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Assessing the US Clean Water Act 303(d) listing process for determining impairment of a waterbody

Arturo A. Keller*, Lindsey Cavallaro

Bren School, University of California, Santa Barbara, CA, USA

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Abstract

This study evaluated the US Clean Water Act (CWA) Section 303(d) listing and delisting processes, based on historical and current federal and state guidelines, to determine whether there are regional differences in water quality assessment criteria used by various states to determine impairment of a waterbody for inclusion in the 303(d) list. A review of almost 50 total maximum daily load (TMDL) and delisting documents revealed that the basis for listing or delisting a waterbody varies considerably and that, in many cases, determination of impairment was based on insufficient water quality information. Historical USEPA guidance on the 303(d) listing and delisting processes has been generally broad, resulting in wide interpretation of the assessment criteria by various states. This has led to unclear or conflicting listing methodologies among states, leading to inconsistencies in impairment determination. Common problems include inconsistent data quality and quantity, differences in frequency of monitoring, variable interpretation of narrative water quality standards, and differences in specificity of implementation and monitoring plans, resulting in significant difference in the basis for listing and delisting waterbodies. In response, several states have taken the initiative to provide much more specific guidance for their internal agencies. Listing and delisting criteria are generally clearer at the state level, but the development of differing state guidance documents has resulted in diversity in the development of the 303(d) lists and in the process of delisting a waterbody. While state guidelines are better able to address local considerations, such as variations in climate, landuse, and water quality objectives, as well as social and economic preferences, the variation in listing criteria has led to inconsistencies across state boundaries in the levels of attainment of national water quality objectives. For stakeholders that participate in the 303(d) listing process within a particular state, these types of discrepancies may not have a significant impact. However, these inconsistencies can lead to confusion for some stakeholders who participate in the process in multiples states, and must deal with differing and sometimes conflicting requirements depending on the location of their facilities.

Keywords: Water quality; Water policy; TMDL; Impairment; Listing; Delisting; 303(d)

1. Introduction

Since the implementation of the Clean Water Act (CWA) in 1972, the water quality of US waterbodies has improved significantly. However, the CWA Section 303(d) list of impaired waters for 2002 included 59,783 impairments for the 34,225 listed US waterbodies. Over half of these impairments are caused by one of five major pollutants: pathogens, metals, excess nutrients, excessive sediment, or organic enrichment. According to data collected by the US Environmental Protection Agency (USEPA, 2006a), the spatial distribution of impaired waterbodies covers most of the US, with the exception of some of the very dry areas in the southwestern portion of the country and some sparsely populated areas in northwestern US. The distribution of impairments across the country demonstrates that poor water quality is endemic in many of the nation's waters.

Assessment of impaired waterbodies for Section 303(d) listing is primarily carried out by states and tribal nations, with oversight and final approval by USEPA. Since the initial 303(d) listing, guidance provided to the states by USEPA was very general with no specific parameters for assessing impairment, a number of waterbodies were included in the 303(d) list with little data to support the

*Corresponding author. Tel.: +1 805 453 1822.
E-mail address: keller@bren.ucsb.edu (A.A. Keller).

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assessment. Additionally, listing decisions were based on criteria that varied widely across the nation. Once a waterbody is listed as impaired, the state is required to develop a total maximum daily load (TMDL) to address the impairment and implement measures to restore the waterbody to its designated use. The development of TMDLs is extremely costly, requiring a considerable amount of time and resources on the part of state agencies and many stakeholders. Therefore, the large number of waterbodies listed as impaired represents a potentially substantial national investment in the TMDL process. There have been some studies that have looked in general at the implementation issues related to the TMDL program (e.g. Freedman et al., 2004; NRC, 2001, Boyd, 2000); although to date the listing and delisting processes have not been evaluated in detail.

Although, in principle, a water quality assessment through a comparison of water quality observations to water quality objectives seems relatively straightforward, in practice there are many challenges. For example, many water quality objectives are based on surrogate variables, such as nutrients concentration or chlorophyll a to indicate excessive algal growth. However, because the objectives may be narrative, there is opportunity for inconsistency in the application of surrogate water quality criteria used to determine impairment. Water quality criteria and numerical targets often differ among various regulatory agencies (e.g. federal, state, local, tribal), and may even be different from one river reach to the next, complicating the assessment even further. In addition, the frequency of monitoring (i.e. annual, semi-annual, quarterly, monthly, daily, arbitrary or strategic) may play a significant role in the determination of impairment, yet is often unaddressed by regulatory agencies. Discrepancies in assessment criteria can not only make it difficult to justify a listing decision, but also make it difficult to support delisting of a waterbody once it has been placed on the 303(d) list.

While USEPA guidance on the 303(d) listing process has improved since the initiation of the CWA, the guidelines are generally broad, leaving it up to state and local agencies to resolve many facets of the assessment, such as frequency of data collection, data quality, statistical method of analysis, and interpretation of water quality criteria. Given the significant resources required to prepare TMDLs for listed waterbodies, in recent years several states have developed their own listing and delisting methodologies with additional guidance for their staff to facilitate and improve listing and delisting decisions. These differing methodologies incorporate a wide range of water quality assessment approaches and interpretations of water quality standards (WQS), and often emphasize different aspects of the listing and delisting processes, depending on the objectives of different state agencies. Additionally, a consistent listing methodology is not always applied throughout a given state. For stakeholders that participate in the 303(d) listing process within a particular state, these types of discrepancies may not have a significant impact. However, these inconsistencies can lead to confusion for stakeholders that participate in the process in multiples states, and must deal with differing and sometimes conflicting requirements depending on the location of their facilities.

This study evaluated the Section 303(d) listing and delisting processes, based on federal and state guidelines, to establish regional differences in assessment criteria used by various states. We first reviewed the historical development of USEPA guidance documents related to the 303(d) listing and TMDL process. This was followed by a review of 41 TMDL documents, to determine whether different water quality assessment methodologies were used by states in listing decisions. Finally, we evaluated and compared various state guidance documents that go beyond USEPA guidance, to establish similarities and differences in listing and delisting water quality criteria used by states throughout the US.

