Delaware River & Delaware Estuary
Nutrient Criteria Plan

(ver. 1.02 - May 2013)

Delaware River Basin Commission

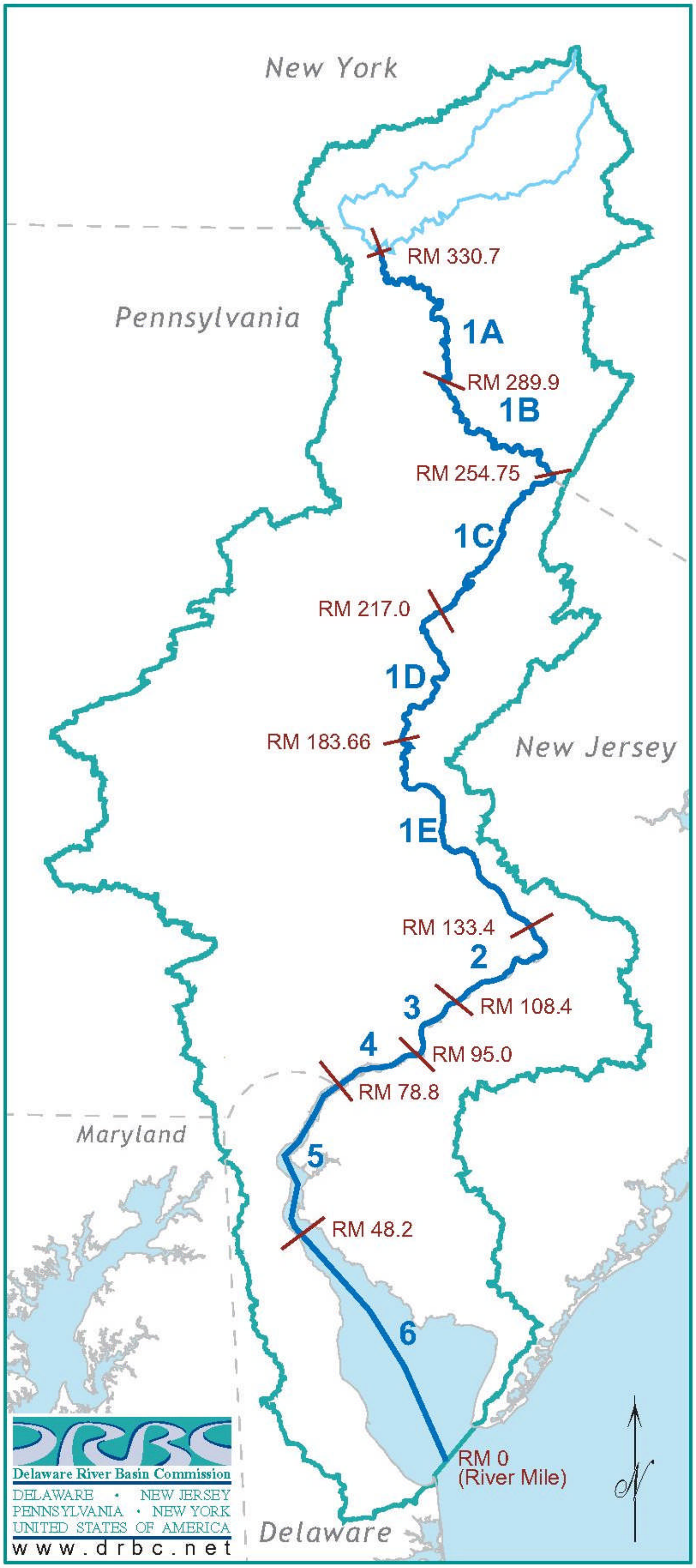
DELAWARE · NEW JERSEY
PENNSYLVANIA · NEW YORK
UNITED STATES OF AMERICA

Executive Summary

This Nutrient Criteria Plan lays out the specific tasks that will be conducted by the Delaware River Basin Commission and its partners over the course of the coming years to evaluate and implement nutrient or nutrient-related criteria for the shared waters of the Delaware River. The Nutrient Criteria Plan is broken into two parts, recognizing the unique ecosystems of the Delaware Estuary and those of the Delaware River above the head-of-tide, while also acknowledging the unique challenges in criteria development for each system.

