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

Tennessee

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TENNESSEE
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 September 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 main stem of the Mississippi River. In this report ELI compares the state numeric water quality criteria to recommended criteria and related standards issued by the United States Environmental Protection Agency (EPA).[2] The findings presented in this document are based on the most recent version of the state's WQS regulations—those finalized in October 2007. 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 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) contained in Tennessee's water quality standards (WQS) regulations[3] present a mixed picture when compared to the criteria published by EPA, in terms of: 1) pollutant /use combinations[4] covered, 2) the degree to which all key elements of criteria are clearly articulated, and 3) level of protection likely afforded to applicable designated uses.

Tennessee has adopted numeric water quality criteria for a significant array of pollutants/use combinations. Indeed, the state has adopted aquatic life and human health-related

[1] The terms "water quality criteria," "WQC," and "criteria" are used interchangeably in this document. Water quality criteria are closely associated with "designated uses," another key element of all water quality standards established under state law and the federal Clean Water Act. 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 and drinking water supply) assigned to specific waters by a state's water quality standards.

[2] Throughout this report, the criteria recommended by EPA will be referred to as the EPA's "issued" or "published" criteria, interchangeably. Terms such as "promulgated" and "established" are not used in reference to the federal EPA's water quality criteria because these values are guidance, rather than federal requirements. By contrast the Primary Drinking Water Standards that EPA promulgates are enforceable regulatory requirements.

[3] Rules of Tennessee Department of Environment and Conservation Tennessee Water Quality Control Board Division of Water Pollution Control, Chapter 1200-4-3, October 2007. Available at: http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf.

[4] As used in this report, "pollutant/use combination" refers to designated use and a particular pollutant or other water quality parameter. Often 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 for most of the toxic chemicals[5] for which the EPA has issued corresponding Section 304(a) criteria under the authority of the Clean Water Act. However, the state has not established criteria for a number of traditional pollutants/use combinations for which EPA has issued WQC. Perhaps most significant, the state is missing[6] aquatic life criteria for a number of traditional pollutants,[7] including the nutrients nitrogen and phosphorous, as well as the related algal growth indicator, chlorophyll a.[8] Unnaturally high density of certain forms of algae resulting from excessive levels of nutrients have adverse effects on aquatic life, as well as use of impacted waterbodies for public water supply and water-based recreation. Tennessee also lacks numeric WQC for suspended, as well as bed, sediments, which also can adversely affect these three uses, as well as others.

Tennessee has adopted acute freshwater aquatic life criteria for 25 of the 31 toxic pollutants for which EPA has issued[9] acute criteria for freshwater aquatic life. Tennessee has adopted chronic freshwater aquatic life criteria for 25 pollutants of the 35 toxic pollutants for which EPA has issued chronic freshwater aquatic life criteria. The pollutants missing acute and chronic aquatic life WQC include organophosphate pesticides and heavy metals.

Tennessee has no criteria that address possible adverse effects of ingestion of toxic substances resulting from consumption of fish, shellfish, and other aquatic species *alone,* whereas EPA has issued such WQC for 106 toxic pollutants. The federal EPA refers to this set of WQC as Human Health: Organisms (HHO) criteria. Likewise, the states lacks WQC addressing the health risk associated with intake of toxic substances resulting from human consumption of both: 1) fish, shellfish, and other aquatic species plus 2) drinking water from a given waterbody, while EPA has issued WQC for 113 toxic substances related to the combination of these two waterbody uses. EPA calls these Human Health: Water and Organisms (HHWO) criteria. Among those pollutants with missing these two specific types of WQC are a number of known or suspected carcinogens, bioaccumulators, and endocrine disruptors.

On the other hand, Tennessee does have two sets of WQC that are closely related to EPA's: 1) Human Health: Organisms, and 2) Human Health: Water and Organisms criteria. First, the state has adopted WQC for 93 toxic chemicals aimed at people who are using a waterbody as

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[5] 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 pollutant," as well as all toxic chemicals not falling in either of these two EPA categories. The one exception is ammonia; see footnote regarding traditional pollutants at foot note 7 below.

[6] For the purposes of this review, the term "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

[7] 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 "traditional" 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-traditional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

[8] The state has a criterion for chlorophyll a, but it applies only to one waterbody in the entire state-Pickwick Reservoir.

[9] Throughout this report, the criteria recommended by EPA will be referred to as the EPA's "issued" or "published" criteria, interchangeably.

1) a supplier of fish and other aquatic foodstuffs, and 2) a place for water-contact recreation, which it calls Recreation: Organisms Only criteria. And, the state has another set of WQC for ninety-three (93) toxics aimed at people who are using a waterbody as 1) a supplier of fish and other aquatic foodstuffs, 2) a place for water contact recreation, and 3) a source of drinking water, which it calls Recreation: Water and Organisms criteria. EPA has not issued any WQC for toxics for either of these two combinations of uses; nevertheless, because the amount of a toxic compound likely to be taken in during water contact recreation should be small, in relation to that resulting from fish consumption or drinking water, it seems reasonable to 1) treat Tennessee's Recreation: Organisms Only criteria as reasonably comparable to the federal EPA's Human Health: Organisms (HHO) criteria, and 2) treat Tennessee's Recreation: Water and Organisms WQC as reasonably comparable to EPA's Human Health: Water and Organisms (HHWO) criteria.

Using the above analogies, whereas Tennessee has Recreation: Organisms Only criteria for 93 toxic substances, EPA has Human Health: Organisms criteria for 106 toxics. And, while there are EPA Human Health; Water and Organisms WQC for 113 toxics, there are just 93 pollutants for which Tennessee has established Recreation: Drinking Water Supply WQC.

Tennessee has adopted "Domestic Water Supply" criteria for 63 toxic pollutants, compared to the total 83 toxic pollutants for which EPA has promulgated somewhat corresponding[10] Primary Drinking Water Standards under the Safe Drinking Water Act. The state also has adopted a "Domestic Water Supply" criterion for nickel while EPA has no Primary Drinking Water Standard for this contaminant.

Turning to comparison of the criterion-concentration in Tennessee's WQC compared to those of corresponding EPA WQC, for those traditional pollutants/use combinations for which both the state and EPA have adopted criteria, most of the criterion-concentrations[11] in Tennessee's criteria are equal to those in EPA's criteria, while some are lower and some are higher. For example, Tennessee's dissolved oxygen (DO) criterion-concentration for wadeable streams in sub-ecoregion 73 is 4.0 mg/L, while those for cold water streams, including recognized trout streams, range from 6.0 mg/L to 8.0 mg/L. EPA has published only one DO criterion, with a concentration of 5.0 mg/L. Furthermore, Tennessee's criterion-concentrations for traditional pollutants are within the same range as those in corresponding WQC of the other nine states covered by this report.

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[10] 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 (CWA). Some of these waters are, or might be, used as a source of "raw" water by public and private drinking water systems. Hence, when a waterbody in Tennessee is designated "Domestic Water Supply" then a certain set of WQC apply to said river or lake, per the CWA. There also is another set of standards that apply to the "finished" water that results from "raw" water from a river or lake being run through treatment processes aimed at removing contaminants. These are called Drinking Water Standards, and are established as national regulations under authority of the SDWA. They are often referred to as "maximum contaminant levels" (MCLs).

[11] 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."

Where there are corresponding state and EPA aquatic life criteria that are applicable to toxic chemicals, the criterion-concentrations in all of Tennessee's aquatic life criteria are equal to the criterion-concentrations in the corresponding EPA criteria.

For the three categories of Tennessee WQC for toxics related to human health (Recreation: Organisms Only; Recreation: Water and Organisms; and Domestic Water Supply), where there are somewhat corresponding EPA human health criteria, the criterion-concentrations in most of Tennessee's human health criteria are equal[12] to the criterion-concentrations in the corresponding EPA criteria or standards.

Most of Tennessee's WQC for traditional pollutants lack a precisely-stated criterion-duration. The majority of its aquatic life criteria for traditionals are expressed in such a way as to imply a criterion-duration of an instant, as do all the WQC for this type of pollutant applicable to drinking water supply. Of the two pollutants for which the state has criteria for water contact recreation, one (chlorophyll a) has a clearly-stated duration equal to six calendar months, while the other (*E. coli*) has a WQC that is worded in such a way as to make criterion-durations ranging over an order of magnitudes possible.

The state's regulations regarding aquatic life criteria for toxics make no direct mention of a criterion-duration,[13] for either its acute or chronic criteria. Durations of 1 hour and 4 days could be inferred by the fact that the names the state gives to its acute and chronic toxics criteria ("Criterion Maximum Concentration-CMC" and "Criterion Continuous Concentration-CCC") are identical to those used by EPA for its corresponding aquatic life criteria. EPA guidance specifies a one-hour duration for its CMCs and a four day/96 hour criterion-duration for its CCC values. However, based solely on what is said in the state's WQS regulations, a duration of just an instant could be presumed for both the acute and chronic aquatic life WQC. However, by definition, the duration of a chronic WQC for some pollutant/use combination must be longer than the duration of the acute WQC for the same pollutant/use pair; hence, a duration of longer than an instant should be assumed for Tennessee's chronic aquatic life WQC for toxics, be it an hour, 24 hours, 48 hours, 96 hours, or longer.

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[12] Of the pollutants with criterion-concentrations that are equal to the criterion-concentrations in EPA's corresponding human-health criteria (HHO and HHWO), there are 51 pollutants which Tennessee considers to be carcinogenic. Strict numerical comparison of the criterion-concentrations appearing in the state's WQC tables with those in EPA's Section 304(a) criteria (http://www.epa.gov/waterscience/criteria/nrwqc-2006.pdf) would show that the criterion-concentrations for the Tennessee criteria covering these carcinogenic pollutants are greater than the EPA's values by exactly ten fold. However, this is because Tennessee assumes an incremental cancer risk level of 10^{-5} for human health criteria that cover carcinogenic pollutants/parameters, while EPA's criteria for these pollutants are based a 10^{-6} cancer risk level. EPA accepts assumptions of cancer risk level within the range of 10^{-5} to 10^{-7}. Hence, it is more instructive to compare Tennessee's numeric human health WQC to the EPA values that are based on a 10^{-5} cancer risk level. When comparison is made under this cancer risk level, Tennessee criterion-concentrations for those 51 pollutants identified as carcinogenic are equal to EPA's 10^{-5} values.

[13] According terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion" – a specified time period over which the 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 cyanide was higher than the chronic 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.

Like EPA, Tennessee's human health-related (Recreation: Organisms Only; Recreation: Water and Organisms; and Domestic Water Supply) all lack any direct specification of a criterion-duration. Absent such, a default criterion-duration of an instant is assumed for purposes of this study.

Tennessee's WQS regulations contain no reference to a criterion-frequency,[14] for any of its WQC for traditional or toxic pollutants, regardless of the applicable designated use.

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 protectiveness 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 Tennessee's WQC is significantly limited by the fact that, though a few of the state's criteria have a specified criterion-duration, the state's WQS regulations make no mention of a criterion-frequency for any 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, and that all of the federal EPA's human health WQC for toxics lack a clearly-stated criterion-duration and criterion-frequency.

The fact that many of the state's water quality criteria have criterion-concentrations equal to corresponding EPA criteria might be taken to suggest that the state's criteria are as protective

[14]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 supports 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 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 of 5.2 µg/L more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

as EPA's. However, the lack of any direct indication of applicable durations and frequencies for most of the state's WQC renders determination of the relative degree of protection provided by the state's criteria versus EPA's criteria an exercise fraught with uncertainty. Specifically, in the case of most of Tennessee's WQC, any attempt to estimate comparative degree of protectiveness between a state WQC and the corresponding EPA WQC would require making assumptions about duration and/or frequency that may or may not turn out to be consistent with the duration and/or frequency intended, or eventually settled upon, by the state. In turn, the results of attempts to compare the protection provided by a state versus an EPA would, therefore, be greatly affected by whatever assumptions were made. Assumption of some short-term duration (such as one hour), rather than a longer term (such as 30 days), would tend to make a criterion more protective. Likewise, assumption of a lower frequency (such as once in five years), rather than a higher frequency (such as once in two years) would have the same effect—more protective than if the alternative were use.

