4-Dichlorophenol 2,4-Dimethylphenol 2,4-Dinitrophenol 2,4-Dinitrotoluene 2-Chloronaphthalene 2-Chlorophenol 2-Methyl-4,6-Dinitrophenol 3,3'-Dichlorobenzidine 3-Methyl-4-Chlorophenol 4,4'-DDD 4,4'-DDE Acrolein Aldrin alpha-BHC alpha-Endosulfan[72] Anthracene Asbestos Barium Benzidine Benzo(a)Anthracene Benzo(a)Pyrene Benzo(b)Fluoranthene Benzo(k)Fluoranthene beta-BHC beta-Endosulfan[72] Bis(2-Chloroethyl)Ether Bis(2-Chloroisopropyl)Ether Butylbenzyl Phthalate Chlorodibromomethane Chlorophenoxy Herbicide (2,4,5,-TP) Chlorophenoxy Herbicide (2,4-D) Chrysene Copper	Alpha particles Beta particles & photon emitters Chloramines Chlorine Chlorine dioxide Radium 226 and Radium 228 (combined) Total Trihalomethanes[73] Uranium

[72] Though the Minnesota WQS regulations do not specify human health-related criteria for the alpha and beta forms of endosulfan in particular, the regulations do specify such criteria for endosulfan.

Table 2 (cont.)

	"Human Health (HH)-based aquatic life" Criteria	**"Domestic Consumption" Criteria**
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Minnesota Has Not	Cyanide Dibenzo(a,h)Anthracene Dichlorobromomethane Diethyl Phthalate Dimethyl Phthalate Di-n-Butyl Phthalate Dinitrophenols Endosulfan Sulfate[74] Endrin Aldehyde Ether, Bis(Chloromethyl) Ethylbenzene Fluoranthene Fluorene Hexachlorobutadiene Hexachlorocyclo-hexane-Technical Hexachlorocyclopentadiene Hexachloroethane Ideno(1,2,3-cd)Pyrene Iron Isophorone Manganese Methoxychlor Methyl Bromide Nitrates Nitrobenzene Nitrosamines Nitrosodibutylamine,N Nitrosodiethylamine,N Nitrosopyrrolidine,N N-Nitrosodimethylamine N-Nitrosodi-n-Propylamine N-Nitrosodiphenylamine Pentachlorobenzene Phenol Pyrene Selenium Toluene Trichloroethylene Zinc	

[73] While Minnesota has not adopted a "Domestic Consumption" criterion for "Total Trihalomethanes," the state has adopted separate a "Domestic Consumption" criterion for chloroform and bromoform.

[74] While Minnesota has not adopted a "Human Health (HH)-based aquatic life" criterion for "endosulfan sulfate," it has adopted a "Human Health (HH)-based aquatic life" criterion for "endosulfan".

Table 3

	Aquatic Life		
	Acute (Classes 2A, 2B, 2C, 2D, 2Bd)	*Chronic*	
		Class 2A, Class 2Bd	*Classes 2B, 2C, 2D*
EXTRA POLLUTANTS: Pollutants for which Minnesota Has Adopted WQC where EPA Has Not	1,1,1-Trichloroethane 1,1,2,2-Tetrachloroethane 1,1,2-Trichloroethylene 1,2-Dichloroethane 2,4,6-Trichlorophenol Acenaphthene Acrylonitrile Alachlor Anthracene Antimony Atrazine Benzene Bromoform Carbon Tetrachloride Chlorobenzene Chloroform Cobalt Di-n-Octyl Phthalate Endosulfan[75] Ethylbenzene Fluoranthene Methylene Chloride Naphthalene Phenanthrene Phenol total PCBs Tetrachloroethylene Thallium Toluene Xylene	Acetochlor Anthracene Di-n-Octyl Phthalate Ethylbenzene Fluoranthene Metolachlor Naphthalene Phenanthrene Phenol Silver Toluene Xylene	Acetochlor Alachlor Anthracene Atrazine Benzene Chloroform Cobalt Di-n-Octyl Phthalate Ethylbenzene Fluoranthene Metolachlor Naphthalene Phenanthrene Phenol Silver Toluene Xylene

[75] While EPA has no criterion for "endosulfan", it has separate, though identical, *acute* and *chronic* aquatic life criteria for alpha- and beta-endosulfan.

