Association of
Metropolitan
Sewerage Agencies

December 10, 2001

Mr. Robert Cantilli
EPA Nutrient Program Coordinator
U.S. Environmental Protection Agency
Ariel Rios Building (MC 4304)
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Re: *Nutrient Criteria Development; Notice of Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters, 66 Fed. Reg. 51665 (October 10, 2001)*

Dear Bob:

The Association of Metropolitan Sewerage Agencies (AMSA) is pleased to provide comments on the U.S. Environmental Protection Agency's (EPA's) *Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters* (*Estuarine Guidance*). Founded in 1970, AMSA represents the interests of over 260 of the nation's publicly owned wastewater utilities (POTWs). AMSA members serve the majority of the sewered population in the United States and collectively treat and reclaim over 18 billion gallons of wastewater every day. Since 1999, AMSA has been active in the nutrient criteria development process, commenting on the National Strategy (November 1999), Lakes/Reservoirs Technical Guidance (July 2000), and Rivers and Streams Technical Guidance (September 2000) documents and participating as a stakeholder in discussions at the national and regional levels.

AMSA is pleased that the *Estuarine Guidance* reflects statements made in a November 14, 2001 memorandum to the states and Regions from Geoffrey Grubbs (USEPA 2001), providing additional direction to states regarding the development of nutrient criteria plans, timeframes, and the available flexibility. AMSA believes this memorandum will play a critical role in ensuring states have the ability to develop more meaningful criteria that take into account nutrient effects on designated uses. In the November 14 memorandum, the Agency describes two conceptual methods that states can employ in the

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development of nutrient criteria, the use of reference conditions and an "effects-based" approach that relates to designated uses. AMSA is encouraged that the Agency is providing the flexibility to establish criteria through an effects-based approach. AMSA believes that states will need to utilize site-specific, effects-based approaches directly related to designated uses in order to develop defensible standards. Otherwise, the decisions are likely to be arbitrary and subject to legal challenges.

AMSA does, however, have serious concerns with the use of the reference condition method for estuaries and coastal waters, as outlined in the *Estuarine Guidance*. Reference condition approaches do not address the assimilative capacity of estuaries and coastal waters and will lead to unrealistic criteria values disconnected from designated uses.

AMSA believes that all nutrient criteria must be developed on the basis of a thorough scientific understanding of nutrient effects on designated uses. Thus, AMSA strongly disagrees with statements in the *Estuarine Guidance* that nutrient criteria can and should be developed even in the absence of an in-depth scientific investigation. To proceed in this manner would likely result in a wasteful expenditure of resources and result in meaningless criteria.

AMSA's comments and concerns are explained in more detail below. Many of our concerns are supported by an independent review of the *Estuarine Guidance* conducted by HydroQual, Inc. on behalf of AMSA, which is included as an attachment.

Issues Associated With the Reference Condition Approach

AMSA has significant procedural and technical concerns with the reference condition approach described in the guidance document. These concerns are associated with apparent conflicts with the requirements of the Clean Water Act and highlight the need to bypass the reference condition approach and proceed directly to effects based methods.

<u>Reference condition approaches that ignore biological effects would not meet Clean Water Act requirements</u>

Reference condition approaches that ignore the biological effects associated with nutrient enrichment do not address the requirements of 304(a) of the Clean Water Act (CWA). This section of the CWA directs EPA to develop and publish "criteria for water quality accurately reflecting the latest scientific knowledge...on the effects of pollutants on biological community diversity, productivity, and stability...." Given these requirements, effects-based methods are essential to the development of defensible criteria, and should not be viewed as optional. AMSA and HydroQual, Inc. as well as other stakeholders have previously commented on the need to establish nutrient criteria directly on the basis of nutrient effects on designated uses (Methods & Data Comparability Board, 2001; NEIWPCC, 2000; NCDNR, 1999 and 2001; Virginia Tech 2001). In some sections of the *Estuarine Guidance*, EPA suggests that biological effects be disregarded entirely and advocates proceeding with criteria development without having the necessary information. Consider the following examples:

- "The best possible understanding of the physical, chemical, and biological interrelationships in the environment is important in nutrient criteria development and the subsequent management response. However, effective nutrient criteria can and should be developed even in the absence of an in-depth scientific investigation of the ecological processing of nutrients in the estuarine and marine environment." (page xvi)

- "An understanding of reference conditions will help resource managers from being blind-sided by complications associated with cause-effect relationships." (page 6-4)

- "It may be necessary to make risk management decisions that extend beyond the current state of the science." (page 7-11)

- "The significance of this reference condition to nutrient criteria development cannot be over-stated. It represents the determination of the existing presently attainable nutrient water quality of the estuarine or coastal waters of concern." (page 7-5)

- "It is important to understand that designated uses may be met but some nutrient-based impairment may have occurred. In such cases it is also desirable to have restoration goals in mind whose objective is to restore the original ecological integrity, at least as represented by the reference conditions and criteria. This information helps determine if new designated uses are appropriate." (page 7-1)

The percentile based method for developing nutrient criteria is a prime example of AMSA's concerns with this type of approach toward criteria development. Similar to the Lakes / Reservoirs and Rivers / Streams guidance documents, the frequency distribution approach continues to be proposed as one of the means to establish reference conditions (page 6-7). This approach does not consider the effects of nutrients on the designated uses. According to HydroQual (2001b) the frequency distribution approach "implies that a predetermined percentage of water bodies will not meet the nutrient criteria regardless of the assimilative capacity or actual nutrient effects of the water body. In effect, designated uses may or may not be attained using these procedures." Because such methods are disconnected from the measurement of biological effects, such methods do not fulfill the requirements of the CWA.