For example, all of Tennessee's chronic aquatic life WQC for toxics have the same criterion-concentration as the EPA chronic life WQC for the same pollutant. If the duration for the state chronic aquatic life WQC is assumed to be four days (same as EPA's) and the criterion-frequency is assumed to be zero (EPA's is a maximum of once in three years), then all of Tennessee's chronic aquatic life criteria would provide a somewhat greater level of protection than the corresponding EPA criterion, given the lower criterion-frequency of the state criteria. On the other hand, if the state's criterion-duration were assumed to be 30 days, and the concentration and frequency remained the same, it would be hard to know, without performing additional laboratory toxicity studies, whether the decreased protection resulting from the state's longer criterion-duration would offset the increased protection provided by its lower criterion-frequency.

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 U S EPA criterion and still provide aquatic life protection equal to that for which the EPA WQC were 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 application of EPA's criterion to the waterbody in question. Nevertheless, site-specific conditions would 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.

The best example in Tennessee's WQS regulations of adoption of different aquatic life WQC for different types of waterbodies is the criteria the state has established for dissolved oxygen. The state's acute criterion-concentration for dissolved oxygen in "wadeable streams" is 4.0 mg/L, for "lakes and reservoirs" it is 5.0 mg/L, for "trout streams" it is 6.0 µg/L, for "streams in ecoregion 66 not designated as naturally reproducing trout streams" it is7.0 mg/L, and for "naturally reproducing trout streams" it is 8.0 mg/L. EPA has issued only one aquatic life

WQC for dissolved oxygen for all inland fresh waters; it has a criterion-concentration of 5.0 mg/L.

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 impacts on just one species, regardless of the location of the waterbody to which the WQC apply. 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. Also, 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. And, of course, patterns of swimming and other water contact recreation can change considerably depending on difference in the climate in which one waterbody versus another is located, along with the type of waterbody (river, lake, ocean beach).

There is no evidence of Tennessee having developed human health-related WQC applicable at a scale any smaller than the entire state, for either traditional pollutants/parameters or toxic substances. That is, the criterion-concentration for the state's Recreation: Organisms Only, Recreation: Water and Organisms, and Domestic Water Supply for a given pollutant or parameter is the same for all waters of the state. Likewise, Tennessee has not developed bacterial WQC for secondary contact recreation, to complement its *E. coli* criteria for primary contact recreation.

Returning briefly to the effects of unaddressed 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 National Pollutant Discharge Elimination System (NPDES) permits. For instance, if a TMDL were being developed because of exceedances of one of Tennessee's Domestic Water Supply WQC for a toxic substance, 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 Water Supply WQC was twelve months—the averaging period used in determining compliance with SDWA standards, then setting a maximum twelve month total load would seem appropriate.[15]

[15] 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.

C. Traditional Pollutants/Parameters[16]

1) *Coverage*

a) Aquatic Life / "Fish and Aquatic Life"[17]

Tennessee lacks acute and/or chronic WQC for a number of the traditional pollutants for which EPA has published criteria. Among the missing[18] criteria are several that correspond to EPA's hyper-eutrophication-related criteria –total phosphorous (P) and total nitrogen (N). In addition, Tennessee lacks criteria for turbidity, whereas EPA has published chronic criteria for turbidity as part of its set of criteria addressing excess nutrients. Tennessee recently adopted a criterion for chlorophyll a, but it is aimed at water-contact recreational uses rather than aquatic life, and it applies only to the Pickwick Reservoir. Tennessee lacks acute criteria for two (3), and chronic criteria for four (4), additional traditional pollutants for which EPA has issued recommended criteria (See Appendix A, Table 1).

On the other hand, Tennessee does have some "extra" criteria.[19] The state has one chronic DO criteria, while EPA has none. Both have acute DO criteria. In addition, the state has acute and chronic aquatic life criteria that are applicable to temperature and to *E. coli* – for both of which EPA lacks criteria (Appendix A, Table 1). EPA does have a chronic criterion for *E. coli*, but it applies to water-contact recreation and not to aquatic life.

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

EPA has issued chronic WQC for fecal coliform bacteria that are applicable to consumption of shellfish, while Tennessee has not.[20]

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[16] 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 "traditional" 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-traditional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

[17] Throughout this document, generic names (e.g., "aquatic life," "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 the same use, the name that the state employs is listed in quotation marks, after the generic name.

[18] 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

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

[20] The significance of the lack of such criteria depends upon whether or not any of Kentucky's waters harbor beds of shellfish that are, or could be, harvested and consumed, for either recreational or commercial purposes.

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

Tennessee lacks criteria applicable to drinking water supply use for five (5) of the eight (8) traditional pollutants/parameters for which EPA has somewhat related standards.[21] However, aside from that pertaining to fecal coliform, the EPA Safe Drinking Water Act (SDWA) standards for these eight pollutants/parameters are "secondary" standards (related to taste, odor, and appearance of drinking water), rather than "primary" drinking water standards (related to health).

For *E. coli* bacteria, Tennessee has chronic public water supply criteria, whereas the EPA's Safe Drinking Water Act standard does not have chronic or acute stipulations for this particular bacterial indicator. Instead, EPA has a primary drinking water standard for total coliform bacteria (Appendix A, Table 2).

Tennessee also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to unnatural blooms of aquatic algae. It also lacks WQC for chlorophyll a (a direct indicator of algal densities) that would apply to drinking water supply, though it does have a criterion for this parameter that applies to water-contact recreation in one particular waterbody—Pickwick Reservoir. High levels of algae in the raw water supply used by a public drinking water system can result in unpleasant taste and odor in finished drinking water, unless special care is taken in the drinking water treatment process. Such extra treatment efforts can, in turn, lead to increased costs to a drinking water utility and its customers.

d) Human Health: Water-Contact Recreation / "Recreation"

Tennessee has adopted acute and chronic criteria for *E. coli*, but none for Enterococci. EPA has issued chronic criteria for both. These WQC appear to apply year round, not just in the warmer months when water-contact recreation is more likely. On the other hand, the following language from Rule 1200-4-3-.05(5) of the Tennessee WQS regulations seems to indicate that the state does not intend for its *E. coli* criteria to apply under certain circumstances: "When interpreting pathogen data, samples collected during or immediately after significant rain events may be treated as outliers unless caused by point source dischargers. Such outlier data may be given less weight in assessment decisions than non-rain even sampling results." This text implies that, in essence, in situations where elevated levels of *E. coli* are caused by nonpoint source runoff, the *E. coli* criteria may not apply.

Tennessee has acute recreational criteria for pH. There are no corresponding acute or chronic corresponding EPA criteria (Appendix A, Table 3).

[21] Unlike the water quality criteria that it 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 for traditional 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.

The state also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to unnatural blooms of aquatic algae. Such blooms can form mats on the water surface which can interfere with a variety of water-based recreational activities. Tennessee has recently adopted a chronic chlorophyll a (an indicator of levels of algae) criterion applicable to recreational use in one waterbody in the state, Pickwick Reservoir.

e) Agricultural Water Supply / "Livestock Watering and Wildlife" and "Irrigation"

EPA has issued agricultural water supply criteria for boron/borates, while Tennessee has not. The only numeric criteria issued by Tennessee for this designated are acute WQC for pH and total dissolved solids (TDS); EPA does not have a pH or a TDS criterion for this use.

f) Industrial Water Supply

Tennessee has issued criteria for temperature, pH, and dissolved solids this use. The only criterion the EPA has issued for this use is for $CaCO_3$, a pollutant for which there is no state criteria.

2) *Criterion-Concentrations,[22] Compared to EPA's*

a) Aquatic Life / "Fish and Aquatic Life"

Most of Tennessee's criterion-concentrations for traditional pollutants for aquatic life appear to be equal or very close to those in the corresponding EPA criteria, as well as corresponding criteria adopted by the nine other states covered by this study.

There are two traditional parameters for which both Tennessee and EPA have adopted aquatic life criteria: DO and pH. The state's acute criterion-concentration for dissolved oxygen in "wadeable streams" is 4.0 mg/L, which is lower than the acute criterion of 5.0 mg/L issued by EPA. However, the state's DO acute criterion-concentrations for "lakes and reservoirs" (5.0 mg/L), "trout streams" (6.0 µg/L), "streams in ecoregion 66 not designated as naturally reproducing trout streams" (7.0 mg/L) and "naturally reproducing trout streams" (8.0 mg/L) are all either as high as or higher than EPA's criterion-concentrations.

Tennessee's criterion for pH is expressed as follows: "The pH value shall not fluctuate more than 1.0 unit over a period of 24 hours …" This is an example of what this report calls "quasi-numeric" criteria – those 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 at earlier times and/or at more than one location (e.g., above and below a discharge pipe). Tennessee also stipulates two ranges of acceptable pH values for two different waterbody types, one of which is the same as that issued

[22] 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."

by EPA, and the other of which allows for more acidity (6.0-9.0). EPA's criterion for pH is expressed as one range (6.5-9.0).

EPA has published recommended ecoregion-specific and waterbody type-specific "nutrient"[23] WQC that are applicable to the two ecoregions present in Tennessee – Ecoregion IX (Southeastern Temperate Forested Plains and Hills) and Ecoregion XI (Central and Eastern Forested Uplands). However, the state has not adopted nor proposed criteria for total N, total P, or turbidity based on these EPA criteria. Comparison of state and EPA criterion-concentrations for these pollutants is not possible. EPA also has issued chlorophyll a WQC for the two above-mentioned ecoregions. Though Tennessee has no aquatic life WQC for chlorophyll a, it recently adopted a chlorophyll a criterion that applies only to recreational uses in one reservoir. This WQC is discussed in Section C(2)(d) of this report, below.

b) Human Health: Shellfish Harvesting

Not applicable. Shellfish harvesting is not among the specific designated uses that can be assigned to waterbodies in the state's WQS regulations.

c) Drinking Water Supply / "Domestic Water Supply"

There are two traditional parameters for which both Tennessee and EPA have adopted drinking water supply criteria: total dissolved solids (TDS) and pH. The criterion-concentration in Tennessee's public water supply criteria for TDS (500 mg/L) is the same as the concentration specified in the secondary drinking water standards issued by EPA under authority of the Safe Drinking Water Act.

The state's range of acceptable pH values (6.0-9.0) is slightly wider than that of EPA (6.5-9.0) for this use.

d) Human Health: Water-Contact Recreation / "Recreation"

There are two traditional parameters for which both Tennessee and EPA have adopted water-contact recreation criteria: *E. coli* and chlorophyll a. Tennessee's chronic criterion-concentration for *E. coli* bacteria is 126 colony-forming units per 100ml, the same as that issued by EPA. For its acute ("concentration … in any individual sample.") *E. coli* bacteria concentration, the state specifies two criterion-concentrations: 1) 487 colony-forming units (CFU) per 100 ml for lakes, reservoirs, State Scenic Rivers, Exceptional Tennessee Waters or Outstanding Resource Waters, and 2) 941 colony-forming units for all other water bodies.

The state's chronic water-contact recreation criterion for chlorophyll a, which applies only at the Pickwick Reservoir, is stated as "the mean of the photic-zone composite chlorophyll a samples[24] collected … April through September shall not exceed 18 µg/L." For the ecoregion in

[23] EPA's package of "nutrient criteria" includes WQC not only for nitrogen and phosphorous but also for turbidity and chlorophyll a.

[24] 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 read something like,

which Pickwick Reservoir is located (Southeastern Temperate Forested Plains and Hills), the EPA recommended criteria-concentration is 4.93 μg/L. There is no state acute water-contact recreation criterion for chlorophyll a.

e) Agricultural Water Supply / "Livestock Watering and Wildlife" and "Irrigation"

Not applicable. Tennessee has no WQC in common with EPA for this use.

f) Industrial Water Supply

Not applicable. Tennessee has no WQC in common with EPA for this use.