2. Background

When the United States Congress passes a law, environmental or otherwise, federal agencies are required to develop rules and regulations that are consistent with the enacted law. However, state and local regulatory agencies are often responsible for the implementation of federal regulations, with guidance and oversight from federal agencies. In addition to rules imposed by federal regulations, states develop their own rules, typically in the form of permits, which are consistent with the federal regulations, if not more stringent. For instance, when the Clean Air Act Amendments (CAAA) were passed in 1990, Congress did not specify the criteria for attainment of clean air standards. Instead, USEPA had the responsibility of writing the regulations to uphold the CAAA. Each State then had to develop an individual State Implementation Plan (SIP) to ensure that regional air quality would meet the standards set by USEPA. While USEPA has final approval over SIPs, the states are ultimately responsible for implementation of the regulations. States are then left to provide guidance to their staff for implementing federal regulations. Such is the case for other environmental regulations, including those mandated by the CWA.

Federal versus state governance is a subject of much debate regarding the implementation of federal laws for a vide range of issues, such as gas distribution (Moring, 1999), illegal immigration (Rhymer, 2005), welfare (Rogers-Dillon, 1999), health care (Parmet, 1993) and education, as well many environmental regulations, including the CAAA and CWA. Because the federal government authorizes states with the power to implement and enforce federal regulations, states have a significant role in the effectiveness of environmental regulation. Advocates of local environmental regulation assert that local policy-makers are better able to set policy that reflects local concerns, while opponents fear that decentralized regulation will lead to a '"race to the bottom' in environmental

quality." (Boyd, 2000). Some argue that environmental decentralization is beneficial because states are actually more stringent with environmental regulations (Sigman, 2003). Others suggest that the stringency in which environmental regulations are enforced, such as the CWA, are determined by other factors, such as budgetary and political concerns (Helland, 1998).

In cases where the Federal government has been slow to implement environmental regulation, or when guidance is too general or unclear, some states have taken the initiative to implement and enforcement federal environmental rules. For instance, the Western Governors Association (WGA), an organization representing the western states, addresses environmental policy and governance in the West in an effort to implement better methods of achieving environmental goals (WGA, 2006). The WGA has identified problems associated with implementation of federal environmental laws and attempts to strengthen the states' role in the federal system by improving the effectiveness and efficiency of environmental regulation. For example, some of the problems related to the development of SIPs that the WGA outlines are that the CAAA emphasize process rather than results, and that overly prescriptive requirements could be barriers to environmental innovation. In addition, the excessive length of development of the SIPs and the lack of effective guidance and technical tools has lead to delays and uncertainties in the implementation process, and an inefficient use of resources (Air Quality Initiative Steering Committee, 1997). While these issues uncovered by the WGA relate to the SIP development process, they are also relevant in implementation of the CWA at a state level, particularly with regards to the 303(d) listing and TMDL process. USEPA cooperates with WGA's efforts and provides grants to assist with the implementation and enforcement of federal environmental regulations. For example, WGA has received grant money from USEPA to assist the western states in implementing the TMDL program.

Recently, the federal government has been working with the states to develop common guidance documents, for example the consolidated assessment and listing methodology (CALM) that requires that each state establish a consistent process for listing and delisting waterbodies (USEPA, 2006b).

Anecdotal experiences with 303(d) listing and TMDL development indicated that insufficient guidance on the listing and delisting process had resulted in wide differences in the criteria applied around the nation. With this in mind, we sought to review the existing guidance documents and then using a sample of listing and delisting decisions determine the main issues that states and stakeholders face.

3. Approach

A review of historical USEPA documents on water quality-based listing was conducted to determine the specificity of guidance provided to the states regarding the 303(d) listing process. The original Section 303(d) of the CWA asserts that states, territories and authorized tribes are required to develop a priority ranked list of water quality limited segments. States develop WQS and criteria for each waterbody, and if a state identifies an exceedance of a WQS, the waterbody must be added to the list of impaired waters. In addition, the Act indicates that the lists (denominated the "303(d) lists") would be used to prioritize each waterbody for TMDL development. Each state is required to establish a TMDL to address impairment of waterbodies on the 303(d) list, which must submitted to USEPA for final approval.

While the concept of the 303(d) process appears inherently simple, the initial USEPA guidelines did not provide states with specific assessment criteria to be used as a basis for listing waterbodies. This led to confusions among state agencies and discrepancies in listing methodologies. Additionally, no guidelines were provided on the criteria required to remove a waterbody from the 303(d) list. As a result, USEPA has released additional guidance documents, generally every listing cycle, in an attempt to clarify the 303(d) listing and delisting process. The following USEPA guidance documents were reviewed for this study:

- Guidance for water quality-based decisions: The TMDL process (USEPA, 1991).
- Guidance for 1994 Section 303(d) lists (USEPA, 1993).
- National clarifying guidance for 1998 State and Territory Section 303(d) listing decisions (USEPA, 1997).
- Integrated water quality monitoring and assessment report guidance (USEPA, 2001).
- EPA Review of 2002 Section 303(d) lists and guidelines for reviewing TMDLs under existing regulations issued in 1992 (USEPA, 2002a).
- Recommended framework for EPA Approval decisions on 2002 State Section 303(d) list submissions (USEPA, 2002b).
- Guidelines for reviewing TMDLs under existing regulations issued in 1992. (USEPA, 2002c).
- Guidance for 2004 assessment, listing and reporting requirements pursuant to Sections 303(d) and 305(b) of the CWA (USEPA, 2003).
- Guidance for 2006 assessment, listing, and reporting requirements pursuant to Sections 303(d), 305(b), and 314 of the CWA (USEPA, 2006c)

These guidance documents typically explain the programmatic elements and requirements of the TMDL process as it relates to the 303(d) list. However, the documents do not provide states with a specific methodology for assessing the water quality of a waterbody, particularly with regards to water quality data collection, interpretation and determination of impairment. States have resorted to developing their own methodology for collecting and evaluating water quality data to determine if

WQS are exceeded; in several cases the procedures and criteria have in the past varied even within a state agency. A more detailed review of each document is available in Keller et al. (2005).

As can be seen, the number of USEPA guidance documents is substantial, and a new guidance document has been developed for every recent listing cycle. The lengthy effort spent by USEPA in the late 1990s seeking to develop a major new "Watershed Rule" (NRC, 2001), which essentially hit a stone wall, is a major reason USEPA is still having to work through guidance to sharpen ideas on improved methods and procedures to achieve grater consistency, transparency, and quality in the way waters are listed under the 303(d)/TMDL process.