Nutrient Criteria Development Should Bypass Reference Conditions and Proceed Directly to an Effects-Based Approach

AMSA recognizes that EPA has attempted to address some of the concerns over the reference condition approach by suggesting means to corroborate the reference based criteria through effects. The following are examples of this concept found within the document:

- "Reference conditions are a primary element of nutrient criteria development, but should be used in conjunction with the other elements described in Chapter 1 and Chapter 7." (page 6-1)

- "Of equal importance in this process are in situ reference sites and supporting data showing the system response to the nutrient increases. The best of both of these worlds is a set of reference sites documenting an optimal nutrient condition as well as response data confirming that system degradation occurs at levels beyond this measure, which also corresponds to the EPA regional reference condition for that area and class of waters." (page 7-5)

- "Even though the reference condition is salient to nutrient criteria development, it should not be interpreted as the only necessary element. It should be interpreted in light of the historical condition of the resource of concern and projections of its future potential." (page 7-5).

- "Criteria to protect designated uses should be developed on a site-specific basis when the individual nature of the estuary or coastal waters require such specificity." (page 7-9)

This is a significant improvement over previous guidance documents that contained few references to such concepts. However, AMSA believes that such "needs" for corroboration make a strong argument for bypassing the reference condition approach and proceeding directly to an effects-based method. This argument is based on three general concepts: (1) if effects measurements are needed to corroborate the criteria then knowledge of the reference condition is unnecessary, (2) reference-based approaches would not lead to practical / useful criteria values because they would ignore assimilative capacity, and (3) states recognize the need to ultimately employ effects-based methods to establish defensible standards. These issues will be addressed in more detail in the sections below.

<u>The reference condition would be redundant when effects measurements are needed to validate the criteria</u>

AMSA believes the corroboration of reference based criteria through effects-based measurements is redundant and unnecessary. Effects based criteria development does not require the determination of a reference condition. If the effects of nutrients on designated uses are known then knowledge of reference / historical conditions is unnecessary and thus redundant to criteria development. Perhaps this concept is best stated by HydroQual (2001b): "Since effects based criteria can be developed without knowing the reference condition of the water body but setting reference conditions will require knowledge of the assimilative capacity, the criteria development should logically proceed to effects based criteria."

<u>The reference condition approach does not adequately address the important role of assimilative capacity and lead to inappropriate criteria values</u>

The reference concept is unworkable for most estuaries and coastal waters that presently receive significant nutrient loading. The *Estuarine Guidance* provides various approaches to determine the reference condition in areas with existing enrichment that involve watershed modeling of pre-development nutrient delivery and sediment cores, among other things. Although these techniques may indeed be effective in reconstructing the reference condition, AMSA believes that obtaining such information will not serve to establish realistic criteria values.

For estuaries with significantly developed watersheds it is generally recognized that natural nutrient levels reflective of a natural reference condition represent an unattainable expectation. Nutrient enrichment is an eventual consequence of human development and civilization. Given these realities the primary question associated with nutrient criteria should not be focused on what the nutrient conditions *were* historically but rather with what they *need to be* to support the designated uses. The latter view recognizes that a certain degree of nutrient enrichment would not necessarily impair designated uses. The difference between natural loads (i.e., reference condition) and those that a system can assimilate without biological impairment (effects) represents a working definition of *assimilative capacity*. Bricker et al. (1999) provides an index based assessment of eutrophic condition compared with nitrogen input. In this report it is apparent that some estuaries receive low to moderate nutrient input and exhibit signals of high eutrophic condition (e.g., Great South Bay, Gardiners Bay), while others receive high nutrient inputs but exhibit low signals of eutrophication (e.g., Delaware Bay, Narragansett Bay, James River). Note that these are just a few examples for the Mid-Atlantic region, but they serve to show variation in assimilative capacity.

One of AMSA's concerns with a reference condition approach for estuaries is that such an approach will result in the establishment of criteria which, by definition, would not adequately address assimilative capacity and thus lead to criteria of unknown relationship to designated uses. AMSA's concern is reflected in the *Estuarine Guidance*: "measuring the nutrient characteristics of minimally impacted sites provides a reliable nutrient goal regardless of how those nutrients may or may not be assimilated. This is the approach upon which the National Nutrient Criteria Program is predicated, and reference sites should always be sought when designing nutrient criteria protocols" (page 6-4). This type of guidance is inappropriate as assimilative capacity is a critical consideration. For example, it would be unnecessary to establish criteria values on the basis of historical / reference data for areas such as the Delaware Bay, James River, or others because they have a high capacity to assimilate nutrients without measurable impairment. Although all estuaries have limits in this regard, these capacities must be adequately considered in order for the criteria to be meaningful:

> Designated uses cannot be assessed based on nutrient levels because they do not relate to endpoints, in addition they are not the perceived condition of a water body. It is the effect of nutrient enrichment (excessive algal growth, low dissolved oxygen, fish kills, etc.) that is the perceived condition (designated use) that should be the focus of criteria development in order for the public or local stakeholders to benefit...the assimilative capacity of the water body needs to be determined that relates nutrient inputs/levels to observable and reproducible effects on specific endpoints (HydroQual 2001b).

