Options for Addressing Continuous Monitoring Data

ACWA Water Quality Standards Forum Discussion Paper

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Problem Statement: With the increased use of analyte probes and continuous data recorders, large quantities of data are now being collected routinely for dissolved oxygen (DO), temperature (T), and pH. How these data are interpreted and used presents a problem for state water quality staff in assessing water quality condition when exceedances can be attributed to diurnal fluctuations/natural variability. The vast majority of criteria recommendation documents and state water quality criteria for these parameters were never developed with the anticipation of using continuous data logging for assessment. Of particular concern are the duration and frequency component of a criterion – how long and how often a numeric criterion for a particular parameter, which fluctuates due to natural variability, can be exceeded before there is an adverse impact on aquatic life.

Options for Addressing: In order to stimulate thought and discussion by State and EPA members of ACWA's Water Quality Standards Forum, six options are herein proposed for addressing the handling of continuous monitoring data for assessment purposes for these parameters: 1) Using State Listing Methodology; 2) Amending State water quality criteria magnitude, duration and/or frequency components; 3) EPA re-evaluating National Recommended Criteria documents for DO, T, and pH with an eye toward the role continuous monitoring may play in terms of the duration and/or frequency components of the criteria; 4) Assessing how continuous monitoring data fits into State credible data laws, State requirements for use of accredited laboratories; and/or State requirements for use of approved laboratory methods; 5) Establishing set "assessment areas" in waterbodies, and 6) Refining uses. The options are addressed below:

1. **Using State Listing Methodology** - States and EPA have typically been handling the interpretation of continuous data through the use of their 303(d) Listing Methodologies (LM). Attachment 1 contains a table that briefly describes how various States handle continuous monitoring data. The list is not intended to be inclusive of all States and relies on some interpretation of State methodologies to condense the data into a usable table.

   The table indicates various methods that are used to interpret continuous monitoring data – from a single measurement resulting in an identified impairment, to assessment of averaged measurements while maintaining data quality and representative considerations outlined in

EPA's Integrated Reporting Guidance.[1] In considering application of these methods, deference should be paid to the States and their respective EPA Regional Offices for selecting and agreeing on a particular method.

While the data in the table indicate States are using a wide variety of interpretations for continuous monitoring data in their LM, there is concern whether the LM is an appropriate vehicle for interpretation of elements of water quality criteria. Much of the concern is based on previous challenges to Florida's LM in their *Impaired Waters Rule* where it was argued that incorporating the LM into rule effectively modified water quality standards (WQS). [Note that, if WQS are modified, they must be formally adopted in rulemaking and approved by EPA.] While the argument in the *Impaired Waters Rule* has not been universally applied, it could be used as a template to challenge LM's in other States. Additionally, States run the risk of having EPA disapprove the State's list (or make a determination under CWA section 303(c)(4)(B) that new or revised WQS are necessary) on the basis of their methodology not being consistent with, or constituting a change to, the applicable WQS.

Recommendation: Request EPA provides listing guidance to help states interpret their continuous monitoring data in a consistent manner, and, where states have adopted EPA's CWA 304(a) recommendations, in a manner consistent with the CWA 304(a) national recommendation criteria guidance for T, DO, and pH.

2. **Amending State Water Quality Criteria Magnitude, Duration and/or Frequency Components** – States could look at modifying the frequency, duration, and/or magnitude (FDM) components of their adopted water quality criteria (WQC) to align with their listing methodologies as long as the FDM are scientifically defensible and provide reasonable protection of a State's designated uses. In some cases there may be sufficient data to justify modification of FDM based on current research. However, in most cases the research is limited and not contemplative of continuous monitoring. For instance, the EPA National Recommended Criteria for DO was published in 1986 and has numeric values for 30-day mean, 7-day mean, 7-day minimum, and 1-day minimum. However, the 1-day minimum carries a footnote that *"All minima should be considered as instantaneous concentrations to be achieved at all times."* [2] It is doubtful the criteria anticipated continuous monitoring when published nearly 30 years ago.

[1] U.S. EPA. 2005. *Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act.*
http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/2006IRG_index.cfm

[2] U.S. EPA. 1986. *Ambient Water Quality Criteria for Dissolved Oxygen*. EPA 440/5-86-003. Washington: GPO, April 1986.