3) *Articulation of Criterion-Duration*[25]

The criterion-duration components in nearly all of Tennessee's criteria for "traditional" pollutants are somewhat ambiguous, as are most of EPA's.

a) Freshwater Aquatic Life / "Fish and Aquatic Life"

Among the clearly expressed criterion-durations applicable to Tennessee's aquatic life criteria for traditional pollutants are the three criterion-durations that are applicable to the state's ammonia-nitrogen criteria. In particular, the acute criterion-duration (one-hour) in the state's ammonia-nitrogen criteria is stated as follows: "The one hour average concentration…shall not exceed the CMC…." The chronic criterion-duration (30 days) is expressed similarly, as well as a "semi-chronic" WQC with a four-day criterion-duration (Rule 1200-4-3-.03(3)(j) of the Tennessee WQS regulations). There also is a chronic Fish and Aquatic Life WQC applicable to wadeable streams in two subecoregions in Tennessee that is expressed as a "daily average" concentration. It is assumed herein that "daily" means a calendar day (period from 12:00 am (midnight) to 11:59 pm), but it could also be taken to mean any 24 hour period. (From a biological standpoint, the later interpretation is more logical, as aquatic life forms are incapable of discerning the difference between what humans choose to call a calendar day and any other 24 hour period.)

The remainder of the state's WQC applicable to Fish and Aquatic Life for traditionals lack clearly articulated criterion-durations; however, most criteria appear to have a criterion-

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"The average level of chlorophyll a over the period of April through September shall be no higher than 18 ug/L." What is presented as a WQC actually reads 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.

[25] 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, 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.

duration of an instant. For example, one of the criteria for temperature states, "the temperature of the water shall not exceed 30.5^{o} C," which strongly implies that the temperature should never exceed this maximum, not even for a second. Similarly, the acute dissolved oxygen WQC for several types of waters is stated as: "dissolved oxygen shall not be less than ___ mg/L," which also implies a criterion-duration of an instant. (EPA's corresponding WQC is worded in a similar fashion.) Clearer statements of an instantaneous criterion-duration that appear in other states' WQS regulations refer to an "instantaneous maximum (or minimum)" concentrations or a "concentration not to be exceeded at any time."

Tennessee's chronic WQC for dissolved oxygen is a minimum daily average (5.0 mg/L), which would suggest a 24-hour duration. There is some ambiguity as to whether "daily" means "one calendar day" or "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." EPA does not have a chronic WQC for dissolved oxygen.

There is similar ambiguity for the state's pH criteria, for which there are two acceptable ranges. Within each range, the pH cannot "fluctuate more than 1.0 unit over a period of 24 hours," implying a default criterion-duration of an instant—that is, the moment the pH exceeds by one unit any other value the pH has had within the last 24 hours an excursion has occurred.

An alternative criterion-duration might be inferred for all of Tennessee's aquatic life criteria (including those for traditional pollutants/parameters) from the following text found in Rule 1200-4-3-.05(4) of the state's WQS regulations, "Water quality criteria for the fish and aquatic life and livestock watering and wildlife criteria set forth shall generally be applied on the basis of the following stream flows: unregulated streams – stream flows equal to or exceeding the seven-day minimum, ten-year recurrence interval; regulated streams – all flows in excess of the minimum flow occurring one in ten years." This suggests a criterion-duration of seven days. Assuming a criterion-duration of seven days for all of Tennessee's aquatic life criteria (acute and chronic) does not appear reasonable because, by definition, the criterion-duration for acute and chronic criteria cannot be identical—the criterion-duration for chronic WQC is always longer than that for an acute WQC. This basic reality is illustrated by Tennessee's acute and chronic WQC for dissolved oxygen—the criterion for the former is apparently an instant and for the latter a day/24-hours. Further reason for not assuming a seven-day criterion-duration for all of the state's aquatic life WQC is the fact that the chlorophyll a criterion is expressed as a 6-month average concentration, and there are ammonia WQC with one-hour, four-day and 30-day criterion-durations.

b) Human Health: Shellfish Harvesting

Not applicable. Shellfish harvesting is not among the specific designated uses that can be assigned to waterbodies in the state's water quality regulations.

c) Drinking Water Supply / "Domestic Water Supply"

Tennessee has one acute Domestic Water Supply criterion with a clearly articulated criterion-duration – its total dissolved solids WQC, which says "at no time shall (the concentration) exceed 500 mg/L." Without a doubt, the criterion-duration is an instant. For this use, all other pollutants have acute WQC with an implied, but not clearly stated, criterion-duration of an instant.

The state's WQC for *E. coli* for Domestic Water Supply is expressed as follows: "The concentration of *E. coli* shall not exceed 630 per 100 ml as a geometric mean based on a minimum of five samples[26] collected …over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than twelve hours." This statement implies a criterion-duration of anywhere from 2.5 days (five samples, each collected at the minimum interval of twelve hours) to 30 days. The EPA does not have an *E. coli* WQC for this use, though it does have a Safe Drinking Water Act standard for total coliform bacteria that applies to finished drinking water, rather than the raw water from which the finished water is created via various types of treatment.

d) Human Health: Water-Contact Recreation / "Recreation"

Only one of the traditional pollutants/parameters for which Tennessee has established WQC applicable to recreation has a clearly-specified criterion-duration—the recently adopted chronic chlorophyll a criterion for Pickwick Reservoir. That WQC ("the mean of the photic-zone composite chlorophyll a samples collected…April through September) shall not exceed 18 μg/L)." This wording articulates a 6-month criterion-duration.

Tennessee has two acute WQC for bacteria that appear to have a criterion-duration of an instant. Both specify a concentration of the *E. coli* group that shall not be surpassed "in any individual sample." Since it takes only a second, or fraction thereof, to "grab" an aliquot of water, this wording implies a duration of an instant. It is worth noting that this reads more like an assessment methodology than a WQC, as it describes the characteristics of a sample set, rather than conditions in the waterbody. A straightforward WQC might read, "The instantaneous concentration … shall not go above ___ colony forming units (CFU) /100 ml at any time."

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[26] 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 lines of: "The average density of E.coli in surface waters shall be higher than 630 organisms/100 ml." That is presented in the Tennessee WQS regulations 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.

Like the chronic *E. coli* WQC for domestic water supply, the *E. coli* WQC applicable to recreational uses is worded in such a way as to suggest a range of criterion-durations that spans an order of magnitude—2.5 days to 30 days. "The concentration of *E. coli* shall not exceed 630 per 100 ml as a geometric mean based on a minimum of 5 samples collected…over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than twelve hours." This statement implies a criterion-duration of anywhere from 2.5 days (five samples collected at the minimum interval of twelve hours) to 30 days.

The criteria for pH and temperature applicable to this use are worded in such a way as to suggest a default to a criterion-duration of an instant.

e) Agricultural Water Supply / "Livestock Watering and Wildlife" and "Irrigation"

Not applicable. Tennessee has no WQC in common with EPA for this use.

f) Industrial Water Supply

Tennessee has one acute Industrial Water Supply criterion with a clearly articulated criterion-duration – its total dissolved solids WQC, which says "at no time shall (the concentration) exceed 500 mg/L." Without a doubt, the criterion-duration is an instant. For this use, the other parameters (pH, temperature) have acute WQC with an implied, but not clearly stated, criterion-duration of an instant.

4) *Articulation of Criterion-Frequency*[27]

None of the WQC for "traditional" pollutants examined have any statement regarding a criterion-frequency, which suggests an acceptable frequency of excursions (periods equal to the criterion-duration in which the ambient concentration averages higher than the criterion-concentration) of zero. For the purposes of this report, a criterion-frequency of zero has been assumed for all traditional pollutants and all uses.

[27] 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 of 5.2 µg/L more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

5) ***Discussion: Traditional Pollutants/Parameters***[28]

Tennessee has adopted numeric WQC for a relatively small portion of the combinations of "traditional" pollutants and uses for which EPA has published criteria.

With regard to aquatic life (Fish and Aquatic Life), the most significant gap in coverage is the lack of numeric criteria for nutrients related to eutrophication (phosphorous and nitrogen) and the response indicator chlorophyll a.[29] Despite this omission, the state has included on its 303(d) list 268 waterbodies assessment units for which "nutrients" is given as a cause of impairment. Tennessee also lacks numeric WQC related to suspended and bottom sediments, yet it has placed 411 waters on its 303(d) list due to "sediments" and another 5 for "turbidity." This indicates that the state has been quite amenable to using one or more of its narrative WQC as the basis for 303(d) listings; nevertheless adoption of numeric criteria for total phosphorous, total nitrogen, chlorophyll a, suspended sediments, turbidity and embedded sediments could still result in listing a substantial number of additional waters per Section 303(d) of the CWA. "Nutrients" and "sediment/sedimentation" are among the five most frequently mentioned causes of impairment for waters on state 303(d) lists nationwide, along with pathogens, mercury, and metals other than mercury.[30]

The state has *E. coli* WQC applicable to Domestic Water Supply and Recreation. Tennessee's WQS also include acute and chronic Fish and Aquatic Life WQC for this group of indicator bacteria. (EPA has published no such criteria – its *E. coli* criteria apply to water-contact recreation. Likewise, most states have no criteria for indicators of the presence of pathogens in pertaining to aquatic life.)

The state lacks Domestic Water Supply criteria for five of the eight traditional parameters for which EPA has somewhat relevant standards. However, given that: 1) EPA has not issued actual water quality criteria for public water supply use; 2) EPA's drinking water standards for all traditionals except pathogens apply to aesthetics of drinking water (appearance, taste, and odor) rather than health; and 3) all public water supplies serving more than 25 connections are covered by Safe Drinking Water Act regulations regarding finished (at the tap) drinking water, the lack of drinking water supply criteria for such pollutants and parameters probably has little relevance to human health. (On the other hand, high levels of contaminants in raw water supplies can increase the cost of meeting federal drinking water standards).

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[28] 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 "traditional" 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-traditional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

[29] Tennessee does have a chlorophyll a WQC pertaining to its Recreation use classification. It applies only to one waterbody in the state—Pickwick Reservoir.

[30] EPA National Section 303(d) List Fact Sheet: Causes of Impairment. Available at: (http://iaspub.epa.gov/waters/national_rept.control#TOP_IMP, last visited September, 2009.)

The criterion-concentrations/magnitudes in Tennessee's aquatic life WQC for "traditional" pollutants are equal to, or very close to, the criterion-concentrations of corresponding EPA criteria and fall within the range of concentrations/magnitudes for WQC for similar use/pollutant combinations adopted by the other nine states covered by this study.

The state's criterion-concentration for total dissolved solids (TDS) is identical to EPA's secondary drinking water standard for this parameter, and the range of units covered by the state's pH criteria for drinking water supply is only slightly wider than that specified in EPA's secondary drinking water standard for pH (lower limit of 6.0 compared to 6.5). The criterion-concentration for *E. coli* bacteria that applies to water-contact recreation is the same for both Tennessee and EPA.

But for four exceptions—ammonia, chlorophyll a, dissolved oxygen, and total dissolved solids—none of the WQC for traditional pollutants/parameters have clearly-stated criterion-durations. Most are expressed as levels not to be exceeded, which implies a criterion-duration of just an instant.

Likewise, none of the state's WQC for "traditional" pollutants/parameters have any reference to a criterion-frequency.

Turning to the matter of level of protection, in cases where both the state and EPA have a well articulated criterion-duration and criterion-frequency, one can draw reliable conclusions about the degree of protection associated with one criterion versus another. For example, if a state and EPA criteria have identical durations and frequencies (most likely duration is instantaneous and frequency is zero, in the case of aquatic life WQC for traditional parameters), then comparison of state and EPA criterion-concentrations would provide a relatively good indicator of comparative levels of protection provided. If this were the case, then given the fact that, with the exception of certain Fish and Aquatic Life criteria for dissolved oxygen, most of Tennessee's WQC for traditionals applicable to aquatic life have criterion- concentrations identical to, or very close to, those in corresponding EPA WQC, then the state's WQC should provide essentially the same protection as would EPA's. And, for those Tennessee dissolved oxygen WQC with criterion-concentrations higher[31] than that of EPA's only published WQC for freshwaters nationwide – 5.0 mg/L, the state criterion would provide greater protection than would application of the EPA criterion to a given waterbody.