For the Delaware Estuary, the plan proceeds along two parallel courses of near-term improvements to dissolved oxygen and long-term consideration of effects-based nutrient criteria. The near-term work on dissolved oxygen seeks to identify the highest attainable uses for the zones of the estuary where uses are below Clean Water Act goals, acknowledging additional on-going work to reconcile the designated uses with existing uses. For the Delaware River above the head-of-tide, the plan likewise recommends different courses for the nutrient-poor Upper and Middle Delaware River and the transition to higher nutrient waters in the Lower Delaware River. In particular, the gradient of increasing nutrient conditions in the Lower Delaware needs careful evaluation in the context of increasing data on important biological shifts for this region of the river. While this Nutrient Criteria Plan seeks to anticipate many of the challenges in the years ahead, DRBC acknowledges that this plan will likely evolve considerably throughout its implementation.

Figure 1. DRBC Water Quality Regulation Zones for the Delaware River and Delaware Estuary (river mileage at boundaries indicated)



Delaware River & Delaware Estuary Nutrient Criteria Plan

Introduction

One of the primary forms for human alteration of the biogeochemical cycles of freshwater and coastal ecosystems is the elevated loading of key plant nutrients, particularly nitrogen and phosphorus (Carpenter et al. 2011, Howarth et al. 2011). The extent of such alterations is so broad that elevated nutrients now constitute one of the nation's most widespread and pervasive forms of water pollution (Gilinsky et al. 2009).

With increasing recognition of nutrient increases and problems, the U.S. Environmental Protection Agency initiated a program in 1998 to identify the effects from nutrient alterations, to abate and perhaps reverse the increases in nutrients seen in many surface waters, and to restore the ecological integrity of those waters where excess or altered nutrient regimes were causing impairments to the structure and function of these biological systems (USEPA 1998, USEPA 2011). Central to these efforts is the development of numeric nutrient criteria in a manner consistent with the Clean Water Act.

The development of nutrient criteria for the 330 miles of boundary waters along the Delaware Bay, the Delaware Estuary, and the Delaware River to Hancock, NY, involves a coordinated effort among the Delaware River Basin Commission and the four states whose borders are defined by these interstate waters (DE-NJ, NJ-PA, and PA-NY borders, respectively). This effort comprises two separate initiatives to address the separate ecological systems along this border: (1) the tidal waters of the Delaware Estuary and Delaware Bay; and (2) the non-tidal riverine waters of the Delaware River. This Nutrient Criteria Plan describes the steps currently planned to develop and evaluate nutrient criteria options for these two systems in the coming years, and as such is intended to be a "living document" which evolves in response to early-stage results, resource allocations, and unanticipated developments.

Because of the distinct nature of nutrient criteria development for each of these two systems, the different conceptual approaches are broadly introduced at the beginning of Part 1 and Part 2 for the Delaware Estuary and Delaware River, respectively. Two additional on-going efforts by EPA and the states are worth highlighting in the context of nutrient criteria, however, before focusing on nutrient criteria development for these two parts of the Delaware River system.