To evaluate the different methodologies used by states to determine impairment of a waterbody, 50 USEPA approved TMDL or delisting documents were reviewed from the following states: Alabama, Alaska, California, Colorado, Georgia, Iowa, Kansas, Maine, Michigan, Mississippi, New Mexico, New York, Pennsylvania, Rhode Island, South Dakota, Utah, Vermont, Washington, and West Virginia (Table 1). A more detailed summary and review of each document is available in Keller et al. (2005). These states were chosen as case studies, in part, because each has developed a sufficient number of publicly available USEPA approved TMDL documents, and, in part, to represent a cross-section of states spanning the country. Each TMDL document was reviewed to determine the listing rationale used by the state and evaluate the effectiveness of the TMDL in addressing impairment of the waterbody. From this analysis, differences within a state and between states were assessed, with regards to the application of listing criteria to support an impairment decision.

Finally, an extensive review of the most recent USEPA and state guidance documents was conducted to compare and contrast the specificity of guidance between USEPA and a number of states that have taken a proactive role in developing documents to assist their staff in the listing and delisting processes. Guidance documents were evaluated from California (California SWRCB, 2004), Colorado (Colorado DPHE, 2005), Iowa (Iowa DNR, 2003), Kansas (Kansas DHE, 2003), Minnesota (Minnesota PCA, 2004), New York (New York DEC, 2002), and Washington (Washington DE, 2006). In many cases, the state guidance documents detail the specific aspects of the 303(d) listing process that USEPA has not sufficiently addressed.

4. Results and discussion

Although guidance regarding water quality assessment and impairment determination is generally more specific at the state level, evaluation of the TMDL case studies demonstrate that, while many states provide more detailed guidance than USEPA, the application of particular criteria to justify impairment decisions are highly inconsistent throughout the country. Not only did listing rationale differ significantly among states, but many states did not apply an internally consistent methodology for determining impairment of waterbodies. Most states did not utilize a uniform approach for data collection, sampling, analysis, or quality assurance, resulting in discrepancies in impairment determination. Frequently, listing decisions were based on insufficient data, and several TMDL documents lacked adequate implementation plans to achieve water quality goals for the waterbody. In several cases, the criteria for delisting were not explicit in the TMDL document.

4.1. Water quality data collection and analysis

Each state is required to develop a 303(d) listing methodology, with guidance and final approval from USEPA, which details how water quality data will be used to determine impairment of a waterbody. The methodology must disclose specific details on data sources, quality control assurance, sampling methods and analysis, and justification of analytical approach. The guidelines for water quality data collection and quality, criteria for credible sources, and requirements for data age vary significantly across states, which has led to many inconsistencies in the listing and delisting process.

Clearly, obtaining sufficient data to make a decision regarding impairment of a waterbody is one of the most important elements of the listing or delisting processes. If a state can prevent unnecessary listing by using current and accurate water quality data, it will avoid the costly and time-consuming development of a TMDL. Many of the problems with associated with inadequate water quality data collection, quality assurance, and analyses are symptomatic of insufficient guidance. Recent guidelines provided by USEPA and the states attempts to clarify some of the major issues associated with water quality data, to varying degrees.

The 2004 USEPA guidance document (USEPA, 2003) suggests that states consider data from a vide range of sources, including but not limited to: prior listing reports, recent CWA 319 non-point source assessment, ambient water quality data, dilution calculations or predictive models, water quality management plans, Superfund Records of Decision, Safe Drinking Water Act source water assessments, and volunteer monitoring networks. While USEPA suggests that states consider data from a range of sources, it requires that states only use credible data for water quality assessment, which is any data consistent with a quality assurance or quality control program. The states generally accept data from a variety of sources, but each data has a different method of data quality assurance and quality control to ensure that water quality data is credible.

The TMDL case studies, however, demonstrate that although each state requires water quality data to meet quality control requirements, significant disparities exist in the way states address data quality assurance. Data quality

Table 1
TMDL or delisting documents reviewed[a]

	State	Year	Waterbody	Impairment
1	Alabama	2002	Big Nance Creek	Fecal coliform
2	Alabama	2002	Big Nance Creek	Low dissolved oxygen/organic loading ammonia
3	Alaska	1995	Eagle River	Metals
4	Alaska	2000	Duck Creek, Mendenhall Valley	Fecal coliform
5	Alaska	2004	Fish Creek in Anchorage	Fecal coliform
6	California	1998	Garcia River	Sediment
7	California	1998	San Diego Creek and Newport Bay	Nutrients
8	California	2000	Navarro River	Temperature and sediment
9	California	2003	Santa Clara River	Nitrogen compounds
10	California	2004	Waddell Creek, Santa Cruz County	Nutrients delisting
11	Colorado	2000	Big Thompson River, Little Thompson River; South Platte Basin	Fecal coliform, determination of inapplicability
12	Colorado	2000	Cripple Creek, Arequa Gulch/Squaw Creek	Determination of TMDL inapplicability
13	Colorado	2000	Big Springs Creek, Rio Grande River Basin	Determination of TMDL inapplicability
14	Colorado	2000	Unnamed tributary to Willow Creek	Ammonia
15	Colorado	2000	Straight Creek, Summit County	Sediments
16	Colorado	2002	Fruitgrowers Reservoir	Determination of TMDL inapplicability
17	Colorado	2002	Upper Animas River Basin	Metals (Al, Cd, Cu, Fe, Mn, Pb, Zn) and pH
18	Colorado	2002	Little James Creek, Boulder County	Metals (Cd, Fe, Mn, Zn) and pH
19	Colorado	2003	N Fork Cache La Poudre River, Larimer City	Sediment
20	Georgia	2001	Middle/Lower Savannah River	Total mercury
21	Georgia	2000	Stekoa Creek Watershed	Sediment
22	Indiana	2004	West Fork White River	*E. coli*
23	Iowa	2000	Rock Creek, Clinton County	Ammonia and NO_x
24	Iowa	2000	Corydon Reservoir, Wayne County	Atrazine
25	Kansas	2004	Neosho Basin, Tar Creek	Lead, cadmium, and zinc
26	Kansas	2004	Neosho Basin, Olpe City Lake	Eutrophication
27	Maine	2003	Goosefare Brook	Metals (Cd, Cr, Cu, Fe, Ni, Pb, Zn)
28	Maine	2004	Annabessacook Lake	Phosphorous
29	Michigan	2002	Carrier Creek, Eaton County	Biota
30	Michigan	2003	Grand River, Jackson County	Dissolved oxygen
31	Michigan	2003	Grand River, Jackson County	Biota
32	Michigan	2003	Bean Creek, Lenawee and Hillsdale Counties	*Escherichia coli*
33	Mississippi	2000	Pearl River	Fecal coliform
34	New Mexico	2001	Silver Creek	Conductivity delisting rationale
35	New Mexico	2001	Whitewater Creek	Metals delisting rationale
36	Pennsylvania	1999	Cheat River, Fayette County	Chlordane
37	Pennsylvania	1999	Susquehanna River	PCBs
38	South Dakota	1999	Hiddenwood Watershed	Sediment and total phosphorous
39	Utah	2003	Beaver River Watershed	Total phosphorus, noxious aquatic plants, riparian habitat alteration, dissolved oxygen, and temperature
40	Utah	2002	Ken's Lake	Temperature
41	Utah	2003	Mill Creek , Grand County	Temperature, TDS
42	Utah	2003	Browne Lake	Dissolved oxygen and phosphorus
43	Vermont/NY	2002	Lake Champlain	Phosphorus
44	Washington	2000	Lower Nooksack River Basin	Bacteria
45	Washington	2001	Granger Drain	Fecal coliform bacteria
46	Washington	2002	Wind River Watershed	Temperature
47	Washington	2003	South Prairie Creek	Bacteria and temperature
48	Washington	2004	Upper Chehalis River	Fecal coliform bacteria
49	West Virginia	2002	Ten Mile Creek	Al, Fe
50	Rhode Island	2004	Chickasheen Brook, Barber and Yawgoo Ponds	Total phosphorous