<u>States ultimately will be required to refine designated uses and employ an effects-based approach to establish valid standards</u>

EPA eventually may develop national criteria values for nutrients in estuaries and coastal waters on the basis of reference conditions. This will leave the states in a position of having to adopt these numbers or develop their own. AMSA believes that most states understand the need to develop their own criteria by refining the designated uses and developing nutrient criteria in association with those uses. However, AMSA still believes that resource constraints may force some states to rely on the reference condition approach. While the November 14 memorandum will alleviate some of the pressures put on states, the availability of the reference condition approach inevitably will lead to its use in the development of nutrient criteria.

Technical Issues Associated With Proposed End Points

Water Clarity

AMSA supports the use of water clarity as a means to establish nutrient criteria in those estuaries where water clarity is related to designated uses such as submerged aquatic vegetation (SAV). However, SAV should not represent a designated use in areas where these plants never grew historically or would never be expected. The Delaware River represents such a case. For areas where SAV represents a valid designated use the effect of nutrients as manifested by excessive phytoplankton shading may represent a genuine concern that can be addressed through nutrient management. In addition to nutrient concerns, equal or perhaps greater emphasis needs to be placed on the role of inorganic suspended solids on water clarity. The estuarine guidance manual mentions the importance of suspended sediment as related to the work of Gallegos (1994), but generally considers water clarity to be affected by the algal component of light attenuation. The role of suspended sediment in controlling water clarity needs to be discussed in more detail in the *Estuarine Guidance*. Cerco and Moore (2001) provide additional information that relates to the relative roles played by background color, suspended solids, and chlorophyll, which are related to SAV restoration efforts. Their relative roles were shown to vary on a site-specific basis where nutrient reduction, sediment reduction, or a combination of both should be prioritized.

POTWs can effectively reduce nutrients, but the control of suspended sediment is primarily a non-point source issue. Nutrient controls implemented by POTWs would be ineffectual and a waste of resources if suspended sediment was the cause of the turbidity. HydroQual (2001b) illustrates the importance of considering the role of suspended solids on water clarity in Pensacola Bay, Florida:

> One of the response variables identified in the document is water clarity but primarily only as affected by the algal component of light attenuation, not inorganic suspended solids. There are three major factors affecting algal growth in natural waters systems: nutrients, residence time and light levels. In estuaries, the interplay of these three variables makes cause and effect relationships difficult to quantify with general approximations. The compounding effect of terrestrial derived inorganic suspended solids on light extinction, not to mention the re-suspension of in place sediments, again highlights the complexity of estuaries and the need to carefully consider the development of nutrient criteria.

Chlorophyll a

The guidance document indicates that chlorophyll *a* represents an initial response variable. AMSA concurs that chlorophyll *a* measurements should play an important role in nutrient management programs. However, AMSA believes the utility of using chlorophyll *a* as the basis of regulatory criteria is limited, because it is very difficult if not impossible to relate chlorophyll *a* to designated uses given the present state of the science. Ecological theory holds that changes in phytoplankton composition and its role as a food source for higher trophic levels diminishes with increasing chlorophyll concentration. Chesapeake Bay Program research has suggested that the chlorophyll *a*/carbon ratio varies with the light environment. Although the results are preliminary, data suggests that chlorophyll pigments contained in algal cells increase in low light environments as a compensatory mechanism (Batiuk et al. 2001, unpublished data - draft). Although these findings are preliminary they could have a significant impact, and ultimately indicate that chlorophyll *a* may not be a reasonable estimate of plankton biomass under lower light conditions. Accordingly, chlorophyll *a* should not be used as a regulatory criteria (or its associated end point) until its relationship with designated uses is understood and measured with a reasonable degree of confidence. Given that chlorophyll *a* criteria poses such a large challenge in the Chesapeake Bay Program (a project where data is abundant) the prospects for its proper use in less studied systems seems unlikely.

Monitoring Data and Models

HydroQual (2001b) highlights a number of technical issues associated with monitoring data and modeling efforts, namely the need to consider the effect of detection limits, disparate sampling locations, monitoring objectives, and proper QA/QC objectives in the sampling protocols.

Summary and Recommendations

- AMSA has significant concerns with the reference condition based approaches included in the guidance document. Depending on how the reference condition approach is used it may not meet the requirements of section 304(a) of the Clean Water Act. The percentile based approach to criteria development is of particular concern because the criteria would be disconnected from designated uses.

- AMSA recognizes that the agency has taken some steps to address previous concerns regarding the reference condition by recommending that criteria be corroborated by effects measures and other means such as models. Although AMSA considers this a positive step, we believe the need for such steps indicates the need to bypass the reference condition approach and proceed directly to effects. The assimilative capacity of estuaries varies considerably from region to region. A reference condition based approach to nutrient criteria would inadequately address the issue of assimilative capacity. Incomplete considerations of assimilative capacity would likely result in criteria values with little relation to designated uses.

- Estuaries are very complex and have many site-specific differences. These issues are adequately explained in the *Estuarine Guidance*. However, AMSA strongly disagrees that effective criteria can be developed in the absence of sufficient scientific information as the document appears to suggest. To the contrary, AMSA contends that defensible criteria require a substantial understanding of nutrient dynamics and the effects of those nutrients on designated uses.

- Consistent with the conclusions of HydroQual (2001b), AMSA concurs that the development of nutrient criteria must follow a consistent, logical development method aimed at defensibly linking cause and effect relationships. Nutrient effects may not be as straightforward as those for toxic pollutants, especially in estuaries and coastal waters. For this reason, criteria may not be the solution but rather target levels that trigger further study into effects and potential limitations to beneficial uses. Such an approach would not preclude the agency from working with the states as already planned consistent with the November 14 memorandum.