Unfortunately, there is not one traditional pollutant or water quality parameter for which both Tennessee and the federal EPA have a corresponding WQC that clearly specifies the criterion-concentration, criterion-magnitude, and criterion-frequency. Hence, any attempt to determine the relative level of protection afforded by corresponding state and EPA criteria to the applicable designated use(s) is an exercise with an inherently high degree of uncertainty. Obviously, any attempt to perform such comparisons with insufficiently precise WQC would require making assumptions that may or may not turn out to be consistent with the duration and/or frequency intended, or eventually decided upon, by the state. In turn, the results of

[31] Unlike most parameters/pollutants, the higher the criterion-concentration of a dissolved oxygen WQC, the more protective it would tend to be.

attempts to compare the protection provided by a state versus an EPA would, of course, be greatly affected by whatever assumptions were made. Assumption of some fairly long-term duration (e.g., 90 days), rather than a short-term (e.g., one hour), would tend to make a criterion less protective. Likewise, assumption of a higher frequency (e.g., once in six months), rather than a lower frequency (e.g., once in five years) would have the same effect—more protective than if the alternative were the case.

For example, Tennessee's Fish and Aquatic Life WQC for dissolved oxygen applicable to lakes and reservoirs has a criterion-concentration identical to the federal EPA's sole WQC for this parameter for fresh waters—5.0 mg/L. Neither the state nor EPA articulates either a criterion-duration or criterion-frequency for their WQC. If one assumes that both have a criterion-duration of an instant and a criterion-frequency of zero, then the two WQC would be equally protective. However, if one assumes that the same criterion-frequency (maximum of one excursion[32] every three years) that EPA employs in its aquatic life WQC for toxics also applies to its WQC for traditional parameters (e.g., dissolved oxygen, pH, temperature, chlorophyll a) and pollutants (e.g., pathogens, nutrients, sediment, chlorides), then the Tennessee criterion would be more protective. This is because, if the criterion-concentration and criterion-durations of the two WQC are identical, and one criterion had a lower criterion-frequency (zero, presumably, for the Tennessee criterion) than the other (once in three years, assumed, per the EPA criterion), then that criterion with the lower acceptable frequency would be more protective than the other.

A different situation is presented by Tennessee's chronic dissolved oxygen WQC that applies to wadeable streams in subecoregions 71i and 73a, which has a criterion-concentration of 5.0 mg/L and a criterion-duration of 24 hours ("daily average), but for which no criterion-frequency is specified. If one assumes that both the state and EPA WQC have a criterion-frequency of zero, and that the EPA's WQC has a criterion-duration of an instant, then the Tennessee WQC would be less protective—identical concentrations, identical frequencies, and longer duration. But, what if a criterion-frequency of once in three years were assumed for the EPA criterion? Now both criteria have the same criterion-concentration, the state has a longer criterion-duration and a lower criterion-frequency. This presents the question of whether the less protective effect of the state's longer criterion-duration would or would not be offset by the more protective effect of the states lower criterion-frequency. Here, the relative degree of protection cannot be ascertained by simply looking at the concentration, duration, and frequency components of the two criteria. Results of laboratory and or field studies of the effect of exposure to the two combinations of concentration, duration, and frequency of dissolved oxygen would be needed to make such a determination.

With specific regard to the state's Domestic Water Supply criteria, simple comparison of the concentration-criterions of the WQC the state has specified for traditional pollutants to those of the Safe Drinking Water Act standard for the same pollutants would not be very informative because of substantial differences in various aspects of the state's and EPA's criteria/ standards. First, the Safe Drinking Water Act standards apply to finished (after the raw source water has

[32] As used in this report, and in some EPA guidance documents, 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.

been treated to remove contaminants); whereas, like all water quality criteria, Tennessee's public water supply criteria apply to raw (untreated) source water. Second, the state's pathogen WQC is for *E. coli* bacteria, while the EPA standard applies to total coliform bacteria. Also, the state's criteria do not specify a criterion-duration or a criterion-frequency.

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 were designed.[33] Of course, if the criterion-duration and criterion-frequency for a state and corresponding EPA criteria are the same (e.g., duration is 24 hours, frequency is zero) and the state's criterion-concentration for a pollutant[34] were 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, the state's WQC could provide not only 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.

There are four traditional water quality parameters for which Tennessee has adopted different WQC for various subsets of waters in the state—dissolved oxygen, pH, temperature, and ammonia. For dissolved oxygen, the state has specific WQC for each of four categories of streams, as well as one for lakes and reservoirs, plus a default WQC that applies to all waters not falling into any of these five categories. For pH, there are distinct criteria for wadeable streams in each of five subecoregions and another that applies to all other wadeable streams in the state, plus default pH that apply to all other types of waters (non-wadeable streams, rivers, lakes and reservoirs, and wetlands.) For temperature, there is one generic Fish and Aquatic Life criterion that applies to all waters in Tennessee, except for trout streams and impoundments greater than 100 acres in surface area that are subject to thermal stratification. Like EPA's, Tennessee's WQC for ammonia are expressed as equations, which allows adjustment to the criterion-duration according to waterbody-specific and time-specific temperature and/or pH.

Turning to human health, site-specific factors generally play less of a role with regard to safe levels of pollutants than they can with aquatic life. One reason is that human health criteria address impacts on just one species, regardless of the location of the waterbody to which the WQC apply, while differences in the assemblage of species of animals and plants native to one waterbody to another is quite common. What often does change from one place to another is the pattern of human use. For example, persons in hotter climates tend to consume more water, on average, than those in cooler areas; in which case, the criterion-concentration would need to be lower in the warmer region, to offset the effect of the greater volume consumed, in order to keep the mass of the pollutant consumed per unit time the same. Also, 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 locale to locale and/or within subpopulations of humans in a given place.

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[33] Possible reasons include differences in waterbody chemistry and in species present in a given type of aquatic ecosystems, compared to what were used in studies on which EPA's criteria were based.

[34] In the case of dissolved oxygen, WQC with higher criterion-concentrations provide a higher (rather than lower) degree of protection, all other factors being equal.

Likewise, patterns of swimming and other water contact recreation can change considerably depending on difference in the climate in which one waterbody versus another is located, along with the type of waterbody (river, lake, wetland).

None of Tennessee's WQC for traditional pollutants/parameters reflect an attempt to take into account differences in patterns of human use from waterbody to waterbody. That is, for any pollutant/parameter, the WQC that applies is the same for all waters in the state to which it applies. An example from the neighboring state Kentucky, which also is employed by a few other states covered in this study, is to have one WQC for those waters designated primary (or whole body) contact recreation and another WQC for waters designated secondary (or partial body) contact recreation.

Returning to the challenges posed by ambiguities in the articulation of any of the three elements of numeric WQC, this also can render considerably more challenging the implementation of CWA programs that are driven largely by water quality criteria – 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, "not too high" or "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, 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?" 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.[35] 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 there would be some uncertainty that a WQC exceedence had occurred, based on the above evidence.[36]

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[35] This statement assumes that all four of the samples passed the state's quality assurance/quality control (QA/QC) tests.

[36] 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.

D. Toxic Chemicals[37]

1) *Coverage*

a) Aquatic Life – Freshwater / "Fish and Aquatic Life"

Acute Toxicity

Tennessee has adopted acute Fish and Aquatic Life criteria for 25 pollutants. Out of the 31 toxic pollutants for which EPA has issued[38] acute criteria for freshwater aquatic life, Tennessee has not adopted, nor proposed, corresponding criteria for five pollutants (Appendix B, Table 1).[39] These pollutants are mostly a combination of organophosphate pesticides and herbicides and toxic metal.

Chronic Toxicity

Tennessee has adopted chronic Fish and Aquatic Life criteria for 25 pollutants.

Out of the 35 toxic pollutants for which EPA has issued chronic criteria for freshwater aquatic life, Tennessee has not adopted, nor proposed, corresponding criteria for ten pollutants (Appendix B, Table 1). These pollutants are mostly a combination of organophosphate pesticides and herbicides and toxic metals.

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

Tennessee has no WQC for toxic chemicals that apply solely to exposure of humans to toxic chemicals via consumption of aquatic organisms from a given waterbody; rather, it has a set of criteria aimed at protecting humans who use a given waterbody not only for fish consumption but also for water-contact recreation (see Subsection D(1)(d) below).

EPA, on the other hand, has adopted human health WQC aimed at fish/aquatic organism consumption alone – so-called Human Health: Organisms" (HHO) criteria. (EPA has not issued any WQC for toxic chemicals directed at water-based recreational use, either alone or in combination with other human health-related uses).

Technically, Tennessee lacks WQC for all 106 of the pollutants for which EPA has issued "HHO" (fish consumption) criteria; however, it is probably more instructive to compare

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[37] 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.

[38] Throughout this report, the criteria recommended by EPA will be referred to as the EPA's "issued" or "published" criteria, interchangeably.

[39] The pollutant that remains unaccounted is selenium, for which Tennessee has adopted an acute aquatic life WQC with a criterion-concentration of 20µg/L. Because the EPA criterion for selenium is expressed in the form of an equation and because the Agency is in the process of developing a more stringent criterion for selenium, direct quantitative comparison of EPA's selenium WQC to Tennessee's selenium WQC was not undertaken in this review.

Louisiana's" fish consumption + contact recreation" criteria to EPA's "Human Health: Organisms only" (HHO) criteria, as is done in Subsection D(1)(d), below.

c) Human Health: Consumption of: 1) Water, plus 2) Fish and Other Aquatic Organisms

Tennessee has not adopted WQC for toxic chemicals aimed at protection of humans using a waterbody for both drinking water supply (DWS) and consumption of fish, shellfish, and other aquatic organisms (FC). The state does have criteria for these two uses, plus water contact recreation, which it calls Recreation: Water and Organisms criteria (see Subsection D(1)(e) below).

EPA, on the other hand, has adopted human health WQC aimed at combined drinking water supply and fish/aquatic organism consumption – so-called Human Health: Water and Organisms (HHWO) criteria for 113 toxic substances. (EPA has not issued any WQC for toxic chemicals directed at water-based recreational use, either alone or in combination with other human health-related uses).

Technically, Tennessee lacks WQC for all 113 of the pollutants for which EPA has issued "HHWO" (drinking water supply plus fish consumption) criteria; however, it is more instructive to compare Tennessee's Recreation: Water and Organisms to EPA's Human Health: Water and Organisms (HHWO) criteria, as is done in Subsection D(1)(e), immediately below.

d) Human Health: 1) Fish Consumption and 2) Water-Contact Recreation/ "Recreation: Organisms Only" Criteria[40]

Tennessee has adopted "Recreation: Organisms Only" criteria for 93 toxic pollutants. Conversely, the state has not adopted such criteria for fourteen of the total 106 toxic pollutants for which the EPA has issued somewhat corresponding Human Health: Organisms criteria (Appendix B, Table 1). These federal EPA WQCs address the effects of ingestion of toxic substances resulting from the consumption of fish and other aquatic organisms. They do not factor in possible exposure to toxics resulting from water contact recreation. Most of the pollutants lacking state equivalents to EPA's HHO criteria are synthetic organics compounds.

On the other hand, the state has adopted a Recreation: Organisms Only criterion for mercury while the EPA has not. EPA, has however, issued such a criterion for methyl mercury while Tennessee has not.