Table 4

	"Human Health (HH)-based aquatic life" Criteria	**"Domestic Consumption" Criteria**
EXTRA POLLUTANTS: Pollutants for which Minnesota Has Adopted WQC where EPA Has Not	1,1,2-Trichloroethylene Alachlor Atrazine Cobalt Endosulfan Mercury (in fish tissue and in water)[76] Naphthalene	Aldicarb Aldicarb sulfoxide Aldicarb sulfone Chloroform[77] Bromoform[78]

Table 5

	Aquatic Life Protection	
	Acute	*Chronic*
Pollutants with a state criterion-concentration **lower** than EPA's	Aluminum Zinc Heptachlor Heptachlor Epoxide Pentachlorophenol Silver Chlordane	Zinc

[76] While Minnesota has adopted a criterion for mercury that is applicable to the water column and one other criterion that is applicable to mercury in fish tissue, EPA only has a WQC for levels of mercury in fish tissue.

[77] Although EPA has not issued an MCL for chloroform, the Agency has issued a Maximum Contaminant Level Goal (MCLG) for Total Trihalomethanes, a group of pollutants of which chloroform is a member. The MCLG for chloroform is 70µg/L.

[78] Although EPA has not issued an MCL for bromoform, the Agency has issued a Maximum Contaminant Level Goal (MCLG) for Total Trihalomethanes, a group of pollutants of which chloroform is a member. The MCLG for chloroform is zero (0) µg/L.

Table 6

	Aquatic Life Protection		"Domestic Consumption"
	Acute	*Chronic*	
Pollutants with a state criterion-concentration **higher** than EPA's	4,4'-DDT Aluminum Arsenic Cadmium Chromium (III) Copper Dieldrin Endrin gamma-BHC Lead Mercury Nickel Parathion	Aluminum Cadmium Chromium (III) Copper Endrin Lead Nickel	

Table 7

	"Human Health (HH)-based aquatic life" Criteria	
	Classes 2Bd, 2C, 2B	*Class 2A*
Pollutants with a state criterion-concentration **lower** than EPA's	Acenaphthene Antimony Chlordane Chlorobenzene Dieldrin DDT Endrin Hexachlorobenzene Lindane Nickel PCB (total)	Acenaphthene Antimony Chlordane Chlorobenzene Dieldrin Endrin Hexachlorobenzene Lindane Nickel PCB (total)

Table 8

	"Human Health (HH)-based aquatic life" Criteria	
	Class 2Bd	*Class 2A*
Pollutants with a state criterion-concentration **higher** than EPA's	1,1,2,2-Tetrachloroethane 1,2-Dichloroethane 1,2-Dichloroethane Acrylonitrile Benzene Bromoform Carbon tetrachloride Chloroform Di-2-ethylhexyl phthalate Heptachlor Heptachlor epoxide Methylene chloride Pentachlorophenol Tetrachloroethylene Thallium Toxaphene Vinyl chloride	1,1,2,2-Tetrachloroethane 1,2-Dichloroethane 1,2-Dichloroethane Acrylonitrile Benzene Bromoform Carbon tetrachloride Chloroform Di-2-ethylhexyl phthalate DDT Heptachlor Heptachlor epoxide Methylene chloride Pentachlorophenol Tetrachloroethylene Thallium Toxaphene Vinyl chloride

APPENDIX C

SITUATIONS IN WHICH STATE WQC ARE CLEARLY <u>LESS</u> PROTECTIVE THAN EQUIVALENT EPA WQC

	Concentration	Duration	Frequency
State vs. EPA[i]	**higher**	**longer**	**higher**
“ “ “	equal	**longer**	**higher**
“ “ “	**higher**	equal	**higher**
“ “ “	**higher**	**longer**	equal
“ “ “	**higher**	equal	equal
“ “ “	equal	equal	**higher**
“ “ “	equal	**longer**	equal

SITUATIONS IN WHICH STATE WQC ARE CLEARLY <u>MORE</u> PROTECTIVE THAN EQUIVALENT EPA WQC

	Concentration	Duration	Frequency
State vs. EPA	**lower**	**shorter**	**lower**
“ “ “	equal	**shorter**	**lower**
“ “ “	lower	equal	**lower**
“ “ “	**lower**	**shorter**	equal
“ “ “	**lower**	equal	equal
“ “ “	equal	equal	**lower**
“ “ “	equal	**shorter**	equal

SITUATIONS IN WHICH COMPARATIVE LEVEL OF PROTECTION CANNOT BE DETERMINED BY SIMPLY LOOKING AT THE TWO CRITERIA

	Concentration	Duration	Frequency
State vs. EPA	**lower**	**shorter**	**higher**
“ “ “	equal	**shorter**	**higher**
“ “ “	**lower**	equal	**higher**
“ “ “	**lower**	**longer**	equal
“ “ “	**higher**	equal	**lower**
“ “ “	**higher**	**shorter**	equal
“ “ “	equal	**longer**	**lower**

[i] The state WQC’s component (e.g. duration) compared to the component for corresponding EPA WQC.

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