- The Chesapeake Bay Program provides a good model for others to follow in developing nutrient criteria. This program has devoted significant resources towards monitoring, data collection, and scientific research over many years. Recent efforts have focused on refining designated uses and determining the effects of nutrient and sediment loading on these designated uses. Although it is recognized that other estuaries and coastal waters are much less studied, the Chesapeake Bay Program approach represents a good approach for others to evaluate in the development of nutrient criteria.

AMSA appreciates the opportunity to provide comments on the *Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters*. AMSA encourages EPA to consider these comments and the attached report when considering whether to revise and republish the guidance document. If you have any questions about our comments, please contact me at 202/833-9106 or *chornback@amsa-cleanwater.org*.

Sincerely,

Chris Hornback
Manager, Government Affairs

ATTACHMENT

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Technical Review of the Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters EPA-822-B-01-003 (October 2001)

Introduction

Most estuarine waters are moderately to severely polluted by excessive nutrients (Bricker et. al., 1999). In addition, a summary of the 1998 State 303(d) lists reports nutrients as one of the top 3 pollutants in the country. Therefore, the need for nutrient criteria is warranted in order to improve the quality of the Nation's waterbodies. Although these conditions exist, the development of nutrient criteria must follow a consistent, logical development method aimed at defensibly linking cause and effect relationships. Nutrient effects may not be as straight forward as those for toxic pollutants (e.g., mortality, growth or reproduction inhibition) and for this reason criteria development may not be the solution but rather a target level that triggers further study into effects and potential limitations to beneficial uses.

The current development of nutrient criteria is aimed at abating human caused eutrophication (anthropogenic sources) in estuarine and coastal marine waters. Natural background levels are not subject to nutrient management but constitute a critical component of the proposed criteria as they relate to the setting of reference conditions. That is, "the criterion developed for each variable should reflect the optimal nutrient condition for the waterbody in the absence of cultural impacts and protect the designated use of that waterbody". This definition of natural background or reference condition is the one of the most critical components of the proposed criteria development process. What constitutes "minimal" human influence or the "absence of cultural impacts" in estuaries or coastal marine waters is directly related to the current or anticipated condition of our coastal watersheds. In addition, determination of the "optimal nutrient condition" will require the determination of the cause and effect relationships between nutrients and endpoints, with the endpoints used as the basis for setting nutrient criteria.

As stated in the document, "coastal counties account for only 17% of the US landmass, but their population exceeds 141 million. Thus, more than half of the Nation's population lives in less than one-fifth of the total area, and this trend is expected to grow". In addition, estuaries and coastal marine waters are the most downstream receiving waters for all inland watersheds in the Nation and, therefore, assimilate nutrient inputs from a much larger population and landmass. These facts, coupled with the desire to "abate human-caused eutrophication" to levels representing the "absence of cultural impacts" should highlight the need to proceed judiciously in establishing nutrient criteria for estuarine and coastal marine waters.

Throughout the document the uniqueness of estuaries and their complex physical, chemical and biological nature are highlighted indicating that regional criteria may not be possible and that site-specific criteria may be necessary. This is clearly stated in the document as follows:

> "The best possible understanding of the physical, chemical, and biological interrelationships in the environment is important in nutrient criteria development and the

> subsequent management response. However, effective nutrient criteria can and should be developed even in the absence of an in-depth scientific investigation of the ecological processing of nutrients in the estuarine and marine environment."

This statement along with the stated purpose of the document ("to provide scientifically defensible technical guidance … in developing nutrient criteria") highlights the difficulty in developing nutrient criteria in a scientifically credible manner. In addition, the document points out that it is difficult to distinguish between the effects of anthropogenic nutrient enrichment and natural variability due to the complex physical, chemical and biological processes present in estuarine and coastal marine waterbodies.