[a]All these documents are available at http://www.epa.gov/owow/tmdl/.

is not typically assessed within the TMDL documents, making it difficult to establish the validity of an impairment determination. For instance, some states, such as Alaska, Maine, and Utah, have in some instances relied on water quality data provided by volunteer groups without sufficient assurance of data quality. While water quality data collected by volunteer groups may be valuable, the validity of a listing decision can be called into question if the data does not meet a quality control standard. Some states, such as Minnesota, have clearly defined guidelines for data collected by volunteer groups (Minnesota PCA, 2003).

Another common problem evident in the TMDL case studies is that listing decisions were often based on little or sometimes no water quality data. For example, Alabama listed Big Nance Creek in 1992 for exceeding the fecal coliform WQS based on a single exceedance in the water quality data (Alabama DEM, 2002). Duck Creek in Alaska was also listed for non-attainment the State's fecal coliform WQS, a standard based on exceedance of the geometric mean over a 30-day period (USEPA Region 10, 2000). Duck Creek was determined to be impaired, even though the TMDL document states that sufficient data to determine the frequency of exceedance or geometric mean was unavailable. Although many TMDL documents indicated the lack of sufficient data to justify listing a waterbody, most did not address the need for improved monitoring or collection of water quality data.

A few TMDL documents, however, did demonstrate listing decisions that were supported by a sufficient quantity of water quality data. For example, Colorado listed Willow Creek for exceeding the nutrient WQS based on a large sampling effort of 229 samples over a 6-year period (Colorado DPHE, 2000). Rhode Island listed Chickasheen Brook, Barber Pond, and Yawgoo Pond for total phosphorus, based on water quality data from monthly sampling efforts between the months of May and November from 1988 through 2001 (Rhode Island DEM, 2004). However, even when water quality assessments were supported by large quantities of data, many TMDL documents made no reference to frequency of exceedance of water quality samples, even though many WQS require a specific exceedance frequency.

While sample collection and analysis are also rarely addressed in the TMDL documents, a number of states did apply a consistent methodology of data sampling and analysis to determine impairment and justify listing decisions. The state of Michigan developed TMDLs for Grand River and Carrie Creek to address biota impairment using a standard biological assessment method, called "Procedure 51" (Michigan DEQ, 2002, 2003). By having a standardized water quality assessment and listing methodology, Michigan ensured consistency in impairment determination and listing decisions.

In addition to these different criteria for data sources and quality control, data age and collection timeframe is also quite relevant in the listing process. USEPA indicates that data should not be excluded from consideration solely based on age, but says that states may choose to exclude data that is no longer representative of current waterbody conditions. While many states do have specific requirements regarding the age of water quality data, the topic is not consistently handled.

Colorado recommends that data be no older than 5 years, unless an explanation is provided proving that the data continues to reflect current conditions (Colorado DPHE, 2005). California directs its staff to consider all data and information, regardless of age, to determine which data should be used in the listing assessments (California SWRCB, 2004). However, California also recognizes that older data may not represent current water quality conditions or may reflect the result of less precise laboratory analytical procedures, so the age of the data used to support listing must be disclosed.

In Minnesota, the Minnesota Pollution Control Agency (MPCA) uses data collected over the most recent 10-year period for all water quality assessments, except in the case of fish contaminated with mercury, where there is no age limit for the use of mercury contaminated fish tissue data (Minnesota PCA, 2004). Similarly, in Washington data used in the assessment should have been collected less than 10 years before the "call for data" period, whenever possible. If no water quality data is provided or too little data is available for an adequate assessment, then data more than 10 years old will be used in the assessment (Washington DE, 2006). New York and Iowa generally only consider data and information from the preceding 5 years for water quality assessments used for Section 303(d) listing (New York DEC, 2002; Iowa DNR, 2003).

Since some states do not place an age limit on water quality data or do not require that past water quality data be assessed for accuracy, this can result in listing decisions based on outdated data that may not reflect the current condition of the waterbody. For instance, Alaska listed Fish Creek as impaired for fecal coliform in 1998 using data samples taken in 1990 (Alaska DEC, 2004). Likewise, Vermont listed Lake Champlain as impaired for phosphorous in 2000 using water quality data from 1990 (Vermont ANR, 2002). Some of these listing decisions were based on older data, without reassessment of more recent water quality to ensure that the data still reflected the current conditions of the waterbodies.