Similarly, T and pH criteria were last updated in 1986, thus it may be difficult to find enough new information to substantiate modified FDM.[3] While there have been attempts in various regions to craft policy specific to those regions, the policies typically rely on reinterpretation of the existing criteria documents. EPA Region 10's temperature guidance document departs from the previous paired criteria (acute-chronic model) and uses a single temperature metric in part to better allow for day-to-day variability in daily maximum temperature.[4] This guidance also tries to acknowledge year to year variability by allowing the recommended criteria to be exceeded in 1 out of 10 years. It does not address the spatial elements of a dense dataset except to say criteria should apply upstream of the furthest downstream extent of a use. Overall, it appears that due to the lack of contemporary data on the criteria, it would behoove state WQS staff to work with their respective Region to establish the minimally required information necessary when submitting a WQS change involving FDM for any of these criteria.

Criteria might also be modified, or their application modified, to allow integration with biological monitoring in a multiple lines of evidence approach. To implement such an approach, a state should currently have and maintain a robust bio-monitoring program that is spatially and temporally sufficient to ascertain the response to the specific contaminants or parameters being assessed (e.g., a program that is being used for other CWA purposes, such as 303(d) listing). A multiple lines of evidence approach would combine traditional causal stressor monitoring – for specific water quality parameters such as T, pH and DO – with monitoring of biological communities for evidence of a response. It is acknowledged that this can be tricky as there may be a lag in biological response and biology may be responding to a stressor not measured, and so selection of early indicators responsive to specific contaminants is important. However, there are tools to thoughtfully sort through cause and effect, a prime example being EPA's CADDIS.[5]

Recently, novel WQS for DO were developed for the Chesapeake Bay, which integrate components of both spatial and temporal variability, taking advantage of a very intensive monitoring effort.[6]

Recommendation: EPA explore whether opportunities exist to coordinate with a State to craft a modified WQS that appropriately accounts for FMD (in light of recent data/literature

[3] U.S. EPA, 1986. Quality Criteria for Water. EPA 440/5-86-001. Washington: GPO, May 1986.
[4] U.S. EPA, 2002. Draft EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards, accessed December 5, 2013. http://yosemite.epa.gov/R10/water.nsf/1507773cf7ca99a7882569ed007349b5/1442c7b1fcde026b88256c4e0074dc2f/$FILE/Temperature%20Std%20Guidance%20Oct%2002.pdf
[5] U.S. EPA. CADDIS: The Causal Analysis/Diagnosis Decision Information System. http://www.epa.gov/caddis/
[6] Tango, Peter J. and Richard A. Batiuk, 2013. Deriving Chesapeake Bay Water Quality Standards. Journal of the American Water Resources Association (JAWRA) 49(5): 1007-1024.

searches). This effort could serve as a "pilot study" for others interested in pursuing this type of WQS revision. In doing this, it could be useful to rely upon existing work/lessons learned from Chesapeake Bay DO WQS as a reference point.

3. **EPA re-evaluating National Recommended Criteria documents for DO, T, and pH** – As indicated in item 2 above, the criteria documents for DO, T, and pH are outdated and likely did not consider the role of continuous monitoring or spatially dense datasets when they were developed. In addition, these same criteria are the most often implicated in questions regarding natural background conditions. Thus, the criteria would appear to be ripe for update, or at a minimum, a literature review to ascertain the need to modify the National Recommended Criteria. It would take time and financial resources on the part of EPA for this undertaking, but if the review could achieve the dual purpose of addressing the appropriate use of continuous monitoring data along with appropriate application to natural conditions issues, the expenditure could have significant value.