Criteria Development

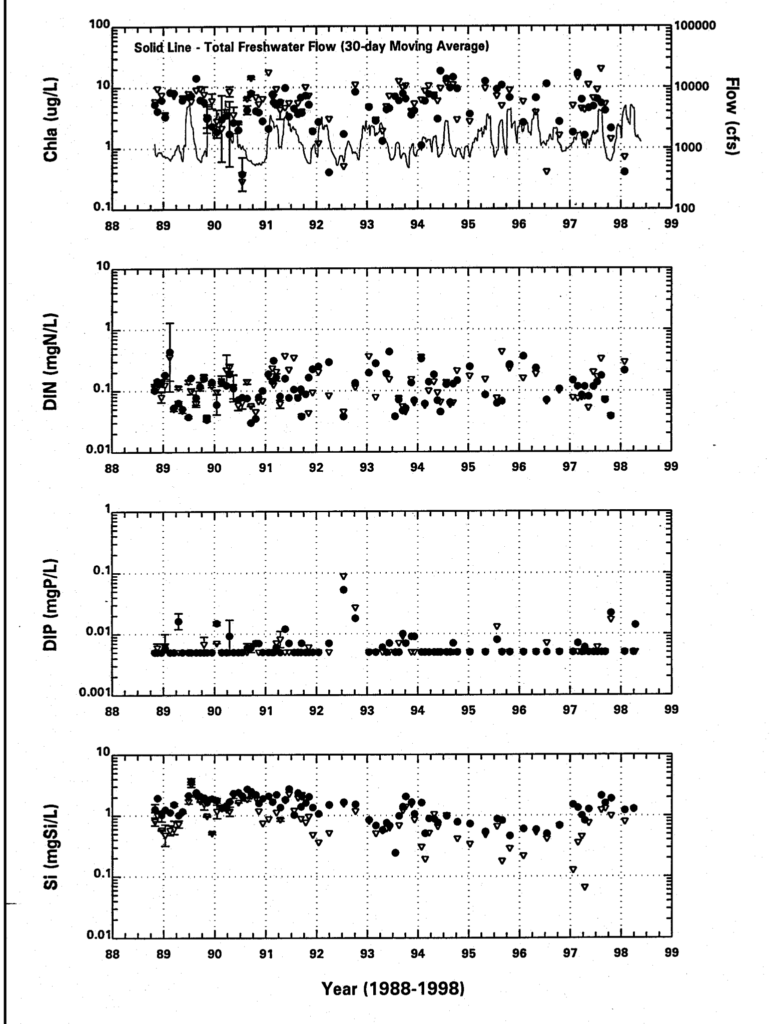
The proposed criteria development process uses two causal variables (TN and TP) and two response variables (chlorophyll-a and some measure of water clarity). Secondary response variables are also suggested for use and include dissolved oxygen (DO) and macrophyte growth and/or density, where these are considered important. Since cause and effect relationships between nutrients and endpoints is a complicated issue in estuarine and coastal marine waters, use of both causal and response variables will "yield the most definitive and comprehensive criteria". This is a valid statement but due to the complexity of these nutrient relationships, nutrient targets or action levels may be a more realistic method of mitigating nutrient loads. This approach can allow for the setting of nutrient targets that protect designated uses ("decision making benchmarks for management planning") based on effects in the waterbody. It can also inherently build in a more complete analysis of nutrient effects (e.g., chlorophyll-a or DO levels) if nutrient targets are not obtained that allows for proper consideration of the individualistic nature of estuaries and coastal marine systems.

Without the determination of the assimilative capacity or of the effects on biology (as supported by Section 304(a) of the Clean Water Act), realistic nutrient criteria aimed at protecting designated uses may not be achieved. Since effects based criteria can be developed without knowing the reference condition of the waterbody but setting reference conditions will require knowledge of the assimilative capacity, the criteria development process should logically proceed directly to effects based criteria. The determination of effects on a site-specific basis is needed to properly relate nutrient inputs to the protection of designated uses, which is the ultimate goal in developing nutrient criteria. Designated uses cannot be assessed based on nutrient levels because they do not relate to endpoints and they are not the perceived condition of a waterbody. It is the effect of nutrient enrichment (excessive algal growth, low DO, fish kills, etc.) that is the perceived condition (designated use) that should be the focus of criteria development in order for the public or local stakeholders to benefit.

Monitoring & Data

The guidance document presents a discussion of analytical techniques for the measurement of the various forms of nitrogen and phosphorus for use in developing monitoring plans and setting nutrient criteria. Detection limit problems can cause problems in analyzing monitoring data and also when completing water quality modeling studies of eutrophication in estuarine or coastal marine systems. That is, a detection limit (DL) that is too high will not allow the analyst to confidently determine actual nutrient levels in a waterbody, which can affect the determination of cause and effect relationships between nutrients and endpoints.

This problem is presented in the figure below for Perdido Bay (FL), which is located along the Gulf of Mexico on the Alabama/Florida state line. The water quality data presented includes chlorophyll-a, dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP) and silica data for a station located in the middle of the bay for the 10-year time period from 1988 to 1998. For much of the DIP record the measured levels are at the DL of 0.005 mgP/L and, therefore, create a problem when attempting to analyze the data for the limiting nutrient or cause and effects relationships between nutrients and endpoints (chlorophyll-a and DO). More recent measurements in the bay have utilized an analytical technique with a lower DL and this data has indicated DIP levels as low as 0.002 mgP/L. Many historical databases may experience similar DL limitations and subsequent data analyses and modeling completed during the criteria development process should keep this potential limitation in mind.



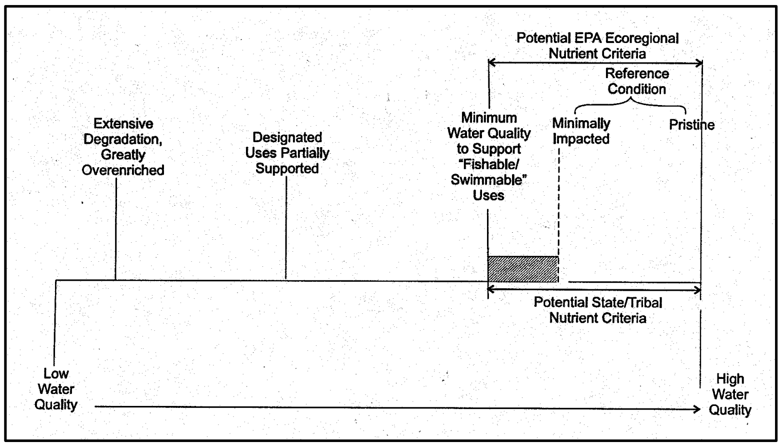
Perdido Bay Stations 31 & 32 Chlorophyll and Nutrient Data
(Filled Circle - Surface, Open Triangle - Bottom)

Another issue raised in the document is potential data sources to be used during the criteria development process. A number of excellent data sources are presented that include databases from the USEPA, NOAA, sanitation districts, academics and literature, and volunteer monitoring programs. It should also be noted that many estuarine and coastal marine databases exist as developed and maintained by numerous private corporations as required through NPDES permits or permitting activities. The data presented in the figure is an example of a database developed and maintained by a private corporate entity.