USEPA indicates that states should also specify a sampling approach and identify target sample sizes for impairment decisions in the listing methodology, but should not exclude from consideration data sets that do not meet a target sample size and should provide for a further assessment of data. Given this somewhat ambiguous approach, states have developed much more specific sampling requirements. For example, California guidelines state that samples collected within 200 m of each other should be considered samples from the same location/station, unless justified as independent (California SWRCB, 2004). Samples collected during a single day or short-term natural event shall not be used as the primary data set to support listing. Timing of sampling should include the critical season for the pollutant and applicable WQS.

In Washington, only one sample per day per segment will be used in water quality assessments (Washington DE, 2006). If more than one sample exists, replicates are averaged. For most pollutants, Washington requires a total of at least three samples for an assessment. Colorado guidelines indicate that a waterbody determined to be impaired based on three or fewer samples will be placed on the Monitoring and Evaluation (M&E) list for further evaluation (Colorado DPHE, 2005). A waterbody

determined to be impaired based on four to 10 samples or biological or physical evidence will be listed on the 303(d) list, unless it is determined that the water quality data is not representative (i.e. the data doesn't account for spatial or temporal variation).

Colorado and Iowa also have specific guidelines for water quality sampling in lakes. Colorado requires 2 years of sample results with a minimum of 12 events, representative of seasonal and diel variation, or where acute conditions result in overwhelming evidence (Colorado DPHE, 2005). In Iowa, lakes are sampled three times during the summer at the deepest point in the lake basin (Iowa DNR, 2003).

In New York, the state water monitoring program conducts rotational drainage basin monitoring and sampling (New York DEC, 2002). The collected data is used to determine if a waterbody is achieving its beneficial use. Minnesota also conducts rotational basin wide monitoring, and has specific data requirements for evaluating impairment, including a minimum number of values and data treatment for the following indicators: total phosphorous, chlorophyll a, Secchi disk depth, IBI scores, and fish tissue concentration of PCBs or mercury (Minnesota PCA, 2004). Exceedance thresholds for these indicators are also provided.

With regards to data analysis and analytical approach, USEPA recommends a probability based monitoring and sampling design and encourages states to consider published statistical methods for data analysis. The methodology should provide a justification of why the state has chosen a specific analytical approach.

California's guidelines, for example, are very prescriptive and recommend a weight-of evidence approach to sample analysis (California SWRCB, 2004). Rationale must be provided for the selection of sampling sites, water quality parameters, sampling frequency and methods that assure the samples are spatially and temporally representative of the surface water and representative of conditions within the targeted sampling timeframe. To be considered temporally independent, samples collected during the averaging period shall be combined and considered one sampling event. For data that is not temporally independent, the measurements shall be combined and represented by a single resultant value. If the averaging period is not stated for the standard, objective, criterion, or evaluation guideline, then samples collected less than 7 days apart shall be averaged.

4.2. Water quality data interpretation and impairment determination

Once water quality data has been collected and analyzed for a particular waterbody, it must then be evaluated and interpreted to determine if a WQS is exceeded. Data is interpreted differently depending on whether water quality criteria are numeric or narrative, as well as whether the data is chemical, biological or physical. USEPA guidance with regards to data interpretation is generally quite vague, and simply requires states to describe methods of interpretation in the documented listing methodology. While the states have attempted to provide more detailed guidance for internal staff, requirements for data interpretation vary greatly among different states agencies.

Although USEPA guidelines do not specifically address the interpretation of chemical data, most states do provide specific guidance on this issue. For example, the following are some of Colorado's criteria that specifically apply to attainment of chemical standards (Colorado DPHE, 2005):

- chronic chemical standards: 85th percentile;
- hardness-based metals: 85th percentile and mean hardness or paired hardness and concentration data;
- total recoverable metals: 85th percentile;
- dissolved oxygen (DO): 15th percentile;
- minimum pH: 15th percentile;
- maximum pH: 85th percentile;
- coliform: geometric mean.

In California, staff must also follow detailed guidelines pertaining to data interpretation. For toxins, and all conventional and other pollutants, the binomial distribution must be evaluated to determine if exceedances supports rejection of the null hypothesis (California SWRCB, 2004). For DO, if measurements taken over the day show low concentrations in the morning and sufficient concentrations in the afternoon, then it shall be assumed that nutrients are responsible for the DO concentrations if riparian cover, substrate composition or other pertinent factors can be ruled out as controlling DO fluctuations. When continuous monitoring data is available, the 7-day average of daily minimum measurements shall be assessed. In the absence of diel measurements, concurrently collected measurements of nutrient concentration shall be assessed using applicable water quality objectives or acceptable evaluation guidelines and using the binomial distribution. For bacteria, if site-specific exceedance frequency data is unavailable, a binomial distribution should be used. If frequency data is available, it may be used instead. For example, for bacteria data from coastal beaches collected from April 1 to October 31, a 4% exceedance percentage must be applied.

In Kansas state guidelines follow USEPA recommendation of a 10% raw score based on binomial analysis to screen for conventional pollutant data from monitoring sites (Kansas DHE, 2003). Those sites that fail the raw score test (greater than 10% exceedance) are subject to a binomial test. If the binomial test indicates impairment, then the waterbody is placed on the 303(d) list. If the binomial test indicates full support, those sites will be subject to a final screening, which includes a check for evidence of recent excursions in the sample data. If the number of excursions is within the critical number of excursions needed to list a waterbody, and any one of those

excursions occurred in the most recent year of sampling, then the waterbody will be listed as impaired.

Lakes and reservoirs present specific water quality considerations, and the interpretation of chemical data in lakes and reservoirs is addressed in detail by three of the states considered in this review. In Colorado, data interpretation must account for seasonal and diurnal variation (Colorado DPHE, 2005). For DO and temperature, a vertical profile must be developed. DO for the entire water column must be assessed for a mixed waterbody, and individual DO samples are compared to the water quality criterion. For all other chemical parameters, samples are compared to numeric standards, using volumetrically weighted measurements when available.

Kansas guidelines provide the following specific cases in which a lake or wetland should be included on the 2004 303(d) list (Kansas DHE, 2003):

- The lake or wetland assessment unit appeared in the 2002 Section 303(d) list and has not had a TMDL developed for its specified impairment(s).
- The lake has a designated use of primary contact recreation and chlorophyll a average concentration greater than 12 ppb,
- The lake has a designated use of secondary contact recreation and chlorophyll a average concentration greater than 20 ppb.
- The lake has average total phosphorus concentration greater than 50 ppb over the last 5 years.
- The wetland has average total phosphorus concentration greater than 100 ppb over the last 5 years.
- The lake or wetland, for any other parameter, exceeded WQS or regional norms for more than 1 year in the last 5 years.