Recommendations:

1) EPA mount an effort to re-evaluate the national recommendations for DO, T, and pH criteria with a focus on the appropriate manner to express frequency, duration, and magnitude for continuous/fluctuating data measurements, especially in light of natural temporal and spatial variability being revealed by these modern monitoring capabilities and networks. This could be in the form of a supplement to the expression of frequency/duration in the current criteria recommendations for DO, T, and pH.
2) In recognition of the time and expense involved in revising criteria, a secondary recommendation is for EPA to conduct a scientific literature review to ascertain whether sufficient research data exist to make recommendations on criteria frequency, duration and magnitude for continuously monitored DO, T, and pH criteria. (Note – USGS has collected a sizable amount of continuous temperature data for its NorEaST Stream Temperature Mapper[7], as has the Forest Service's Rocky Mountain Research Station via their NorWeST regional stream temperature project.[8])
3) As a short term bridge to completing recommendations 1 and 2, EPA could develop WQS templates for T, DO and pH that reflect existing flexibilities expressed in the magnitude, duration and frequency components expressed in EPA's Gold Book for 304(a) National Recommended Criteria.

[7] U.S. Geological Survey. NorEaST: Stream Temperature Data Inventory. http://wim.usgs.gov/NorEaST/
[8] U.S. Forest Service, Rocky Mountain Research Station. NorWeST Stream Temp Regional Database and Model. http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html -and- http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temperature.shtml#monitoring

4. **Assessing the application of continuous monitoring data in light of State data laws and regulations** – This option is different from the others in that it poses the question of whether continuous monitoring data meet thresholds established in State law or regulation regarding credible data, laboratory certification, and approved test methods. Data not meeting these thresholds could possibly be used to help inform State actions, but not used for regulatory purposes.

   Where passed by State legislatures, State credible data laws typically require any data used for regulatory purposes to meet a certain level of data quality, which doesn't typically take into account continuous monitoring data collection methods. It is unclear as to whether all data collected with continuous monitors would meet current credible data requirements and would ultimately be utilized pursuant to a State's discretion. If they were deemed *non-credible*, data may not be usable for regulatory purposes but could still be used to direct other activities focusing on improving water quality. Even in absence of credible data laws there are increasing data quality requirements such as the need for Quality Assurance Project Plans (QAPPs) for all environmental data used in decision making and the need for Standard Operating Procedures (SOPs). QAPPs assure that the data collected, by whatever methods, meet objectives before it is used and SOPs work to assure data collection is standardized and representative.

   Some States have requirements that all data used for regulatory purposes must be analyzed by a laboratory certified by their State agency or the National Environmental Laboratory Accreditation Conference (NELAC). It is unclear how continuous monitoring stations would meet certain requirements of those programs such as qualified staff, proficiency testing, laboratory space and equipment, approved QA/QC protocols, etc. In a similar vein, States with certification programs certify specific parameters and methods. It is unclear whether continuous monitoring for DO, T, and pH follows EPA approved methods, and whether the method requirements such as instrument calibration and QA/QC would be met. As with *non-credible* data, these data could also prove to be of value to a State water quality program, but not be permissible for regulatory purposes.

   The entire issue of credibility with continuous monitoring data is recognized within the monitoring community. The US Geological Survey (USGS) has developed documentation for continuous monitoring data collection and reporting that is used by USGS staff.[9] While others in the industry have adopted the USGS procedures, national standards are still lacking.

[9] Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed February 6, 2014, at http://pubs.water.usgs.gov/tm1d3

Recognizing the lack of national standards, the National Water Quality Monitoring Council has formed an Aquatic Sensor Workgroup to explore standardized processes for the various steps involved in collecting and analyzing field data.[10] Once these standards are developed, any concerns with data credibility should be greatly diminished.

However, even if data comply with all quality requirements, States are still left with the question of how to best evaluate the volume and density of data that continuous monitoring provides (per sections 2 and 3 above). This is of particular concern when current water quality criteria and standards were formulated without consideration for continuous monitoring data. In addition, new questions arise about the range of natural variability, both spatially and temporally, that could not be considered absent rich data sets.

Recommendations:

1) Make states aware of efforts to standardize continuous data collection and analysis, such as guidelines being developed by the National Water Quality Monitoring Council's Aquatic Sensor Workgroup.
2) Until accepted standards are published, create a Forum-moderated clearinghouse for states to share monitoring protocols and QAPPs that account for the temporal and spatial range of natural variability captured by continuous monitoring data, in order to assist states in utilizing their discretion on the use and interpretation of continuously collected water quality data.
3) Create a clearinghouse to share the actual software used by states/available to states to upload, access, and assess data. Also share the format of the data states find most useful.