The development of proper sampling protocols is also discussed and one critical item deserves to be noted. Many sampling plans (whether for lakes, rivers or estuaries) are initially developed to assess water quality conditions for State water quality assessments, 303(d) listing, permit compliance issues and for a host of other reasons. Given the assessment nature of the sampling protocols, many databases were not focused on providing information for potential modeling studies of the waterbody. This may cause many databases to sometimes fall short of providing the necessary information for completing a reasonable modeling study of the waterbody. Future monitoring efforts should keep water quality modeling needs in mind when designing sampling protocols. Such issues to be aware of may include:

- Station location (longitudinal, lateral and vertical placement);
- Parameters of interest (e.g., nutrients, chlorophyll-a, salinity, temperature, DO, water clarity, light attenuation, solar radiation, wind speed and direction, boundary condition quality, tidal stage and currents); and
- Special studies (e.g., sediment oxygen demand (SOD), light and dark bottle, reaeration and time of travel, long term BOD, settling and resuspension).

Reference Conditions

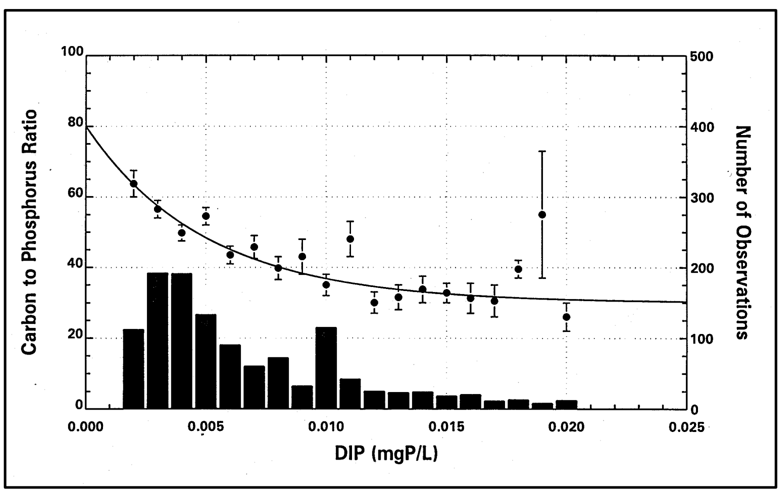


One component of the proposed nutrient criteria is the identification of a reference condition for determining acceptable nutrient levels. As defined in the document, “a reference condition is the comprehensive representation of data from several similar, minimally impacted, ‘natural’ sites on a waterbody or from within a similar class of waterbodies”. This concept is presented in the document as reproduced in the figure above. It should be noted that this figure identifies “fishable/swimmable” uses as a potential endpoint for determining nutrient criteria but other beneficial uses must be included such as drinking water uses. The potential reference condition nutrient levels may range from pristine (“precolonial period”) levels to minimum water quality levels needed to support designated beneficial uses. There is an acknowledgment that this pristine condition is a hypothetical ideal but not because it is unrealistic given today’s current coastal population and land-use but because the methods required to estimate this condition “contain a high degree of uncertainty”.

This understanding that pristine conditions are unattainable given current conditions and the statement that designated beneficial uses are a common water quality goal is a good approach to defining reference conditions for estuarine and coastal marine waterbodies. It seems that consideration of the desired attainment level is wise considering the physical uniqueness and complex cause and effect relationships between nutrients and endpoints in estuarine and coastal marine waterbodies. This figure implies that the designated uses or level of degradation must be determined prior to setting the reference condition. That is, the assimilative capacity of the waterbody needs to be determined that relates nutrient inputs/levels to observable and reproducible effects on specific endpoints. The figure above represents this concept as the shaded region. That is, the assimilative capacity can be defined as the difference between nutrient levels required to maintain the designated beneficial use and those identified for a minimally impacted state. With the determination of assimilative capacity completed, an appropriate reference condition can then be established. Granted the definition of designated beneficial uses or attainment level may be open to debate, there are regulatory processes for defining designated uses of a waterbody. Use Attainability Analyses (UAA) allow for the review and analysis of current water quality conditions for determining what level of designated uses can be achieved given realistic management measures. Inherent in the UAA process is the need to establish effects based criteria as a function of uses or in other words, nutrient relationships to uses need to be determined. At least consideration of designated uses or the completion of UAAs will allow for the impacted communities or stakeholders to be involved in the process early on so that concerns can be discussed and resolved in the nutrient criteria development process.

The document outlines five approaches to establishing reference conditions based on the degree of estuarine or coastal marine degradation. There are two main estuarine approaches and one for coastal marine waters that utilize either data analysis or some form of modeling to assist in defining the reference condition. As with the other guidance documents (lakes and reservoirs or rivers and streams), the data analysis approach uses frequency distributions whether for unimpacted or degraded waterbodies. Inherently this approach does not consider cause and effect relationships between nutrients and endpoints, whether chlorophyll-a and DO levels, submerged aquatic vegetation (SAV) loss, species shifts, or fish kills. It also implies that a predetermined percentage of waterbodies will not meet the nutrient criteria regardless of the assimilative capacity or actual nutrient effects in the waterbody. In effect, designated uses may or may not be attained using this procedure.