[40] Subsection "j" of Rule 1200-4-3-.03(4) (titled Recreation) of the Tennessee WQS regulations provides lists of two categories of criteria for toxics, one of which is "Organisms Only Criteria." Rule 1200-4-3-.03(4)(j) states, "The waters shall not contain toxic substances, whether alone, or in combination with other substances, that will render the waters unsafe or unsuitable for water contact activities including the capture and subsequent consumption of fish and shellfish." Hence, Tennessee's Organisms Only Criteria appear to address the combined effects of ingestion of toxics in drinking water supplies and exposure to toxics during water contact recreation.

e) Human Health: 1) Consumption of a)Water plus b) Fish and Other Aquatic Organisms and 2) Water-Contact Recreation/ "Recreation: Water & Organisms" criteria"[41]

Tennessee has adopted Recreation: Water and Organisms criteria for 93 toxic pollutants. Conversely, the state has not adopted such criteria for 21 of the total 113 toxic pollutants for which the EPA has issued somewhat corresponding Human Health Water and Organisms (HHWO) criteria (Appendix B, Table 1). These federal EPA WQCs address the effects of ingestion of toxic substances resulting from the consumption of fish and other aquatic organisms. They do not factor in possible exposure to toxics resulting from water contact recreation. Though some are toxic metals, most of the pollutants lacking state equivalents to EPA's HHWO criteria are synthetic organic compounds.

On the other hand, the state has adopted a HHWO criterion for mercury while EPA has not. EPA's criterion is expressed as methyl mercury.

f) Drinking Water Supply / "Domestic Water Supply"

Tennessee has adopted Domestic Water Supply criteria for 63 toxic pollutants. Conversely, the state has not adopted such criteria for 21 of the total 83 3toxic pollutants for which EPA has promulgated somewhat corresponding[42] primary drinking water standards under the Safe Drinking Water Act. (Appendix B, Table 2).

On the other hand, the state has adopted a Domestic Water Supply criterion for nickel while EPA has not.

g) Human Health: Water-based Recreation / "Recreation"

Tennessee does not have numeric WQC for toxic chemicals that are designed solely to protect humans engaged in various forms of water-contact recreation. Rather, the state's "Recreation" criteria for toxic chemicals are aimed not only at water contact recreation but also that use in combination with either: 1) intake of toxics in contaminated fish and other aquatic life; and 2) intake of toxics in drinking water supply as well as toxic in contaminated aquatic life.

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[41] Subsection "j" of Rule 1200-4-3-.03(4) (titled Recreation) of the Tennessee WQS regulations provides lists of two categories of criteria for toxics, one labeled "Water and Organisms Criteria." This subjection states, "The waters shall not contain toxic substances, whether alone, or in combination with other substances, that will render the waters unsafe or unsuitable for water contact activities including the capture and subsequent consumption of fish and shellfish." The water and organisms criteria should only be applied to those waters classified for both recreation and domestic water supply." Hence, Tennessee's Water and Organisms Criteria appear to address the combined effects of ingestion of toxics in drinking water supplies and in the flesh of fish and other aquatic organisms consumed by humans, as well as exposure to toxics during water contact recreation.

[42] 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 (CWA). Some of these waters are, or might be, used as a source of "raw" water by public and private drinking water systems. Hence, when a waterbody in Tennessee is designated "Domestic Water Supply" then a certain set of WQC apply to said river or lake, per the CWA. There also is another set of standards that apply to the "finished" water that results from "raw" water from a river or lake being run through treatment processes aimed at removing contaminants. These are called Drinking Water Standards, and are established as national regulations under authority of the SDWA. They are often referred to as "maximum contaminant levels" (MCLs).

These Recreation: Organisms Only and Recreation: Water and Organisms WQC are discussed in subsections (d) and (e) above.

h) Industrial Water Supply

Tennessee has not adopted any numeric WQC that are applicable to toxic chemicals for industrial water supply uses. However, Rule 1200-4-3-.03(2)(i) does specify a narrative criterion for irrigation uses, stating: "The waters shall not contain toxic substances whether alone or in combination with other substances, which will adversely affect industrial processing."

EPA has no numeric criteria for toxic chemicals applicable to this use.

i) Agricultural Water Supply

Tennessee has not adopted any numeric WQC that are applicable to toxic chemicals for agricultural water supply uses. However, Rule 1200-4-3-.03(5)(f) does specify a narrative criterion for irrigation uses, stating: "The waters shall not contain toxic substances whether alone or in combination with other substances which will produce toxic conditions that adversely affect the quality of the waters for irrigation." In addition, the state has also adopted a narrative criterion applicable to toxic substances that protects for livestock watering: "The waters shall not contain substances whether alone or in combination with other substances, which will produce toxic conditions that adversely affect the quality of the waters for livestock watering.…" [Rule 1200-4-3-.03(6)(f)].

EPA has no numeric criteria for toxic chemicals applicable to this use.

2) *Criterion-Concentrations,[43] Compared to EPA's*

a) Aquatic Life – Freshwater / "Fish and Aquatic Life"

Acute Toxicity

Among the pollutants 25 pollutants for which Tennessee has adopted Fish and Aquatic Life criteria, 24 pollutants have criteria that correspond to a EPA recommended criterion. All of these 24 pollutants have acute freshwater aquatic life criteria for which the criterion-concentrations that are equal to the acute criterion-concentrations in the corresponding EPA aquatic life criteria.

[43] According to EPA guidance, numeric water quality criteria (WQC) consist of 3 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."

Chronic Toxicity

Among the 25 pollutants for which Tennessee has adopted Fish and Aquatic Life criteria, 24 pollutants have criteria that correspond to a EPA recommended criterion.[44] All of the pollutants 24 pollutants for which Tennessee has adopted chronic aquatic life criteria have criterion-concentrations that are equal to those in the corresponding EPA chronic aquatic life criteria.

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

Not applicable. Tennessee has no WQC for toxic chemicals that apply solely to exposure of humans to pollutants via the consumption of fish and other aquatic life forms caught in a given waterbody. (It does, however, have WQC applicable to the combination of fish consumption plus water contact recreation. See subsection "d" below.)

c) Human Health: Consumption of: 1) Water plus 2) Fish and Other Aquatic Organisms

Not applicable. Tennessee has adopted no WQC for toxic chemicals aimed at protection of humans using a waterbody for both drinking water supply (DWS) and consumption of fish, shellfish, and other aquatic organisms. (It does, however, have WQC applicable to the combination of: 1) drinking water consumption, 2) fish consumption, and 3) water contact recreation. See subsection "e" below.)

d) Human Health: 1) Fish Consumption and 2) Water Contact Recreation/ "Recreation: Organisms Only" Criteria[45]

Among the 93 pollutants for which Tennessee has adopted Recreation: Organisms Only criteria, there are 92 pollutants[46] for which there are somewhat corresponding EPA recommended criterion—Human Health: Organisms (HHO). Within this subset, the state's Recreation: Organisms Only for two (2) pollutants have criteria for which the criterion-concentrations are higher than EPA's (arsenic and dioxin) and 90 pollutants have criteria for which the criterion-concentrations are equal to those in the somewhat corresponding EPA criteria. (EPA's Human Health: Organisms WQC address risk to humans resulting from ingestion of toxic substances resulting from eating contaminated fish and other aquatic life.

[44] The pollutant that remains unaccounted is iron, for which Tennessee has adopted a narrative aquatic life criterion that is not directly comparable to EPA's numeric WQC: "The waters shall not contain iron at concentrations that cause toxicity or in such amounts that interfere with habitat due to precipitation or bacteria growth" [rule 1200-4-3-.03(3)(i)].

[45] Subsection "j" of Rule 1200-4-3-.03(4) (titled Recreation) of the Tennessee WQS regulations provides lists of two categories of criteria for toxics, one of which is "Organisms Only Criteria." Rule 1200-4-3-.03(4)(j) states, "The waters shall not contain toxic substances, whether alone, or in combination with other substances, that will render the waters unsafe or unsuitable for water contact activities including the capture and subsequent consumption of fish and shellfish." Hence, Tennessee's Organisms Only Criteria appear to address the combined effects of ingestion of toxics in drinking water supplies and exposure to toxics during water contact recreation.

[46] The unaccounted pollutant is mercury, for which the state has adopted a HHO criterion while EPA has not. EPA does have a WQC for methylmercury, but unlike Tennessee's mercury WQC, EPA's applies to concentrations in fish tissue, rather than in ambient water.

Unlike Tennessee's Recreation: Organisms Only WQC, these EPA-issued WQC do not also address risk from exposure to toxic substances during water contact recreation.)

e) Human Health: 1) Consumption of a)Water plus b)Fish and Other Aquatic Organisms and 2) Water Contact Recreation/ "Recreation: Water & Organisms" Criteria"[47]

Among the 93 pollutants for which Tennessee has adopted "Recreation: Water and Organisms" criteria, there are 92 pollutants[48] for which there are somewhat corresponding EPA recommended criterion—Human Health: Water and Organisms (HHWO). Within this subset, three (3) pollutants have state criteria for which the criterion-concentrations are higher than EPA's (arsenic, dioxin, and hexachloroethane) and 89 pollutants have criteria for which the criterion-concentrations are equal to those in the corresponding EPA criteria. EPA's Human Health: Water and Organisms WQC address risk to humans resulting from ingestion of toxic substances in drinking water as well as in contaminated fish and other aquatic life. Unlike Tennessee's Recreation: Water and Organisms: WQC, these EPA-issued WQC do not also address risk from exposure to toxic substances during water contact recreation.

f) Drinking Water Supply / "Domestic Water Supply"

Among the 63 pollutants for which Tennessee has adopted "domestic water supply" criteria, there are 62 pollutants for which there are somewhat corresponding[49] Primary Drinking Water Standards (often called Maximum Contaminant Levels—MCLs).[50] Within this subset, one pollutant (lead) has a WQC for which the criterion-concentration is lower than EPA's MCL value, and 61 pollutants have criteria for which the criterion-concentrations are equal to the corresponding MCL value promulgated by EPA.

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[47] Subsection "j" of Rule 1200-4-3-.03(4) (titled Recreation) of the Tennessee WQS regulations provides lists of two categories of criteria for toxics, one labeled "Water and Organisms Criteria." This subjection states, "The waters shall not contain toxic substances, whether alone, or in combination with other substances, that will render the waters unsafe or unsuitable for water contact activities including the capture and subsequent consumption of fish and shellfish…. The water and organisms criteria should only be applied to those waters classified for both recreation and domestic water supply." Hence, Tennessee's Water and Organisms Criteria appear to address the combined effects of ingestion of toxics in drinking water supplies and in the flesh of fish and other aquatic organisms consumed by humans, as well as exposure to toxics during water contact recreation.

[48] The unaccounted pollutant is mercury, for which the state has adopted a HHWO while EPA has not.

[49] 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 (CWA). Some of these waters are, or might be, used as a source of "raw" water by public and private drinking water systems. Hence, when a waterbody in Tennessee is designated "Domestic Water Supply" then a certain set of WQC apply to said river or lake, per the CWA. There also is another set of standards that apply to the "finished" water that results from "raw" water from a river or lake being run through treatment processes aimed at removing contaminants. These are called Drinking Water Standards, and are established as national regulations under authority of the SDWA. They are often referred to as "maximum contaminant levels" (MCLs). Another difference between Tennessee's Domestic Water Supply water quality criteria and EPA's SDWA standards pertaining to waterborne pathogens is that the former are expressed in terms of fecal coliform bacteria, while the latter employ the more encompassing grouping total coliform bacteria as the indicator parameter

[50] The unaccounted pollutant is nickel, for which the state has adopted a "domestic water supply" criterion and for which EPA has not promulgated an MCL.

g) Human Health: Water-based Recreation / "Recreation"

Not applicable. Tennessee does not have numeric WQC for toxic chemicals that are designed solely to protect humans engaged in various forms of water-contact recreation. Rather, the state's "Recreation" criteria for toxic chemicals are aimed not only at water contact recreation but also that use in combination with either: 1) intake of toxics in contaminated fish and other aquatic life; and 2) intake of toxics in drinking water supply as well as toxic in contaminated aquatic life. The "Recreation: Organisms Only and Recreation: Water and Organisms WQC" are discussed in subsections (d) and (e) above.

h) Industrial Water Supply

Not applicable. Tennessee has not adopted any numeric WQC that are applicable to toxic chemicals for industrial water supply use. Similarly, EPA has no WQC for toxic chemicals that are applicable to this use.

i) Agricultural Water Supply

Not applicable. Tennessee has not adopted any numeric WQC that are applicable to toxic chemicals for industrial water supply use. Similarly, EPA has no WQC for toxic chemicals that are applicable to this use.

