Rationale Supporting Application of a Reference Curve for Assessment of the Chesapeake Bay Deep Channel Dissolved Oxygen Criterion

Briefing Document for the
CBP Scientific and Technical Advisory Committee's
Peer Review Team

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History of EPA Guidance Regarding the Deep Channel Reference Curve

In April 2003, the U.S. Environmental Protection Agency (EPA) published a guidance document, *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries* (U.S. EPA 2003). In this publication, the EPA documented the derivation of the dissolved oxygen criterion protective of the seasonal deep channel designated use. For this particular designated use, an instantaneous minimum criterion of 1 mg/L was determined to protect benthic organisms residing in the:

> "deep water-column and adjacent bottom surficial sediment habitats located principally in the river channel at the lower reaches of the major rivers and along the spine of the middle mainstem Chesapeake Bay at depths below which seasonal anoxic (< 0.2 mg/L dissolved oxygen) to severe hypoxic conditions (< 1 mg/L dissolved oxygen) routinely set in and persist for extended periods of time under current conditions" (p. 60 in U.S. EPA 2003).

In support of the instantaneous minimum criterion of 1 mg/L, U.S. EPA (2003) summarized findings published in peer-reviewed literature sources indicating that several keystone benthic species "are resistant to dissolved oxygen concentrations as low as 0.6 mg/L," and that "extensive mortality is likely only under persistent exposure to very low dissolved oxygen concentrations at high summer temperatures" (p. 61).

U.S. EPA (2003) also reported that in the mesohaline Chesapeake Bay (the primary location of the seasonal Deep Channel designated use), "dissolved oxygen concentrations of less than 1 mg/L lead to mortality for even tolerant species (p. 61) and that "when dissolved oxygen drops significantly below 1 mg/L for even short periods of time (on the order of hours) mortality increases, even for tolerant species" (p. 65). Furthermore, it was stated that "States and other users must recognize that the deep-channel dissolved oxygen criterion is stated as an instantaneous minimum, thus *any* exceedance is assumed to have direct consequences to the survival of the bottom-dwelling community" (p.151).

Regarding the definition of a water quality standard, it is explained in U.S. EPA 2003 and in Chapter 3 of the U.S. EPA's *Water Quality Standards Handbook, 2nd Edition* (EPA 823-8-94-005a, August 1994) that water quality criteria definition and assessment

comprises not just the *magnitude* of a water quality criterion (i.e. "the quantifiable condition," in this case the concentration of dissolved oxygen), but also the *duration* and *frequency* of that condition.

In this context, *duration* is addressed by restricting the applicability of the criterion to the summer period (June – September) when stratification and severe hypoxia occur in Deep Channel regions of the Chesapeake Bay, and by defining the assessment period as "the most recent three consecutive years for which relevant monitoring data are available" (U.S. EPA 2003; p. 150-1).

The *frequency* component of the criterion "is directly addressed through comparison of the generated cumulative frequency distribution (CFD) with the applicable criterion reference curve (U.S. EPA 2003; p. 151).

In summary, statements were made in U.S. EPA 2003 suggesting that the benthic community can tolerate small violations of the Deep Channel instantaneous minimum criterion, but statements were also made suggesting that any violation of this criterion has negative effects on the survival of Deep Channel benthic species.

However, as also described in U.S. EPA 2003, national guidelines define a water quality standard as comprising not only the *magnitude* of a given condition, but also the *duration* over which that condition is assessed and the *frequency* of violation allowed within the given assessment *duration*. For the case of the Chesapeake Bay, the *frequency* of allowable violation is defined by the location of a reference CFD, more commonly called a "reference curve" (both the rationale for use of a biological reference curve and the development of the 10 percent reference curve are also well documented in U.S. EPA 2003).

Therefore, the water quality criterion for the Deep Channel designated use can be understood as a whole to be: the instantaneous minimum of 1 mg/L, assessed for the summer months over a 3-year period, with an allowable frequency of natural exceedance defined by the applicable reference curve.

Further confusion on this point was caused by the dissemination in December 2006 of the following statement in a draft version of an addendum to the original U.S. EPA 2003 document published in July 2007:

> "there are no 'biologically acceptable exceedances of the applicable criteria' for the instantaneous minimum criteria, given the impairment is death (see page 151 in U.S. EPA 2003a). Therefore, EPA recommends attainment assessment of the instantaneous minimum dissolved oxygen criteria be conducted strictly based on analysis of violations of the observed data within the appropriate designated use segment over the appropriate time of the year and three year assessment period without application of the CFD methodology and use a reference curve." (Pages from draft document were provided as

a pdf via email message from Beth McGee, Chesapeake Bay Foundation)

This draft document also contained a note to reviewers stating that the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) would soon provide a formal recommendation against the use of a biological reference curve and any other procedure other than direct analysis of the available data.