In Iowa, the interpretation of fecal coliform in lakes (Iowa DNR, 2003) is typically based on USEPA guidance which requires a comparison of: (1) the geometric mean of at least five samples collected over a 30-day period to state water quality criteria for indicator bacteria (fecal coliforms, *E. coli*, and/or enterococci); and (2) the percentage of samples that exceed a single-sample maximum value. In cases where the geometric mean exceeds the state water quality criterion or more than 10% of the samples exceed the single-sample maximum value, primary contact uses should be assessed as impaired. However, the frequency of sampling at lakes in Iowa with a designated use of primary contact recreation does not provide an adequate number of data to use USEPA method, and thus modified techniques are used to interpret data from these locations.

USEPA guidelines indicate that states using biological assessment to make impairment determinations should also consider other types of information, such as chemical or physical data. Threshold values for impairment determination should be addressed in the state's individual listing methodology.

California, Colorado, Iowa and Washington, in general, have consistent guidelines for biological data. Data can be used to support non-attainment of numeric standards, or narrative standards/designated use classifications. An assessment is typically compared to expected reference condition, such as a Benthic Macroinvertebrate Index of Biotic Integrity (BM-IBI) or a Fish Index of Biotic Integrity (F-IBI). These indexes use metrics to provide a broad assessment of stream biological conditions, which are based on qualitative scoring. In addition, California recommends that visual assessment may be used as a secondary line of evidence (California SWRCB, 2004). Whenever possible, a binomial distribution must be used in the assessment. In Colorado, sampling of multiple sites to determine reference conditions is recommended but not required (Colorado DPHE, 2005).

USEPA and most states do not specifically address the interpretation of physical data, although some use the same guidelines for biological data. California does require evaluation of physical habitat data and other water quality data, when available, to support conclusions about the status of the water segment (California SWRCB, 2004). Kansas also has specific cases in which streams or lakes and wetlands should be listed based on biological data (Kansas DHE, 2003):

- The stream biological impairment appears on the 2002 Section 303 (d) list and has not had a TMDL developed.
- One or more of the biological metrics indicate partial or non-support for biological monitoring stations with three or more samples over the latest 5 years.
- Fish tissue samples show excessive amounts of bioaccumulative pollutants (PCB, chlordane, mercury, etc.) for 3 or more years over the latest 5 years.
- For lakes and wetlands, one or more of the biological metrics indicate partial or non-support for biological monitoring stations with three or more samples over the latest 5 years.

Another concern related to data interpretation is that states often use narrative standards to determine impairments, but usually have no consistent method of interpreting narrative standards across states or even within a particular state. For instance, many states have narrative WQS that apply for nutrient levels and eutrophication in waterbodies. Some states use a Tropic State Index (TSI) to determine impairment, while others use dissolved oxygen levels or other concentration based water quality data. States have also justified listing waterbodies that lack numeric WQS by using Best Professional Judgment (BPJ). However, the use of BPJ can lead to inconsistencies in impairment determination. For instance, Rock Creek in Iowa was listed in 1998 as impaired for ammonia and NO_x (NO_2^-/NO_3^-) based on BPJ, but was later determined to be not impaired for NO_x during the development of the TMDL, again based on BPJ (Iowa DNR, 2000). This

indicates a potential for inconsistency when using BPJ as a basis for determining impairment of a waterbody.

USEPA provides little specific guidance for determining impairment based on narrative standards, but the states need to address this issue. USEPA does have a program to support development of numeric nutrient criteria and target concentration ranges by ecoregion, which could overcome the interpretation of narrative standards. Freedman et al. (2004) and others have also worked on developing a method for addressing narrative standards, since their interpretation can result in wide differences in listing criteria.

However, in the meantime states must deal with the evaluation of existing narrative standards. For example, Colorado guidelines indicate that determination of impairment based on narrative standards may be supported by chemical data and/or biological/physical assessments that provide clear and convincing evidence, or when physical/habitat data or biological community conditions are significantly less that reference conditions (Colorado DPHE, 2005).

In Washington, listing based on narrative standards must include all of the following (Washington DE, 2006):

- Documentation of environmental alteration related to deleterious chemical or physical alterations, such as nutrients or sediment deposition, as measured by indices of resource condition or resource characteristic or other appropriate measure.
- The alteration must be measured and documented using a generally accepted method based on site-specific information, with literature thresholds appropriate to the situation or with reference sites.
- Documentation of impairment of an existing or designated use related to the environmental alteration on the same waterbody segment.
- Identification of a human contribution to the environmental alteration.

For impairment decisions in California based on narrative and qualitative standards, the data submittal must (California SWRCB, 2004): (1) describe events or conditions that indicate impacts on water quality; (2) provide linkage between the measurement endpoint (e.g. a study that may have been performed for some other purpose) and the WQS of interest; (3) be scientifically defensible; provide analyst's credentials and training; and (4) be verifiable by the State Water Resources Control Board (SWRCB) or the Regional Water Quality Control Board (RWQCB).

In New York, narrative assessments resulting in impaired status results from one of the following (New York DEC, 2002):

- Occasional water quality, or quantity, conditions and/or habitat characteristics periodically prevent specific uses of the waterbody.
- Waterbody uses are not precluded, but some aspects of the use are limited or restricted.
- Waterbody uses are not precluded, but frequent/persistent water quality, or quantity, conditions and/or associated habitat degradation discourage the use of the waterbody.
- Support of the waterbody use requires additional/advanced measures or treatment.

In Iowa, numerical standards have a preference over narrative standards (Iowa DNR, 2003). A narrative standard shall not constitute the basis for determining impairment unless the department identifies specific factors as to why a numeric standard is not sufficient to assure adequate water quality.