The first effort involves EPA's revisions to the recommended aquatic life criteria for ammonia, which would update and address the toxic effects of ammonia to various species of aquatic animals. Draft documents from this process highlight the particular sensitivity to ammonia by freshwater mussels (family Unionidae), which are common in all freshwater settings of the Delaware River, both tidal and non-tidal. Any revision to ammonia criteria for the Delaware River could affect this nutrient criteria development in two ways. First, as a readily available form of nitrogen, ammonia is a key part of the nutrient regime for any surface water body. Second, and more importantly, ammonia serves as a key component in overall biochemical oxygen demand (BOD). In the Delaware Estuary, the discharge of high concentrations of ammonia by various point source facilities has been highlighted as a key driver in the persistent dissolved oxygen sag within the estuary. As a result, any criteria revision for ammonia could strongly influence dissolved oxygen conditions and criteria development, and vice versa. DRBC recognizes these links between ammonia criteria, BOD loading, and dissolved oxygen criteria and will coordinate criteria development among these efforts.

The second effort initiated by EPA relates more directly to nutrients and nutrient criteria efforts by states and EPA. In 2011, EPA affirmed its commitment to addressing water quality degradation via nutrient over-enrichment in a memo to its regional offices (USEPA 2011; often referred to as the "Stoner Memo" in recognition of its author, Acting Assistant Administrator Nancy K. Stoner). This memo, in particular, highlighted the need to begin nutrient reduction efforts in high-priority watersheds early in the process in order to both reduce the negative effects from nutrients and to facilitate the effective implementation of nutrient criteria. Such efforts may have a substantial influence on the long-term development of nutrient criteria for the Delaware River and the implementation of remedies for any areas identified as negatively impacted by elevated nutrient regimes. As a result, these joint state and federal efforts at nutrient reduction will influence the long-term trajectory of this Nutrient Criteria Plan.

Part 1. The Delaware Estuary: Trenton (RM 133) to the Atlantic Ocean (RM 0)

A. Overview & Conceptual Approach

Estuarine ecosystems vary greatly in the key drivers of system function, from hydrodynamics and stratification to patterns of salinity and water clarity. Because of these varied conditions and unique qualities, the development of nutrient criteria for estuaries necessarily becomes a system-specific endeavor where the particular effects of anthropogenic nutrient inputs are evaluated relative to key ecological endpoints and important estuarine resources (see Cloern 2001, USEPA 2001a). For the Delaware Estuary, this Nutrient Criteria Plan recognizes the unique form and function of the Delaware Estuary and therefore seeks to develop site-specific nutrient criteria and/or nutrient related criteria based on the particular settings within this estuary.

Among the challenges in developing nutrient criteria for the Delaware Estuary is first addressing and resolving the persistent dissolved oxygen depression within the urban corridor of the Delaware Estuary. Depressed dissolved oxygen is among the most ubiquitous and problematic outcomes from anthropogenic increases in nutrient loadings and concentrations (Diaz 2001, Bricker et al. 2007). For the Delaware Estuary, past and contemporary dissolved oxygen problems have been linked most strongly to direct loading of oxygen-demanding compounds (i.e., BOD), both carbon-based and nitrogen-based (FWPCA 1966, HydroQual 1998). Because of these persistent dissolved oxygen issues related to BOD loading, and the key role that dissolved oxygen plays in evaluating the direct and indirect effects of elevated nutrient loading, this Nutrient Criteria Plan also recognizes a need to initially address the persistent BOD depression of dissolved oxygen and to seek a Highest Attainable Use designation, with associated dissolved oxygen criteria, for zones of the Delaware Estuary currently below Clean Water Act goals. As a result, dissolved oxygen issues in the estuary will need to be addressed in the immediate future as well as long-term within the context of this Nutrient Criteria Plan.

For the Delaware Estuary, work on nutrient criteria and nutrient-related criteria will therefore be divided into two interrelated and parallel tracks. The first will address dissolved oxygen directly, particularly the direct effects on oxygen from BOD loading, and will include an evaluation of the uses currently falling below Clean Water Act goals. Outcomes from this first track may include revised “use” designations for portions of the estuary and appropriate dissolved oxygen criteria revisions to support those uses. The second track will more comprehensively evaluate the site-specific effects of nutrient loading into the Delaware Estuary on the ecology and ecosystem health of the estuary, including indirect effects of nutrient loading on dissolved oxygen. Outcomes from this second track may include nutrient criteria and/or nutrient related criteria that support the designated uses of the Delaware Estuary.