No such recommendation was ever made by STAC. Furthermore, the passage quoted above was not present in the final version of this addendum—*Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries: 2007 Addendum*—published in July 2007 (U.S. EPA 2007).

A statement contained both in the draft quoted above and on page 43 of the July 2007 published addendum (U.S. EPA 2007) further contributes to the confusion surrounding this issue. It is erroneously stated that

> "The 2003 EPA criteria guidance stated that there were no 'biologically acceptable exceedances of the applicable criteria' for the instantaneous minimum criteria, given that the impairment is death (page 151 in U.S. EPA 2003a)"

where "U.S. EPA 2003a" is cited as EPA 903-R-03-002, referred to in this document as U.S. EPA 2003. However, no such statement can be found on page 151 or on any other page of U.S. EPA 2003.

As described in U.S. EPA 2003, the preferred methodology for defining the reference curve is to determine levels of allowable violation based on the demonstrated tolerance of the living resources for whose protection the water quality standards were designed. In the case of the Deep Channel designated use, the application of a biological reference curve was recommended in U.S. EPA 2007 (p. 43). This recommendation was based on the identification of a small number of Deep Channel segment-periods within which the benthic communities were categorized as "healthy" and therefore appropriate for use as a biological reference. These benthic communities were categorized using the methodology described on pp. 39-41 of U.S. EPA 2007.

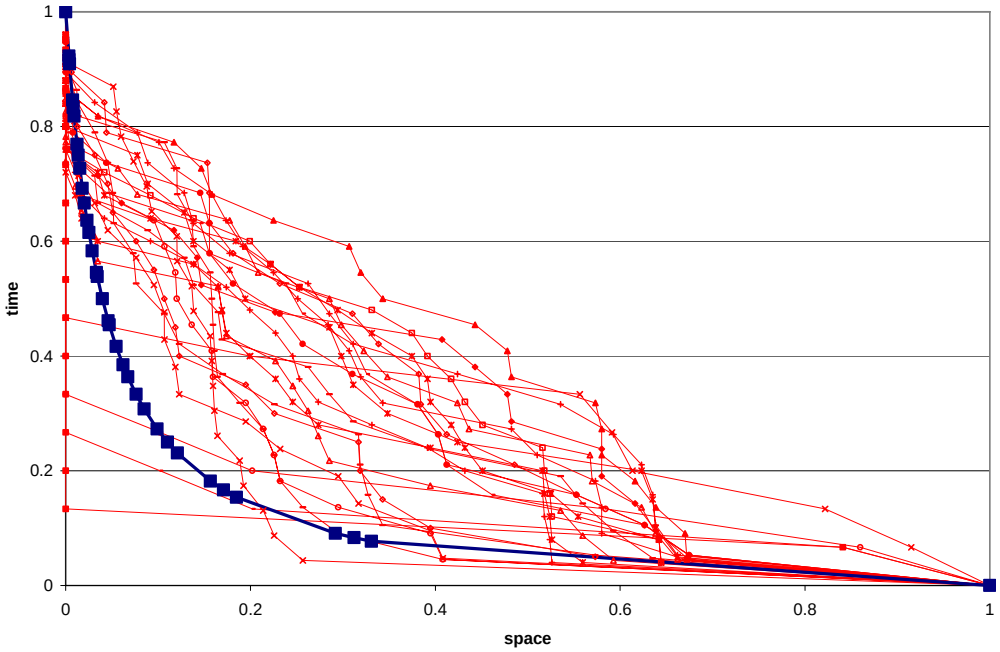
Revisions to the Reference Curve Methodology

Based on a review conducted in April-June 2009, EPA is now recommending revisions to the methodology for categorizing benthic communities as "healthy" for the purposes of providing a reference for allowable *frequency* of dissolved oxygen criteria exceedance (these revisions are detailed in accompanying documents). The intent of these revisions is to improve the accuracy with which benthic communities are categorized. Using the revised methodology, the Chesapeake Bay Program Office data analysts have found that for the period 1996-2005 for which sufficient data are available, there are no segment-

periods in which Deep Channel benthic communities can be categorized as healthy enough to serve as biological reference communities.

While no benthic communities could be categorized as "healthy" in the most recent review, 25 "degraded" reference benthic community segment-periods were identified. The CBPO conducted analyses that showed that all 25 segment-periods for which Deep Channel benthic communities were categorized as "degraded" failed a dissolved oxygen assessment conducted using the 10% reference curve (see Figure 1).