Impairment from unknown pollutants is a far more challenging issue. USEPA guidelines, which follow the CWA directly, indicate that: "Waterbodies should be placed on the 303(d) list if the impairment or threat is caused by a pollutant, even if the pollutant is unknown". In Colorado, if it is unclear if impairment is caused by pollution, it is placed on the M&E list (Colorado DPHE, 2005). If impairment is caused by an unidentified pollutant, then the waterbody is listed. However, discharges to the waterbody will not be regulated until the pollutant is identified. In Washington, if the source of impairment is unidentified by suspected to a pollutant, the segment is placed on the 303(d) list (Washington DE, 2006). In Iowa, if a pollutant causing impairment is unknown, the waterbody may be listed (Iowa DNR, 2003). However, the department shall continue to monitor the waterbody to determine the cause of impairment before a TMDL is developed and the listing will have low priority, unless otherwise determined. Finally, in New York waters known to be impaired, but by causes/pollutants that have not been identified, will not be included on the Section 303(d) list (New York DEC, 2002). Some states seem to follow USEPA guidance regarding unknown pollutants, while others either do not address the issue or take an approach contrary to what USEPA suggests.

In a number of instances, states have relied on fish consumption advisories as a basis for listing decisions, even though the advisory may not actually indicate a WQS is exceeded. Georgia listed the Middle and Lower Savannah River in 2000 for exceeding mercury WQS, but the decision was based on a fish consumption advisory, which did not provide indication of exceedances of the numeric WQS (USEPA Region 4, 2001). States sometimes also use fish consumption advisories to determine impairment of WQS, but then set TMDL targets based on other criteria. For example, Pennsylvania developed a TMDL to address Chlordane impairment in the Cheat River, which was listed after issuance of a fish consumption advisory (Pennsylvania DEP, 1999). However, the TMDL was established based on human health water quality criterion, not on the fish advisory action level. It does not always make sense to use these criteria interchangeably, and these types of

inconsistencies can be confusing to stakeholders who are required to adhere to load reductions in the TMDL. In part the confusion arises from the fact that in some cases USEPA asserts that Food and Drug Administration (FDA) action levels do not provide an adequate level of protection, leading to inconsistent values between the fish advisory based on FDA levels and human health criteria.

For fish consumption advisories, USEPA has specific guidance (e.g. USEPA, 2000). For example, USEPA considers impairment based on fish or health advisory if the following conditions are met: (1) the advisory is based on fish/shellfish tissue data, (2) a lower than approved national shellfish sanitation program classification is based on water column/shellfish data, (3) data is collected from the specific segment, and (4) risk assessment parameters are equal or less protective than state WQS.

Many states go further in providing guidance to their staff on the use of fish consumption advisories for determining impairment. In Minnesota, an advisory to limit fish consumption to less than one meal per week for any member of the population is an indication of impairment (Minnesota PCA, 2004). For Washington, impairment is determined if the average of three single-fish samples with the highest concentration or one composite sample made up of at least five fish exceeds the criteria for human health impacts based on EPA's bio-concentration factors and water column criteria (National Toxic Rule) (Washington DE, 2006).

In California, impairment is determined if tissue pollutant levels exceed a pollutant-specific evaluation guideline using the binomial distribution (California SWRCB, 2004). The frequency of exceedance is based on sample size. Colorado guidelines for impairment based on fish advisories are currently being re-evaluated. For now, they are analyzed on a case-by-case basis taking into account: scientific basis for advisory; any existing, relevant sediment or water column data; associated risk level; other relevant technical info; consideration of EPA guidance on fish and shellfish consumption advisories (Colorado DPHE, 2005). For acute standards, impairment is determined by an exceedance frequency of greater than once in 3 years.

In Iowa, the existence of a fish consumption advisory indicates impairment. Generally, impairment is determined if two samples are collected in consecutive years that show contaminant levels exceed an FDA action level (Iowa DNR, 2003). An advisory is rescinded if two consecutive samples show levels are below the action level. A single fish kill during the most recent 3-year period, caused by a pollutant or unknown origin, determines impairment. The maximum frequency of violation is once in 3 years.

4.3. Unnecessary development of TMDLs

Another issue in the TMDL development process is that some states establish TMDLs for waterbodies where WQS either are already attained or cannot be attained. Some TMDL documents are developed without reassessing the water quality of a waterbody to determine if the basis for listing is still valid. For example, in 2002 Utah developed a TMDL for Browne Lake to address non-attainment of WQS for DO (Utah DEQ, 2003b). However, the document states that "analysis of the most recent dissolved oxygen data (1993–2001) indicates attainment of the appropriate dissolved oxygen criterion," which demonstrates that Browne Lake was in attainment of the dissolved oxygen WQS at the time the TMDL was established. Utah also developed a TMDL for Ken's Lake, which was listed as impaired for temperature (Utah DEQ, 2002). However, a technical analysis was conducted for the TMDL that determined solar energy to be the only thermal input into the lake. Based on the results of the analysis, the document asserts that "Ken's Lake is unable to meet the current state WQS for temperature." A use attainability analysis would have been more appropriate.

Additionally, TMDLs are not required for waterbodies that are expected to attain WQS through other programs. However, some states still develop TMDLs for these waters. The Middle and Lower Savannah River Watershed in Georgia was listed for total mercury based on fish consumption advisories (USEPA Region 4, 2001). It was estimated that approximately 99% of the mercury loading to the watershed is from atmospheric deposition, a non-point source. The TMDL established specific load allocations for atmospheric deposition, even though the EPA expected most of the reduction to be achieved through implementation of the current Clean Air Act (CAA) requirements in the local airshed. Additionally, the TMDL does not specify the sources of atmospheric deposition, how to reduce loading, or how load reductions could be assessed. The TMDL also established a point source waste load allocation, even though the point source polluters were already regulated by NPDES permits, and the amount of point loading to the watershed was negligible compared to atmospheric deposition. States that develop such TMDLs may be unnecessarily using resources needed for addressing waterbodies in real need of a TMDL. However, it must be noted that this TMDL has since been withdrawn by Georgia.

4.4. TMDL implementation and monitoring

Many load and waste load allocations established in TMDLs do not identify specific loading allocations for every pollutant source, and are usually based on reductions that do not consider the feasibility of the source(s) achieving the required reductions. The lack of specificity in load allocations is generally a result of inadequacy in the data used in the listing and subsequent TMDL development process. Load reductions in TMDLs that address impairment from non-point source pollution often do not include methods of ensuring that reductions by the non-point sources will achieve WQS. For instance, Alabama's Big Nance Creek TMDL for fecal coliform relies on

voluntary, incentive-based mechanisms to reduce pollutant loading from non-point sources, with no mechanism for determining if targeted reductions are met (Alabama DEM, 2002). The TMDLs that address nutrient impairment for Annabessacook Lake (Maine DEP, 2004) and Beaver River, (Utah DEQ, 2003a), were developed with limited understanding of pollutant loading from non-point sources due to lack of sufficient data, yet the TMDLs required non-point source load reductions. The TMDLs did not adequately establish effective methods of reducing pollutant loading because the sources were unknown.