5. **Establishing set "assessment areas" in waterbodies.** For monitoring locations where the state is performing the monitoring, and the use to be protected is location-specific, states may find it useful to identify assessment areas that are the most appropriate for collecting continuous monitoring data. This approach would constrain representative monitoring locations within a waterbody, vs. a situation where data are collected anywhere in a waterbody for use in assessing attainment or non-attainment with water quality criteria. This would be one way to deal with spatially overlapping uses in a particular water body without having to segment the waterbody further. The assessment location for a given use would be characteristic of core or optimum conditions to be expected in the waterbody for that use. As an example, for temperature criteria protective of a salmonid spawning use, an assessment would likely not be near the mouth where warmer temperatures are expected but rather upstream in a cooler area where spawning activity is actually focused. In such a situation, locations could be carefully

[10] The Aquatic Sensor Workgroup. http://www.watersensors.org/about.html

chosen taking into account the longitudinal increase in temperature typical of flowing waters, and knowledge of use occurrence and timing of use.

To avoid the limitations of fixed location constraints on acceptable monitoring locations, locations could be specified as boundaries – e.g., above river mile 525, above elevation 5000', or 2nd and 3rd order tributaries to River Y.

States would also need to address the perception of biasing site selection to avoid potentially degraded areas and be sensitive to potential limitations on the application of this option as a consequence. Similar issues arise in attempting to hand pick a location and call that location representative of a broader area. As we develop this option further, we may need to consider what it would mean for credible data collected and submitted for consideration that is located outside of these assessment areas.

Recommendations:

1) Request EPA work jointly with states to explore whether this is a viable option (under what circumstances and with what limitations) and work with states where potential exists.
2) Explore existing application of this general concept used by Colorado in deriving and assessing site-specific criteria to understand whether it is useful/applicable to other states.

6. **Refining Uses** – Where states have general uses applying to large waterbody segments, it may be useful to consider subcategorization to refine the uses to better reflect the (aquatic life) use the state is striving to protect. This option would more appropriately target which criteria apply where. It offers great potential in the long run but will be limited in its usefulness in the near term due to the level of effort likely needed to refine uses, refine the scale on which they are applied, and to potentially also refine criteria. Questions about existing uses will need to be confronted and hurdles of ESA consultation overcome in some regions. One way to minimize the workload and maximize the considerable transaction costs for both states and EPA in this option would be to approach use refinement for categories or groups of waterbodies of similar character.

Recommendation: EPA provide ACWA with locations of current materials and tools on EPA's website that address questions on designated and existing uses, and ACWA could then disseminate this information. EPA could also provide guidance on determining existing uses and work collaboratively with selected States or Regions on pilot projects of categorical use refinement. Canals, ditches and other irrigation water conveyance systems may be a prime example of where a categorical use refinement makes sense.

Concluding Thoughts: As displayed in the table in Attachment 1, numerous States are currently facing the question of how to apply continuous monitoring data to naturally-variable parameters in the implementation of the Clean Water Act. Ideally, States and EPA would like to have a better, science-based understanding of the ecological response caused by diurnal or other short term fluctuations in DO, T, and pH. Understanding the interplay between continuous or near-continuous fluctuation of these parameters and ecological health would allow States to better craft their criteria. However, since it is unlikely EPA has the resources to develop new criteria guidance founded on continuously changing frequencies, durations, and magnitudes, States must use their best professional judgment in the application of continuous monitoring data to Clean Water Act Programs. Whether this judgment is expressed through 303(d) assessment methodologies or other means, States need to have the flexibility to exercise that judgment in order to best use available data.