Figure 1: CFD graph of dissolved oxygen Deep Channel violation rates corresponding to benthic communities categorized as "degraded" (red lines) in relation to the 10% reference curve (blue line). Analyses conducted by the CBP show that all segment-periods with known degraded benthic communities (in the time period from 1996-2005) failed a dissolved oxygen criteria assessment conducted using the 10% reference curve.



In the absence of a suitable reference community, a biological reference curve for the Deep Channel designated use can not be constructed at this time.

Under these circumstances, "a default reference curve such as the normal distribution curve representing approximately 10 percent exceedance is appropriate in this case to account for anticipated natural criteria exceedances" (U.S. EPA 2003; p. 173).

Rationale for Acceptable Exceedances of the Criterion

EPA determined that there are allowable criteria exceedances that would not adversely effect protection of the designated use. As documented on p. 168 in U.S. EPA (2003):

> "The recommended criteria attainment assessment approach is designed to protect the living resources as defined by the designated uses. The criteria levels themselves were largely based on scientific studies performed in laboratory settings or under controlled field conditions. The criteria establish the level of a given habitat condition that living resources need for survival. They do not account for many other environmental factors that could affect survival.
>
> Reference curves were developed to provide a scientific-based, direct measure of the 'allowable' criteria exceedances. These exceedances are defined to be those that last a short enough time or cover a small enough area to have no adverse affects on the designated use. It is assumed that the designated uses can be attained even with some limited level of criteria exceedances and thus, the reference curves define those criteria exceedances deemed to be allowable—chronic in time but over small areas, or infrequent occurrences over large areas. Exceedances that occur over large areas of space and time would be expected to have significant detrimental effects on biological communities, which would imply nonattainment of designated uses."

As reported in a recent paper (Batiuk et al. in press) on the Chesapeake Bay dissolved oxygen criteria by the key members of the original dissolved oxygen (DO) criteria team:

> Unlike chemical contaminants or other more conventional pollutants, there were no clear, well established guidelines for deriving criteria for DO, particularly for estuarine waters inhabited by fresh-water and marine species. The goal in setting Chesapeake DO criteria was to use the best science possible to define conditions that would improve or sustain the suitability of Chesapeake Bay habitats for finfish and invertebrates, with the states ultimately factoring in consideration of attainability in adopting the criteria as water quality standards. Thus, we developed criteria that would greatly increase the spatial and temporal extent of Bay waters in which oxygen concentrations were not major limitations to growth and survival of organisms dependent on particular Bay habitats. We did not, however, derive criteria that would require oxygen concentrations high enough at all times and in all locations such that no organism would be negatively affected in any location in the Bay. The states and U.S. Environmental Protection Agency (EPA) determined that such conditions would not be achievable either economically nor technologically (U.S. EPA, 2003d) and may not, in fact, reflect pre-historical conditions of Chesapeake Bay, which showed that low oxygen conditions, although not nearly as severe as today, may have been a historical feature in the deep channel of the bay (Cooper and Brush,1991; Karlsen et al., 2000; Adelson et al., 2001; Zimmerman and Canuel, 2002; Bratton et al., 2003; Colman and Bratton, 2003; Cronin and Vann, 2003; Zheng et al., 2003).

In support of the instantaneous minimum criterion of 1 mg/L, U.S. EPA (2003) summarized findings published in peer-reviewed literature sources indicating that several keystone benthic species "are resistant to dissolved oxygen concentrations as low as 0.6 mg/L," and that "extensive mortality is likely only under persistent exposure to very low dissolved oxygen concentrations at high summer temperatures" (p. 61).

In light of both (1) the recognition that low dissolved oxygen conditions are a 'pre-historical' feature of these deep channel habitats, and (2) the observation that keystone benthic species of these deep channel habitats can tolerate small-scale occurrences of severe hypoxia (DO concentrations below 1 mg/L), EPA believes that an allowance for a small, limited set of exceedances in time and space is acceptable in assessment of the deep-channel designated use dissolved oxygen criterion.

EPA's Recommended Guidance

EPA has recommended application of the default 10% reference curve for assessment of the Deep Channel dissolved oxygen criterion to the Chesapeake Bay Program's Water Quality Steering Committee. At its June 22, 2009 conference call, the Water Quality Steering Committee agreed "to the use of these updated curves for the process of developing the TMDL contingent on the STAC review and approval and the assumption that the states can get these curves adopted for their Water Quality Standards."

References

Batiuk, R.A., D.L. Breitburg, R.J. Diaz, T. M. Cronin, D.H. Secor and G. Thursby. In Press (2009). Derivation of habitat-specific dissolved oxygen criteria for Chesapeake Bay and its tidal tributaries, J. Exp. Mar. Biol. Ecol.

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