Ultimately, a TMDL will not be effective in addressing water quality if it is not properly implemented. A clear and concise implementation strategy is an essential component of the TMDL process. A monitoring schedule is also necessary to ensure that the TMDL effectively reduces pollutant loading and WQS are attained. The majority of the reviewed TMDL documents did not include an implementation or monitoring program, or if they did, many are vague. Sometimes a TMDL will offer several alternatives for implementation, but will not specify which alternative to implement. Additionally, many TMDLs do not include schedule or timeframe for attainment of WQS.

However, a few TMDLs do provide a framework for implementation and targets for long term monitoring. The Santa Clara River, CA TMDL includes a comprehensive monitoring program, including monitoring for publicly owned treatment works, municipal separate storm water sewer systems (MS4s), and non-point sources (California LARWQCB, 2003). An implementation schedule is provided with specific dates for completion of various components of the implementation plan. In addition, a cost analysis of implementation was conducted. In addition, California, as well as other states, will sometimes include TMDL implementation and monitoring programs in their regional basin plans. The TMDLs with prescriptive implementation plans and scheduled monitoring programs are more likely to be effective in attaining desired water quality goals.

4.5. Delisting issues

The purpose of establishing a TMDL for a waterbody is to attain WQS for designated uses, resulting in removal of the waterbody from the Section 303(d) list. Many states have refrained from delisting waterbodies due to lack of clear guidance from USEPA. The requirements provided by USEPA for removing a waterbody from the 303(d) list generally follow the criteria for the listing process, but also include some additional considerations. USEPA (2003) guidelines indicate that a waterbody may be delisted with demonstration of "good cause," such as:

- more recent or more accurate data or modeling demonstrate that the applicable WQS(s) is being met;
- demonstration that the waterbody was incorrectly listed;
- development of a new listing methodology concluding that WQS are in attainment;
- demonstration that more stringent effluent limitations or other pollution control measures will result in the attainment of WQS;
- approval or establishment by EPA of a TMDL since the last 303(d) list.

To successfully remove a waterbody from the 303(d) list, a state must apply the same methodology used to justify initially listing the waterbody, or a methodology that is consistent with the state's WQS and deemed statistically reasonable by the EPA. In most cases, delisting follows USEPA's biannual review process, to coincide with the listing cycle.

While the delisting process is arguably just as complicated, if not more so, than the listing process, a small handful of states, including Colorado and New Mexico, have documented rationale for delisting decisions. In 1998, Colorado listed Fruitgrowers Reservoir as impaired for fecal coliform and ammonia, but it was unclear if listing was based on a quantitative assessment of water quality data (Colorado DPHE, 2002). In 2001, water quality data was re-assessed, including 90 samples for fecal coliform and 67 samples for ammonia, which indicated that Fruitgrowers Reservoir was in attainment of the fecal coliform and ammonia WQS. Colorado delisted Fruitgrowers Reservoir based on USEPA guidance that states a waterbody may be removed from the 303(d) list at such time as review of the original listing decision is found to be in error.

In 2000, Colorado successfully removed Big Thompson River and Little Thompson River, previously listed for non-attainment of WQS for fecal coliform, from the 303(d) list (Colorado DPHE, 2000). An analysis of 50 samples from Big Thompson and 14 samples from Little Thompson indicated that each waterbody was in attainment of the designated fecal coliform WQS. Colorado's decision to delist these waterbodies was supported by USEPA guidance asserting that a waterbody may be removed from the list at such times as the waterbody is meeting all applicable WQS. Similarly, a segment of Whitewater Creek in New Mexico was listed on the 2000–2002 303(d) lists for non-attainment of WQS for metals based on an inaccurate data assessment (New Mexico ED, 2001). Re-evaluation of the data did not show any exceedances of the WQS. Therefore, the segment of Whitewater Creek was removed from the next 303(d) list.

5. Conclusions

The process of determining impairment in a waterbody has become much more formalized in the past 15 years. Earlier guidance provided by USEPA resulted in wide differences in criteria used for including waterbodies on the 303(d) list. While it is clear that USEPA guidance has improved from the early 1990s, several states decided in the early 2000s to develop additional guidance for their own agencies for the listing and delisting processes, given the

significant resources required to prepare TMDLs. This has resulted in significant disparities among states in emphasis on different aspects of the listing and delisting processes.

The review of numerous TMDL documents from more than 10 states throughout the country illustrates the range of the issues associated with impairment determination and TMDL development, most notably the general lack of consistency in impairment determination. Common problems, including unclear or conflicting listing methodologies, inconsistent interpretation of narrative and numeric WQS, arbitrary and unmeasured pollutant loading allocations and reduction requirements, varying data quality and quantity, and vague and inadequate implementation and monitoring, can result in TMDLs that do not adequately address impairment. The results of this analysis demonstrate the need for adequate guidance in the 303(d) listing and TMDL development process.

In general, while states have taken the initiative to address these pertinent issues, it is clear from the review of the TMDL documents that even within a state there are significant differences in application of particular criteria. States needed to address specific aspects of the listing process, such as consideration of data sources and data quality or interpretation of narrative water quality criteria, because USEPA did not provide clear guidance on these issues. Sampling frequency, number of exceedances, duration of exceedance, age of data, timeframe to be considered, and many other such issues had been left to the interpretation of local staff, but are now being addressed more specifically by the States.

Although listing and delisting criteria is generally clearer at the state level, the development of differing state guidance documents has resulted in diversity in the development of the 303(d) lists and in the process of delisting. For many stakeholders, this has no significant impact, since they operate within a particular state. However, this can lead to confusion for some stakeholders that participate in the 303(d) process in several states, and thus must deal with differing and sometimes conflicting requirements depending on the location of their facilities. Several more iterations of the listing and delisting process may be necessary before common national criteria for the determination of impairment of a waterbody are established.

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