3) *Articulation of Criterion-Duration*[51]

None of Tennessee's numeric WQC for toxic chemicals, whether applicable to aquatic life or human health, has a clearly stated criterion-duration.

a) Aquatic Life / "Fish and Aquatic Life"[52]

No clear indication of a criterion-duration applicable to Tennessee's acute or chronic Fish and Aquatic Life criteria is provided in the relevant tables, footnotes to such tables, or the definitions section of the regulations. The only language that provides any clue as to the duration applicable the state's aquatic life criteria for toxic pollutants appears in Rule 1200-4-3-.03(3)(g), and these serve only to indicate that the state has, to some extent, drawn upon EPA's aquatic life criteria. First, this subsection states, "References on this subject include, but are not limited to:

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[51] 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, 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.

[52] Throughout this document, generic names (e.g., "aquatic life," "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 the same use, the name that the state employs is listed in quotation marks, after the generic name.

Quality Criteria for Water (Section 304(a) of Public Law 92-500 as amended); Federal Regulations under Section 307 of Public Law 92-500 as amended." Also, the two columns of criterion-concentrations are titled "Criterion Maximum Concentration µg/l (CMC)" and "Criterion Continuous Concentration µg/l (CCC)." Only persons with considerable expertise in the federal Clean Water Act itself would know that Section 304(a) of said Act is where Congress charged EPA to publish water quality criteria that the states might use in adopting their own criteria. Likewise, only those with a working knowledge of EPA's water quality criteria program would know that EPA uses CMC in reference to its own aquatic life criteria with a criterion-duration of one hour (acute) and CCC when addressing the Agency's criteria with criterion-duration of four days/96 hours (chronic).

Absent this background information, a person reading the Tennessee water quality standards regulations would likely surmise that the "Criterion Maximum Concentration (CMC)" refers to WQC with a criterion-duration of just an instant, and might also assume that the "Criterion Continuous Concentration (CCC)," because of the use of "continuous" has an open-ended duration, i.e., it applies to the long term (years/decades) average concentration of a pollutant in a waterbody. Alternatively, the absence of any mention of a criterion-duration, or averaging period, with regard to these CCC criteria could be taken to infer a duration of an instant. This would not seem logical because this would result in the criterion-duration for both the acute and chronic criteria being the same—an instant. Also, a criterion-duration of a mere instant would not seem consistent with the concept of chronic exposure.

A criterion-duration might be inferred for Tennessee's acute and chronic aquatic life criteria from the following text found in Rule 1200-4-3-.05(4), "Water quality criteria for the fish and aquatic life and livestock watering and wildlife criteria set forth shall generally be applied on the basis of the following stream flows: unregulated streams – stream flows equal to or exceeding the seven-day minimum, ten-year recurrence interval; regulated streams – all flows in excess of the minimum flow occurring one in ten years." This suggests a criterion-duration (length of time over which the average waterbody concentrations of a pollutant excursions needs to be equal or less than the criterion-concentration) of seven days. Assuming a criterion-duration of 7 days for all (both acute and chronic) of Tennessee's aquatic life criteria does not appear justifiable because, by definition, the criterion-duration for acute and chronic criteria cannot be identical—the criterion-duration for chronic WQC is always longer than that for an acute for example, EPA's acute aquatic life WQC for toxics have a duration of one hour, while its chronic criteria have a duration nearly 100 times as long—four days, which equals 96 hours.

On balance, a criterion-duration for Tennessee's acute (Criterion Maximum Concentration) Fish and Aquatic Life WQC of an instant seems the most appropriate assumption. And, for the chronic (Criterion Continuous Concentration) Fish and Aquatic Life criteria, an assumed criterion-duration of four days/96 hours seems most appropriate.

b) Human Health: Consumption of Fish and Other Aquatic Organisms (HHO)/ "Organisms Only Criteria"

It is unclear from the Tennessee WQS regulations what criterion-duration might apply to the state's "Organisms Only" criteria. Indeed, no direct reference to a criterion-duration for

Tennessee's human health criteria appears section of the regulations[53] in which the table listing "Organisms Only" criteria-concentrations for toxic pollutants appears, footnotes to such tables, or the definitions section of regulation. Possible assumptions include: 1) instantaneous, 2) 30 days, 3) 365 days, and 4) 70 years.

Defaulting to a criterion-duration of an instant is supported by the fact that the state made no reference to any duration, in terms of an averaging period or otherwise. It would seem that if Tennessee intended for any duration other than an instant to apply to its human health-related WQC for toxics, it would have said so, as it did for some of its WQC for traditional pollutants.

On the other hand, the introductory paragraph to its list of criterion-concentrations for toxics applicable to its "water and organisms criteria" does refer to WQC published by EPA: "Available references include, but are not limited to: Quality Criteria for Water (Section 304(a) of Public Law 92-500 as amended)." Given this reference, which suggests that the state's "organisms only criteria" are based, at least in part, on EPA's 304(a) criterion, once might assume that the same duration applicable to the corresponding EPA criteria (HHO) would apply to the state's. Unfortunately, EPA guidance regarding a criterion-duration for its human health criteria is unclear. Some text strongly suggests an instantaneous duration, while other portions of relevant guidance seem to indicate durations of either a year (365 days, not a calendar year), or even 70 years (average human life span).

A criterion-duration of 30 days could perhaps be inferred from the following text from 1200-4-3-.05(4), "Water quality criteria for the fish and aquatic life and livestock watering and wildlife criteria set forth shall generally be applied on the basis of the following stream flows…. All other criteria shall be applied on the basis of stream flows equal to or exceeding the 30 day minimum 5 year recurrence interval."

On balance, a default to a criterion-duration of an instant seems to be the best assumption for the purposes of this report.

c) Human Health: Consumption of Water plus Fish and Other Aquatic Organisms / "Human Health: Water & Organisms"

It is unclear from the Tennessee WQS regulations what criterion-duration might apply to the state's "Water & Organisms" criteria. As such, a default criterion-duration of an instant is assumed for the purposes of this report. (See discussion of duration for state's "Organisms Only" criteria in Subsection D.3(b) of this report, immediately above.)

d) Human Health: Drinking Water Supply/ "Domestic Water Supply"

It is unclear from the Tennessee WQS regulations what criterion-duration might apply to the state's "Domestic Water Supply" criteria. No direct reference to a criterion-duration for Tennessee's Domestic Water Supply criteria appears in the table listing criteria-concentrations for toxic pollutants for this use,[54] footnotes to such tables, or the definitions section of

[53] Rule 1200-4-3-.03(4)(j)
[54] Id.

regulation. .Possible assumptions include: 1) instantaneous, 2) 30 days, 3) one year (365 days), and 4) 70 years.

Defaulting to a criterion-duration of an instant is supported by the fact that the state made no reference to any duration, in terms of an averaging period or otherwise. It appears that if Tennessee intended for any duration other than an instant to apply to its human health-related WQC for toxics, it would have said so, as it did for some of its WQC for traditional pollutants.

The introductory paragraph to the list of criterion-concentrations for toxics applicable to Domestic Water Supply in Section 12-4-3-.03(1)(j) of Tennessee's WQS regulations refers to the Section 304(a) WQC published by EPA under authority of the CWA. Given this reference, which suggests that the state's Domestic Water Supply criteria are based, at least in part, on EPA's 304(a) criteria, once might assume that the duration applicable to the EPA Section 304(a) criteria for drinking water supply (the Human Health: Water and Organisms criteria [HHWO criteria]) would also apply to Tennessee's Domestic Water Supply criteria. Unfortunately, EPA guidance regarding a criterion-duration for its human health criteria is unclear. Some text strongly suggests an instantaneous duration, while other portions of relevant guidance seem to indicate durations of either a year (365 days, not a calendar year), or even 70 years (average human life span).

Rule 1200-4-3-.03(1)(j) of the Tennessee WQS regulations also refers to "Federal Regulations under Section 1412 of the Public Health Service Act as amended by the Safe Drinking Water Act (Public Law 93-523)." The same duration that applies to the concentrations specified in EPA's Primary Drinking Water Standards would apply to Tennessee's Domestic Water Supply criteria for toxics. EPA's regulations and guidance pertaining to drinking water standards do not employ the term "criterion-duration," nor related terms like "standard-duration" or just "duration." Nevertheless, given that compliance with drinking water standards under the Safe Drinking Water Act is based on the average of samples collected over four "rolling" calendar quarters (12 months total), one might possibly assume that the same duration applies to these state water quality for Domestic Water Supply.

Yet another criterion-duration (30 days) could perhaps be inferred from the following text from Rule 1200-4-3-.05(4) of the Tennessee WQS regulations, "Water quality criteria for the fish and aquatic life and livestock watering and wildlife criteria set forth shall generally be applied on the basis of the following stream flows." All other criteria shall be applied on the basis of stream flows equal to or exceeding the 30 day minimum five year recurrence interval."

On balance, a criterion-duration of an instant seems to be the assumption most consistent with the wording of the Tennessee WQS regulations.

e) Human Health: Water-Contact Recreation/ "Recreation"

Not applicable. Tennessee does not have numeric WQC for toxic chemicals that are designed to protect humans engaged in various forms of water-contact recreation. (The state does, however, have WQC for nearly 100 toxic chemicals aimed at risk to human health resulting from another exposure route—consumption of sport-caught fish and other aquatic food

stuffs. The criteria durations for these WQC are addressed in Sections D(3)(b) and D(3)(c) of this report, above.)

f) Industrial Water Supply

Not applicable. Tennessee has not adopted any numeric WQC that are applicable to toxic chemicals for industrial water supply use. Similarly, EPA has no WQC for toxic chemicals that are applicable to this use.

g) Agricultural Water Supply

Not applicable. Tennessee has not adopted any numeric WQC that are applicable to toxic chemicals for industrial water supply use. Similarly, EPA has no WQC for toxic chemicals that are applicable to this use.

4) *Articulation of Criterion-Frequencies*

None of Tennessee's numeric WQC for toxic chemicals have fully articulated or clearly stated criterion-frequencies.

a) Aquatic Life (Fish and Wildlife) – Freshwater and Marine

Given none of Tennessee's numeric aquatic life WQC for toxic chemicals have fully articulated or clearly stated criterion-frequencies, a default to a criterion-frequency of zero might seem appropriate for such criteria. However, since Tennessee's WQS regulations do include explicit references to EPA's 304(a) criteria in general and do employ the same terminology as EPA with regard to its acute aquatic life criteria ("criterion maximum concentration" or "CMC") and its chronic aquatic life criteria ("criterion continuous concentration" or "CCC"), use of the same criterion-frequency as that for corresponding EPA aquatic life criteria could, for purposes of this study, possibly be justified. Following this logic, a maximum frequency of excursions (conditions worse that those described by the combination of the criterion-concentration and criterion-duration) of one in three years appear reasonable – for acute and chronic aquatic life criteria both.

Another way in which a criterion-frequency could be inferred for Tennessee's acute and chronic aquatic life criteria for toxics is the following text from Rule 1200-4-3-.05(4): "Water quality criteria for the fish and aquatic life and livestock watering and wildlife criteria set forth shall generally be applied on the basis of the following stream flows: unregulated streams – stream flows equal to or exceeding the 7-day minimum, 10-year recurrence interval; regulated streams – all flows in excess of the minimum flow occurring one in ten years." This suggests a criterion-frequency (acceptable frequency of excursions) of no more than one in ten years.