The modeling approaches use some form of watershed loading analysis or receiving water modeling to relate nutrient loading to instream effects or concentrations, in essence to determine the assimilative capacity of the waterbody. This latter approach is more similar to modern criteria development (e.g., toxic pollutants) in that there can be a reasonable attempt to link nutrient loads with effects in the receiving water body. Prerequisite to this approach (for the watershed and receiving water models) is that the applied models are calibrated/validated to some degree of accuracy in order to minimize uncertainty in model projections (or hind-casts) to determine reference conditions for the estuary or coastal marine waterbody.

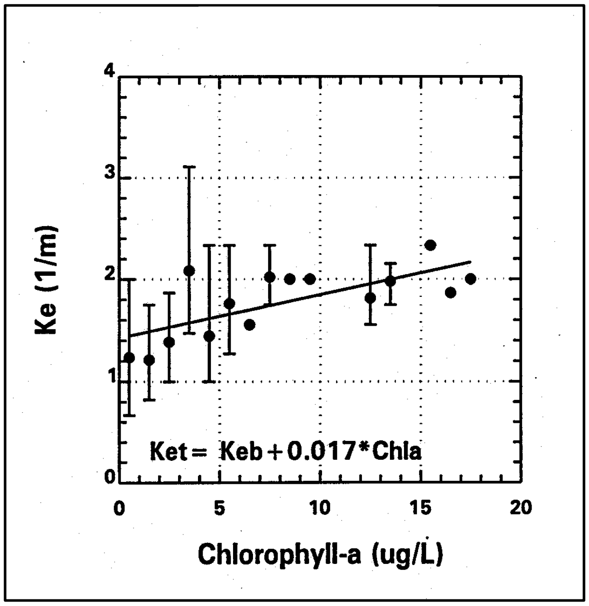


Although the approaches to developing reference conditions are outlined in a somewhat quantitative manner, there still is a considerable amount of professional judgement involved. This is primarily due to the fact that estuaries and coastal marine waterbodies are complicated environmental systems. Physical water advection and dispersion (mixing) is a function of freshwater flow; tides; meteorology (wind, atmospheric heat exchange); and density gradients due to salinity and temperature. Water quality dynamics may be even more complicated due to nutrient transformations; algal nutrient uptake and recycle; dissolved oxygen interactions with the atmosphere, oxygen demands (carbon, nitrogen, SOD), algal oxygen production and respiration; water clarity associated with detritus (TSS) and algae; settling and resuspension; and meteorological effects such as wind and solar radiation.

The nutrient storage and recycling capacity of estuarine sediments can be a large nutrient load that derives its source from settling in-situ algae and organic matter derived from upland terrestrial sources. Algal nutrient stoichiometry (algal nutrient requirements for growth) can also change as a function of ambient nutrient levels (variable stoichiometry). That is, as nutrient levels decrease algal nutrient needs can decrease (adapt) to allow maintenance of the algal population during periods of nutrient stress (decreasing P/C ratios). This concept is presented in the figure above for C/P ratios as a function of DIP levels. Conversely, algal nutrient requirements increase to approximate Redfield ratios when nutrients are in surplus, which is sometimes referred to as "luxury" algal nutrient uptake. Also, carbon to chlorophyll-a ratios can change as a function of ambient light limitations as do they change for the various species of algae present in estuarine and coastal marine waterbodies.

Further complication exists if assessing living resources such as SAV growth and abundance, bivalve survival and mortality, fish populations and other endpoints that are meaningful to the local stakeholders involved. These complexities coupled with the somewhat qualitative professional judgment involved in the criteria development process will be sure to cause some inconsistencies in the setting of nutrient criteria in estuarine and coastal marine waterbodies.

Water Clarity



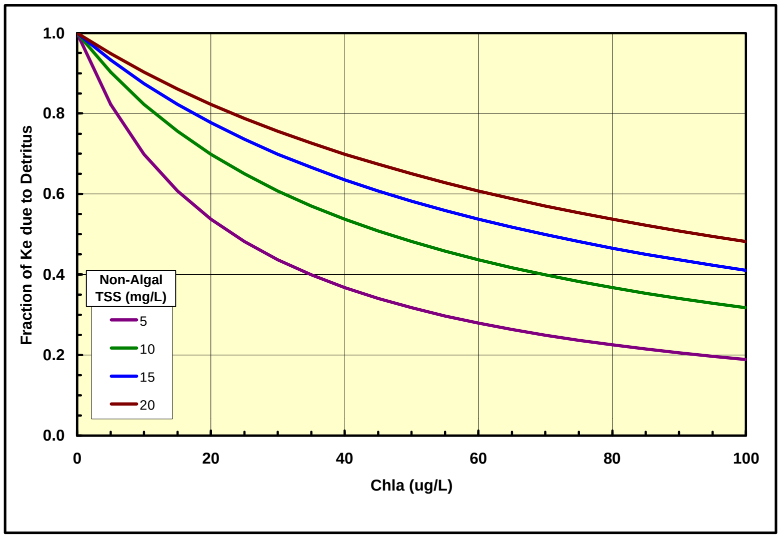
One of the response variables identified in the document is water clarity but primarily only as affected by the algal component of light attenuation. As identified in the document, light attenuation due to non-algal components such as "color from humic-like materials may significantly compete with particulate material" in estuaries. Many algal populations in estuaries are potentially light limited due to high turbidity as opposed to higher saline and coastal marine waters, which tend to be less turbid and, therefore, less light limited. Light extinction data from Pensacola Bay (FL) is presented in the figure below as a function of chlorophyll-a levels and highlights the high background light extinction (1.4/m) due to factors other than algae such as inorganic suspended solids derived from terrestrial runoff. A theoretical and empirical relationship developed by DiToro (1978) relates light extinction to non-algal (inorganic) detritus and algae with the following equation:

$$K_e = 0.052 * NVSS + 0.174 * VSS + 0.031 * Chla$$

where: K_e – light extinction coefficient (1/m);
NVSS – non-volatile inorganic solids (mg/L);

VSS – volatile inorganic solids (mg/L); and
Chla – chlorophyll-a (μg/L).