Attachment 1 - States' Use of Continuous Data in 303(d)/305(b) Assessments– Generally applicable to streams

State	Parameter	Minimum Threshold for Not Supporting Determination	Data Used in Calculations	Comments
Colorado	Max. temperature,	2 exceedances of WQS in a 3 year block	Highest 2 hour average temperature for each day	While the methodology document doesn't explicitly mention continuous data, the data used in the calculations would need to be developed with continuous monitoring.
	Weekly average temperature	2 exceedances of WQS in a 3 year block	Averages of daily average temperatures for 7 consecutive days	
Delaware	Average DO	10^{th} percentile of daily averages < WQS	Daily averages	If no continuous data available, field measurements considered to be representative of daily average
	Min. DO	1^{st} percentile of all continuous data < WQS	All continuous data	
Idaho	Max. daily temp.; max. daily avg. temp.; max. 7-day avg. of daily avg.; max. 7-day avg. of daily max.	Tied to biological condition. Any exceedance of critera if biological condition is poor or there are no biological data. With biological data showing good condition, if ≥10% of days during periods of interest (Jun 21 – Sep 21 for coldwater; minimum of 45 day period for salmonid spawning) exceeds criteria there is impairment	Continuous temperature data and biological data when available. Temperature data are reduced to various metrics: Daily maximum values; daily averages; averages of daily average temperatures for 7 consecutive days; averages of daily maximum temperatures for 7 consecutive days	Exceedances of greater than 2 hours duration are considered a violation regardless of frequency. However, generally we have not been in the habit of scrutinizing duration. In large part this is because we have found that, at least for temperature, the magnitude duration and frequency of exceedance are all correlated. This listing methodology is based on language adopted into state WQS and approved by EPA.
	DO, pH, & turbidity	The same 10% rule applies to these parameters as well, but no guidance has been developed on particulars, such as the critical time periods used for temperature	All continuous data	
Louisiana	Min. DO	>10% exceedance of WQS	All continuous data	In the event that grab data shows >10% exceedance, continuous data are used for follow-up assessment. Continuous data runs are approximately 48-72 hours in duration.
Nevada	Min. DO, max. temperature, min/max pH	>10% exceedance of WQS	Daily min/max values (calculated from continuous datasets) and grab sample data	If water listing based upon continuous data, continuous data are needed to delist for future reporting cycles
New Hampshire	Min. DO	>10% exceedance of WQS	Daily minimum values (calculated from continuous datasets) and grab sample data	Continuous data defined as preferred over field grab measurements
	Average DO	>10% exceedance of WQS	Daily averages	

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State	Parameter	Minimum Threshold for Not Supporting Determination	Data Used in Calculations	Comments
New Mexico	Min. DO	1 exceedance of WQS for 4 or more consecutive hours in any day	All continuous data	Requires continuous data to be collected at least in 1 hour intervals
	Max. temperature	1 exceedance of WQS	Daily maximum values	
	Min./max. pH	Any one of the following: 1) ≥10% exceedance of WQS based upon all data 2) Any exceedances occur for more than 24 consecutive hours 3) pH exceeds 9.5 at any time	All continuous data	
New Jersey	Min. DO	2 exceedances of WQS with each exceedance at least 1 hour in duration	All continuous data	
	Average DO	1 exceedance of WQS	Daily averages	
	Max. temperature	2 exceedances of WQS with each exceedance at least 1 hour in duration	All continuous data	
	Weekly average temperature	1 exceedance of WQS	Averages of daily average temperatures for 7 consecutive days	
	Min./max. pH	1 exceedance of WQS at least 1 hr duration	All continuous data	
Oregon	7-day average daily max. temperature	1 exceedance of WQS	Averages of daily maximum temperatures for 7 consecutive days	Grab temperature readings are not evaluated
Virginia	Min. DO, max temperature, min/max pH	>10.5% of readings in a 24 hour period (including grab samples) exceed WQS	All continuous data and grab sample data	A day violates WQS when >10.5% of readings violate WQS. Min. data requirement for temperature – 15 days during critical period (May-Sept.)
Washington	Min. DO	3 exceedances of WQS	Daily minimum values	Grab DO readings not used to place water in Category 1
	7-day average daily maximum temperature	1 exceedance of WQS	Averages of daily maximum temperatures for 7 consecutive days	
Wisconsin	Min. DO	≥10% exceedance of WQS	All continuous data	Min. data requirement – 3 days of continuous measurements (no less than 1 sample per hour) in July or August; minimum of 3 years of data
	Max. temperature	≥10% exceedance of WQS	Daily averages	The methodology is confusing for this parameter. It appears that daily average temperatures are being compared to daily MAXIMUM temperature WQS.

	Min./max. pH	≥10% exceedance of WQS	All continuous data	