On balance, an assumed criterion-frequency of once-in-three years appears most appropriate.

b) Human Health: Various Uses

Since neither Tennessee's WQS regulations nor EPA's water quality criteria guidance mentions a human health criterion-frequency for toxic chemicals, there seems to be no basis for inferring that any excursions are acceptable.

A human health criterion-frequency of once in five years could perhaps be inferred from the following text from Rule 1200-4-3-.05(4) of the Tennessee WQS regulations: "Water quality criteria for the fish and aquatic life and livestock watering and wildlife criteria set forth shall generally be applied on the basis of the following stream flows ...." All other criteria shall be applied on the basis of stream flows equal to or exceeding the 30 day minimum five year recurrence interval."

On balance, a criterion-frequency of zero seems most consistent with the wording of the Tennessee WQS regulations.

c) Industrial Water Supply

Not applicable. Tennessee has not adopted any numeric WQC that are applicable to toxic chemicals for industrial water supply use. Similarly, EPA has no WQC for toxic chemicals that are applicable to this use.

d) Agricultural Water Supply

Not applicable. Tennessee has not adopted any numeric WQC that are applicable to toxic chemicals for industrial water supply use. Similarly, EPA has no WQC for toxic chemicals that are applicable to this use.

5) *Discussion: Criteria for Toxic Chemicals*

Criteria Related to Aquatic Life Protection

The state has adopted acute aquatic life criteria for more than 80%, and chronic aquatic life criteria for more than 70%, of the total number pollutants for which US has issued corresponding WQC.

When there are corresponding state and EPA criteria, the criterion-concentrations in all of Tennessee's aquatic life criteria for toxic chemicals are equal to the criterion-concentrations in the corresponding EPA criteria.

Tennessee's WQS regulations contains no mention of a criterion-duration for either its acute or chronic aquatic life WQC. The regulations do refer to EPA's 304(a) criteria in general, and employ EPA terminology ("criterion maximum concentration-CMC" and "criterion continuous concentration-CCC") for what appear to be its acute and chronic aquatic life criteria, respectively. Persons familiar with this EPA terminology might also be aware that the criterion-duration of one hour applies EPA's CMC criteria and the criterion-duration of four days (96

hours) applies to the Agency's CCC criteria. Those lacking this specialized background information might well surmise that "Criterion Maximum Concentration (CMC)" means a criterion-duration of just an instant, and that "Criterion Continuous Concentration (CMC)" implies an open-ended duration, i.e., the criterion-duration applies to the long term (years/decades) average concentration of a pollutant in a waterbody.

There is also no mention of a criterion-frequency in the Tennessee WQS regulations, which might be taken to mean that none is intended (i.e., the acceptable frequency of excursions – conditions worse than those described by the combination of the criterion-concentration and criterion-duration – is zero). A criterion-frequency of once-in-three-year might be implied by the reference to EPA's WQC in Tennessee's regulations, but an assumption of a criterion-frequency of zero seems more consistent with what actually appears (in this case, what does not appear) in the state's regulations.

Because of the absence of specific mention of a criterion-duration and criterion, the utility of comparing of the criterion-concentrations in Tennessee's Fish and Aquatic life criteria with those in the corresponding EPA criteria for purposes of determining the relative degree of protection provided by attainment of their respective aquatic life criteria is limited. The necessity of making assumptions about criterion-duration and criterion-frequency for this category of Tennessee WQC means that uncertainty is inherent in such an exercise.

If one assumes, for discussion purposes, that the criterion-durations and criterion-frequencies applicable to Tennessee's aquatic life WQC are the same as those that are applicable to EPA's aquatic life criteria (acute criteria: one hour, once-in-three-years; chronic criteria: 96 hours, once in 3 years), then it would be reasonable to conclude that those state criteria having criterion-concentrations that are equal to those in EPA's corresponding criteria are as protective as EPA's criteria. And since it is found that the criterion-concentrations in all of Tennessee's aquatic life criteria for toxic chemicals are equal to the criterion-concentrations in the corresponding EPA criteria, it might be further inferred from these assumptions that Tennessee's WQC provide aquatic life protection at levels equal to those provided by EPA's corresponding WQC.

On the other hand, if a criterion-duration of an instant is assumed for Tennessee's acute Fish and Aquatic Life criteria for toxics while keeping the frequency at once-in-three-year, then all of the state's WQC would seem to provide greater protection than would EPA's criteria (same criterion-concentration, shorter state criterion-duration, same criterion-frequency). In contrast, if one assumes that the criterion-duration for the state's chronic criteria is, in essence, the entire period for which a given water has been monitored for a particular toxic pollutant (long-term average), then the state WQC with criterion-concentrations equal to those in EPA's chronic WQC would be less protective than corresponding EPA WQC (assuming that the criterion-frequencies applicable to such criteria are identical).

Using an assumed criterion-frequency of zero (rather than using the once-in-three-year criterion-frequency that is applicable to EPA's aquatic life criteria (both acute and chronic) further complicates the task of comparing the level of protection afforded to aquatic life by state's criteria to that by EPA's criteria. If, for a given WQC, the criterion-concentration and

criterion-duration for Tennessee's and EPA's are the same, then a frequency of zero for the state WQC would make the WQC issued by EPA less protective. However, if the state's criterion-duration for its CCC values is indeed a "long term average" and the state's criterion-frequency is zero, it would be difficult to determine whether, with the relevant criterion-concentrations being equal, the effects of a lower criterion-frequency would be offset by the effect of potentially a much longer state criterion-duration (years or even decades versus four days for EPA). Only if data were available regarding the impacts, on a variety of species, of an exposure pattern identical to that specified by the concentration, duration, and frequency of the state's WQC for a particular toxic substance, would such a comparison be possible. (Appendix C presents tables in which various combinations of relative criterion-concentrations, criterion-durations, and criterion-frequencies are displayed, according to the relative level of protection provided.)

There could also be state-specific, watershed-specific, or even waterbody-specific reasons that a state aquatic life criterion can have a criterion-concentration higher or lower than that for the corresponding EPA criterion and still be equally protective of aquatic life.[55] Kentucky has not, however, developed any such WQC for toxics—the same criterion-concentration for a given pollutant/designated use combination applies throughout the state, (except for the criteria for certain heavy metals, which, like the EPA WQC for these pollutants, vary according to the hardness of the water in a given waterbody.)

Criteria Related to Human Health Protection

Tennessee has adopted criteria for a large number of toxic pollutants to address risks associated with: a) human consumption of fish and other aquatic organisms plus water contact recreation, and b) the combined consumption of fish and drinking water plus water contact recreation. For human health, Tennessee has adopted "Recreation: Water & Organisms" criteria for more than 80% of the toxic substances for which EPA has issued somewhat corresponding[56] criteria (Human Health; Water and Organisms), and "Recreation: Organisms Only" criteria for more than 90%, of the total number of pollutants for which EPA has issued somewhat corresponding criteria (Human Health: Organisms Only).

On the other hand, of those pollutants for which the state has not adopted either of these two types of human health-related "Recreation" criteria, most are synthetic organics and several are suspected or known carcinogens (e.g., 1,2,4,5-Tetrachlorobenzene; Bis(chloromethyl) ether; N-Nitrosodiethylamine) and/or persistent bioaccumulators (e.g., pentachlorobenzene; N-Nitrosodibutylamine; N-Nitrosopyrrolidine). Also, among the pollutants without state human health "water and organisms" criteria are 2,4-D and methoxychlor – both of which are substances frequently mentioned as potential endocrine disruptors. Methoxychlor and

[55] Possible reasons include differences in waterbody chemistry and in species present in a given type of aquatic ecosystems, compared to what were used in studies on which EPA's criteria were based.

[56] The term "somewhat corresponding" is used because unlike Tennessee's "Recreation: Water and Organisms" and "Recreation: Organisms Only" criteria, EPA's "Human Health: Water and Organisms" and "Human Health: Organisms" criteria do not take account of possible intake of toxic substances resulting from water contact recreation. However, because the amount of a toxic substance likely to be taken in due to water contact recreation is likely to be quite small in comparison to the intake resulting from consumption of contaminated fish or water.

pentachlorobenzene are also contaminants reported to be associated with suspended material in the Mississippi River.[57]

In addition to its Recreation: Water and Organisms and Recreation: Organisms Only criteria, Tennessee has also adopted Domestic Water Supply criteria for more than two-thirds (2/3) of the total number of pollutants for which EPA has promulgated somewhat corresponding[58] Primary Drinking Water Standards (often referred to as Maximum Contaminant Levels—MCLs) under the Safe Drinking Water Act.

Where there are corresponding state and EPA human health criteria, the criterion-concentrations almost all of Tennessee's human health-related criteria are equal to the criterion-concentrations in the corresponding EPA criteria or standards. This might be taken to suggest that virtually all the state's human health criteria are as protective as EPA's; however, as mentioned in various parts of this report, the relative degree of protection to designated uses provided by a particular state WQC compared to the corresponding EPA WQC cannot be determined simply by comparing their respective criterion-concentrations. In order for relative criterion-concentrations to correlate directly to level of protection, the criterion-duration and criterion-frequency for the two criteria in question must be clearly identical. The following paragraphs discuss what the Tennessee WQS regulations indicate about to the criterion-durations and criterion-frequencies that apply to the state's human health criteria.

None of Tennessee's WQC for addressing potential effects of waterborne toxic chemicals on human health make any direct reference to a criterion-duration, whether as an average period or otherwise. This seems to indicate a criterion-duration of just an instant. The reference, in Rule 1200-4-3.03(3)(j) and in Rule 1200-4-3.03(3)(j), to EPA's 304(a) criteria and EPA's drinking water standards, could be taken to suggest that the same criterion-duration applicable to the corresponding EPA criteria (HHO and HHWO) and primary drinking water standards would also apply to the state's human health criteria. Unfortunately, EPA guidance regarding a criterion-duration for its Section 304(a) human health criteria is unclear – criterion-durations of an instant, a year, or even 70 years are suggested by text in various Agency guidance documents. On balance, a presumed duration of 365 days seems reasonable, at lease for the purposes of this report. As for EPA's drinking water standards established under the SDWA, a *de facto* criterion-duration of twelve-month is created by the rules governing interpretation of monitoring data for levels of toxics in finished drinking water, though the term "duration" is never employed in such rules.

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[57] "Polychlorinated Biphenyls and other Synthetic Organic Contaminants Associated with Sediments and Fish in the Mississippi River" Colleen E. Rostad, et. al. Contained in U.S. Geological Survey Circular 1133, "Contaminants in the Mississippi River." (1995).

[58] 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 (CWA). Some of these waters are, or might be, used as a source of "raw" water by public and private drinking water systems. Hence, when a waterbody in Tennessee is designated "Domestic Water Supply" then a certain set of WQC applies to said river or lake, per the CWA. There also is another set of standards that apply to the "finished" water that results from "raw" water from a river or lake being run through treatment processes aimed at removing contaminants. These are called Drinking Water Standards, and are established as national regulations under authority of the SDWA. They are often referred to as "maximum contaminant levels" (MCLs).

Both of the following also lack direct mention of a criterion-frequency: 1) those portions of Tennessee's WQS regulations pertaining to its three categories of human health WQC for toxics, and 2) EPA's literature regarding: a) 304(a) criteria applicable to human health, and b) Primary Drinking Water standards.

The lack of any direct indication of applicable durations and frequencies for the state's WQC for toxic chemicals and human health, combined with the same situation with regard to the concentrations published by EPA under authority of the CWA and the SDWA, renders determination of the relative degree of protection provide by the state's criteria versus EPA's criteria or standards an exercise with an inherently high degree of uncertainty.

Hypothetically, if the criterion-durations and criterion-frequencies for Tennessee's human health criteria are the same as those of EPA's, then it would be reasonable to conclude that those state criteria having criterion-concentrations higher than EPA's are less protective than EPA's, those having criterion-concentrations lower than EPA's are more protective than EPA's, and those criteria having criterion-concentrations that are equivalent to EPA's are as protective as EPA's. This would then suggest that most of Tennessee's human health criteria are as protective as EPA's, though a few are less protective.