This relationship is used in the figure below to present the portion of the total light extinction due to inorganic suspended solids as a function of chlorophyll-a. For a system with an inorganic TSS level of 10 mg/L and a chlorophyll-a level of 20 μg/L, approximately 70% of the total light extinction is due to the inorganic solids and not until chlorophyll-a levels are greater than 50 μg/L is the total light extinction due equally to inorganic solids and chlorophyll-a.



There are three major factors affecting algal growth in natural waters systems: nutrients, residence time and light levels. In estuaries, the interplay of these three variables makes cause and effect relationships difficult to quantify with general approximations. The compounding effect of terrestrial derived inorganic suspended solids on light extinction, not to mention the resuspension of in place sediments, again highlights the complexity of estuaries and the need to carefully consider the development of nutrient criteria.

Modeling Tools

"Models of estuarine susceptibility to nutrient over enrichment are at an early stage of development, and even less may be known about coastal ecosystems" (page 6-1). To some extent this may be true but water quality models of eutrophication processes have been in use for over 20 years. For example, water quality modeling studies of Lake Ontario (1975,76,79), Lake Erie (1980), Potomac Estuary (1982) and Western Delta/Suisun Bay, CA (1981) have employed eutrophication models to analyze nutrient related phytoplankton dynamics and the associated effects on dissolved oxygen. More recently, eutrophication studies have included modern hydrodynamic models to account for the complex physical circulation patterns in estuaries such as Long Island Sound (NY/CT), Tar-Pamlico River (NC), Pensacola/Escambia Bay (FL) and Chesapeake Bay. These studies have also included sediment flux models for calculating internal sediment nutrient cycling and also models of SAV/seagrass growth and benthic bivalve biomass to assess living resources in these systems.

Although these modeling frameworks may require a large effort as it relates to budget, labor and time to complete, they do provide state-of-the-art tools for assessing nutrient related cause and effect relationships in estuarine and coastal marine waterbodies. The hydrodynamic component of these frameworks includes general estuarine and coastal marine circulation physics but can also include wind/wave driven circulation and sediment transport models for assessing settling and resuspension dynamics. The water quality component includes eutrophication kinetics with coupled sediment flux models for calculating SOD and nutrient flux as a function of delivered organic matter. They can also include living resource models of SAV/seagrass and benthic bivalves in order to provide potentially more meaningful endpoints for stakeholders, as opposed to chlorophyll-a or dissolved oxygen levels that may be more obscure to relate the needs or desires of the communities involved. As the state of estuarine science increases to an understanding of more detailed estuarine water quality dynamics (e.g., harmful algal blooms (HAB), algal species composition and competition, secondary effects of nutrient enrichment), these processes can then be quantified into modern estuarine models to allow calculation of how nutrient enrichment relates to these processes in the context of nutrient management.

Other modeling tools (as nicely presented in the document) that may also provide valuable information to assess nutrient related cause and effect relationships involve coupling a simplified circulation model (Pritchard two-layered box model) with a eutrophication model of varying complexity. The Pritchard two-layered box model derives laterally and tidally averaged, steady-state, two-layered estuarine circulation patterns based on measured salinity and freshwater flows. This method has been applied in a number of estuarine WLAs but is limited to relatively long and narrow estuaries where vertical salinity and temperature gradients produce stratification. The resulting two-layered transport field (seaward surface flows, landward bottom flows, vertical flows and dispersions) can then be coupled with a eutrophication model to assess nutrient, chlorophyll-a and dissolved oxygen levels due to nutrient management strategies. The limitation to this approach is that the conditions analyzed are based on a steady-state distribution of salinity, typically chosen as a relatively stable low-flow, summertime condition. Granted this time period is typically when estuarine susceptibility is the greatest, ultimately questions will be asked as to what water quality conditions would be like if freshwater flow and meteorology were different and also what water quality would be like in more localized areas of the study area that were lumped into the lateral segmentation of the estuary.

As with any modeling exercise, the results of the model are only as good as the model calibration/validation. It needs to be stressed that valid calibration/validation of these models is necessary for their proper use in determining nutrient management measures in coastal watersheds. The calibration/validation of a model should combine both qualitative assessments with numerical/statistical comparisons of model and data in order for a robust, well tested model to be developed. There is already inherent uncertainty in any model due to the approximations that must be made to analyze the natural environment and, therefore, a well calibrated/validated model is critical in minimizing uncertainty in model calculations, especially when using the model for assessing nutrient management questions. As clearly stated in the document, “how a model is used is more important to its success than exactly which model is used”.

As with all numerical models, they are only as good as the underlying framework or scientific understanding of the processes to be included in the models. As the science improves and incorporates new concepts of estuarine dynamics (HABs, species competition, living resources), these ideas can be formulated into the existing models to improve their predictive capability to nutrient related endpoints that are more closely associated with the coastal communities the criteria are intended to protect.