If, on the other hand, if one makes different assumptions about Tennessee's and/or EPA's criterion-duration and criterion-frequency, then an evaluation of degree of protection can become more difficult. (See discussion of this issue in the "*Criteria Related to Aquatic Life Protection"* subsection immediately above. Also see Appendix C, which illustrates the effect of different combinations of relative criterion-concentrations, criterion-durations, and criterion-frequencies on the relative degree of protection provided by two WQC.)

Another point regarding the degree of protection provided by the state's "organisms only" criteria (protecting fish consumption) is that EPA's human health criteria dealing with fish consumption (Human Health: Organisms—HHO) and Human Health: Water and Organisms--HHWO) assume a per-person daily intake of 17.5 grams of fish and other aquatic organisms. 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 the EPA HHO and 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 the HHO and HHWO criteria for such waterbodies need to be set at lower levels than that which has been set by EPA.

Another point regarding the degree of protection provided by the state's Fish Consumption criteria is that EPA's human health criteria dealing with fish consumption (HHO and HHWO) assume a per-person daily intake of 17.5 grams of fish and other aquatic organisms. 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, 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 10 times the 17.5 g/day national average. Since, for virtually all the toxics for which Kentucky has established Human Health: Fish Consumption, its criterion-concentration is identical to that of corresponding EPA criteria (Human Health: Organism), if there are any waterbodies in Kentucky 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 the Human Health: Fish Consumption criteria need to be set at lower levels than that which has been set by EPA.

There is no indication that different rates of fish consumption have been taken into account in establishing Tennessee's Recreation: Organisms Only or Recreation: Water and Organisms WQC. The criterion for a given pollutant for one of these two sets of WQC for a given toxic substance is the same for all waters in the state to which these uses apply.

As for the relative degree of protection provided to consumers of drinking water by Tennessee's Domestic Water Supply water quality criteria, and EPA's Primary Drinking Water Standards, simple comparison of the concentration stipulated by each of these threshold values is not a reliable methodology, for several reasons. First, as previously mentioned, Tennessee's Domestic Water Supply criteria for toxic chemicals lack specification of a criterion-duration or criterion-frequency. Consequently any effort to determine comparative levels of protection requires making assumptions about the criterion-duration and criterion-frequency for the state's WQC. If one assumes that the criterion-durations and criterion-frequencies for Tennessee's Domestic Water Supply criteria are the same as those of EPA's Primary Drinking Water Standards (whatever those might be, given that EPA's literature is not clear on these points), this would, at least at first, suggest that the vast majority of the state's Domestic Water Supply criteria provide the same level of protection as EPA's SDWA Standards. corresponding SDWA criteria.

However, in the case of the state's Domestic Water Supply WQC, additional factors must be taken into account when thinking about level of protection comparative to EPA's Primary Drinking Water Standards. Actually, those state Domestic Water Supply WQC with criterion-concentrations identical to the level set forth in the corresponding EPA drinking water standards are likely, in most cases, to provide greater levels of protection as EPA's drinking water standards because typically the concentration of a given pollutant in the raw water supply will have been significantly lowered by drinking water treatment process before it is delivered as "finished water" by the drinking water distribution system. Primary Drinking Water Standards apply to finished drinking water, not raw water supply. Hence, for those 61 pollutants with a Tennessee Domestic Water Supply WQC with a concentration *equal to* that specified in the EPA drinking water standard for that pollutant the state's criterion could actually provide greater protection to consumers of finished drinking water. This assumes that the same durations and frequencies apply to the state criteria and the federal standard. For instance, if the drinking water treatment process to which the raw water is subjected removes 50% of a certain pollutant, 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, both

the Tennessee Domestic Water Supply criteria and EPA's Drinking Water Standard for vinyl chloride are both 100 μg/L, so if a public water supply utility was using a river or lake with water meeting the state's water quality criterion for its raw drinking water supply, then finished drinking water supply with a concentration equal to half that of the drinking water standard (50 μg/L) should emerge from the treatment process. If the drinking water treatment system could remove more than 50% of the styrene, e.g., 80%, then finished drinking water with a level of this contaminant of 20 μg/L.

Only if the drinking water treatment system had the effect of increasing levels of a given pollutant found in the raw water supply—rather than achieving the reductions for which the treatment is intended—would there be any chance that raw water meeting state water quality criteria would end up providing finished water that failed to meet EPA drinking water standards. Though this is apparently not the case with most contaminants, it does happen with one set of chemicals, trihalomethanes, such as trichloromethane and bromodichloromethane, which are formed as a byproduct of the use of halogens (chlorine and/or bromine) to disinfect drinking water, whereby the halogen(s) combine with natural organic compounds in the raw water supply to create trihalomethanes.

Finally, we return briefly to the effects of the fact none of Tennessee's human health WQC for toxic chemicals has a clearly stated criterion-duration or a clearly stated criterion-frequency. Lack of clearly-stated criterion-durations and criterion-frequencies 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 a state Recreation: Water and Organisms WQC is an instant and the 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 for human health criteria were 365 days, then exceedance of WQC would not be indicated by having just one sample out of several collected over any 365-day period with a concentration above the criterion-concentration. In this latter case, the appropriate determinant of criterion exceedance would be having a set of samples collected over some 365-day periods with an average concentration higher than the criterion-concentration.

Appendix A

Missing and Extra Criteria for Conventional Pollutants: TENNESSEE

1) Aquatic Life

i) MISSING POLLUTANTS[59]

	ACUTE	CHRONIC
Warm water[60]	calcium carbonate chloride	hydrogen sulfide chloride chlorophyll a[61] dissolved gases nitrogen (total) phosphorous (tot.) turbidity (NTU) turbidity (Secchi)
Cold water (trout streams)	calcium carbonate chloride	dissolved gases chloride hydrogen sulfide nitrogen(total) phosphorous(tot.) turbidity (NTU) turbidity (Secchi)

ii) EXTRA POLLUTANTS[62]

	ACUTE	CHRONIC
	temperature	temperature E.coli dissolved oxygen

[59] For the purpose of this review, "missing pollutants" means 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.
[60] EPA's criteria do not distinguish between warm and cold water habitats.
[61] Tennessee has recently adopted a chlorophyll a criterion, but it applies only to one waterbody in the entire state-Pickwick Reservoir.
[62] For the purposes of this review, "extra pollutants" are those pollutants for which the state has formally proposed or officially adopted WQC, while EPA has not published recommended WQC of the type specified.

2) Drinking Water Supply/ "Domestic Water Supply"[63]

i) MISSING POLLUTANTS

ACUTE	CHRONIC
total coliform bacteria	chloride color foaming agents odor (total dissolved) solids sulfate

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
(total dissolved) solids	*E. coli*

3) Water-Based Recreation

i) MISSING POLLUTANTS

ACUTE	CHRONIC

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
pH	pH

4) Industrial Water Supply

i) MISSING POLLUTANTS

ACUTE	CHRONIC
Calcium carbonate	---

[63] 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.

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
(total) dissolved solids	
pH	
temperature	

5) Irrigation/Livestock Watering and Wildlife

i) MISSING POLLUTANTS

ACUTE	CHRONIC
---	---

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
pH	--

Appendix B

Table 1

	Aquatic Life Protection		Human Health Protection	
	Acute	*Chronic*	*Fish Consumption (HHO)*	*Water & Organisms (HHWO)*
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Tennessee Has Not	Aluminum Chlorpyrifos Diazinon Nonylphenol Parathion	Aluminum Chloropyrifos Demeton Diazinon Guthion Malathion Methoxychlor Mirex Nonylphenol Parathion	3-Methyl-4-Chlorophenol Dinitrophenols Ether, Bis(Chloromethyl) Hexachlorocyclo-hexane-Technical Methylmercury[64] Nitrosamines Nitrosodibutylamine,N Nitrosodiethylamine,N Nitrosopyrrolidine,N Pentachlorobenzene Selenium 1,2,4,5-Tetrachlorobenzene 2,4,5-Trichlorophenol Zinc	3-Methyl-4-Chlorophenol Asbestos Barium 2,4,5,-TP 2,4-D Copper Dinitrophenols Ether, Bis(Chloromethyl) Hexachlorocyclo-hexane-Technical Iron Manganese Methoxychlor Nitrosamines Nitrosodibutylamine,N Nitrosodiethylamine,N Nitrosopyrrolidine,N Pentachlorobenzene Selenium 1,2,4,5-Tetrachlorobenzene 2,4,5-Trichlorophenol Zinc

[64] While Tennessee lacks a HHO criterion for methyl mercury, the state has adopted a HHO criterion for mercury while the EPA has not.

Table 2

	Drinking Water Supply
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Tennessee Has Not	Alpha particles Asbestos Beta particles & photon emitters Bromate Chloramines Chlorine Chlorine dioxide Chlorite Fluoride Haloacetic acids Nitrates Nitrite Radium 226 and Radium 228 (combined) Total Trihalomethanes Uranium Aluminum (s) Copper (s) Iron (s) Manganese (s) Silver (s) Sulfate (s) Zinc (s)

Note: Pollutants labeled with the "(s)" notation are those for which EPA has issued secondary drinking water criteria.

Table 3

	Human Health	
	Water and Organism (HHWO)	*Organism Only (HHO)*
Pollutants designated as suspected or known carcinogens by Tennessee	Arsenic Acrylonitrile Benzene Bromoform Carbon tetrachloride Chlorodibromomethane Chloroform Dichlorobromomethane 1,2-Dichloroethane 1,2-Dichloropropane 1,3-Dichloropropene Methylene chloride 1,1,2,2-Tetrachloroethane Tetrachloroethylene 1,1,2-Trichloroethane Trichloroethylene Vinyl chloride Pentachlorophenol 2,4,6-Trichlorophenol Benzidine Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Bis(2-Chlorethyl)ether Bis(2-Ethylhexyl)phthalate Chrysene Dibenz(a,h)Anthracene 3,3-Dichlorobenzidine 2,4-Dinitrotoluene 1,2-Diphenylhydrazine Hexachlorobenzene Hexachlorobutadiene Hexachloroethane Ideno(1,2,3-cd)Pyrene Isophorone N-Nitrosodimethylamine N-Nitrosodi-n-Propylamine N-Nitrosodiphenylamine Aldrin a-BHC b-BHC Chlordane 4-4'-DDT 4,4'-DDE 4,4'-DDD Dieldrin Heptachlor Heptachlor epoxide PCB, total Toxaphene	Arsenic Acrylonitrile Benzene Bromoform Carbon tetrachloride Chlorodibromomethane Chloroform Dichlorobromomethane 1,2-Dichloroethane 1,2-Dichloropropane 1,3-Dichloropropene Methylene chloride 1,1,2,2-Tetrachloroethane Tetrachloroethylene 1,1,2-Trichloroethane Trichloroethylene Vinyl chloride Pentachlorophenol 2,4,6-Trichlorophenol Benzidine Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Bis(2-Chlorethyl)ether Bis(2-Ethylhexyl)phthalate Chrysene Dibenz(a,h)Anthracene 3,3-Dichlorobenzidine 2,4-Dinitrotoluene 1,2-Diphenylhydrazine Hexachlorobenzene Hexachlorobutadiene Hexachloroethane Ideno(1,2,3-cd)Pyrene Isophorone N-Nitrosodimethylamine N-Nitrosodi-n-Propylamine N-Nitrosodiphenylamine Aldrin a-BHC b-BHC Chlordane 4-4'-DDT 4,4'-DDE 4,4'-DDD Dieldrin Heptachlor Heptachlor epoxide PCB, total Toxaphene

APPENDIX C

SITUATIONS IN WHICH STATE WQC ARE CLEARLY LESS PROTECTIVE THAN EQUIVALENT EPA WQC

	Concentration	Duration	Frequency
State vers 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 MORE PROTECTIVE THAN EQUIVALENT EPA WQC

	Concentration	Duration	Frequency
State vers 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 vers 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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