B. Highest Attainable Uses for the Delaware Estuary & Revised Dissolved Oxygen Criteria

The Delaware Estuary has undergone a long history of severe pollution, with many past and on-going implications of this heavy human influence on the water quality and the biology of this estuary (Kiry 1974, Albert 1988, Sharp 2010). Among the legacies from this period of severe pollution are aquatic life "use" designations and dissolved oxygen criteria for parts of the estuary that are below those articulated in the Clean Water Act (often referred to as the "fishable" goal of Section 101(a)(2) in the act; 33 U.S.C. 1251 *et seq.*). Specifically, for Zones 3, 4, and the upper portion of Zone 5 (29% of the estuary's length from River Mile [RM] 70 to RM 108.4; see Figure 1 for zone boundaries), the aquatic life use designation includes only "maintenance of resident fish and other aquatic life" rather than the broader "maintenance and propagation" of fish and other aquatic life that is both consistent with Section 101(a)(2) of the Clean Water Act and which applies in all other mainstem Delaware River zones (tidal and non-tidal, freshwater and saltwater; DRBC 2010)[1]. Because of this more limited "maintenance" only use for over a quarter of the estuary's length, the dissolved oxygen criteria in these zones are below recommended and state-adopted standards for such water body types (USEPA 1986, N.J.A.C. 7:9B-1.14(d), 25 PA Code § 93.7(a), 7 DE Admin. Code 7401-4.5.2). Moreover, actual dissolved oxygen concentrations within these zones of the estuary can frequently dip into potentially stressful levels, precluding full attainment of the 101(a)(2) goals for the Delaware Estuary (DRBC 2012, PDE 2012).

Because of the critical role dissolved oxygen plays in both the health of aquatic ecosystems and the development of nutrient criteria, this combination of lower aquatic life uses, lower dissolved oxygen criteria, and depressed dissolved oxygen concentrations for a large portion of the estuary precludes meaningful evaluation of whether the current loadings and concentrations of nutrients in the Delaware Estuary are a causative agent in poor ecosystem health. As a result, a comprehensive strategy to address nutrient criteria for the Delaware Estuary will require an initial effort to resolve (to the extent resolution is attainable) the persistent dissolved oxygen sag for the estuary and redefine both the uses and the dissolved oxygen criteria to their highest

[1] Propagation by some estuarine species may be occurring in these zones where the designated use does not include propagation; separate efforts are underway to reconcile the designated uses within the estuary to the existing uses that may be higher than the designated uses.

possible levels. In particular, the process of evaluating a designated use and determining what is technologically and economically achievable in terms of improved "uses" of a water body has been termed the Highest Attainable Use process by the EPA. The first track for the Delaware Estuary thus requires a rigorous evaluation of what is attainable both in terms of dissolved oxygen regimes and in terms of aquatic life support.

An important consideration for the estuary in this evaluation is the possibility that full attainment of the Clean Water Act 101(a)(2) goals may be possible within the near future. Indeed, recent data suggest some degree of reproduction and juvenile rearing for some fish species within these degraded zones of the estuary, and DRBC is engaged in a process to reconcile the designated uses for these zones with the expanded existing uses (see footnote above). As a result, although the terms "highest attainable use" and "use attainability" typically refer to the water quality standards process wherein designated uses are set below the Clean Water Act goals, this Nutrient Criteria Plan explicitly acknowledges that both designated uses attaining as well as designated uses falling below the aquatic life use goals of the Clean Water Act will be considered and evaluated during the proposed Highest Attainable Use process identified herein.

In addition to resolving long-standing issues with dissolved oxygen, this attainability process further serves as the core foundation for future criteria development efforts in the Delaware Estuary. Currently, it is not clear how protective any nutrient or nutrient-related criteria would need to be, whether to protect to the lower "maintenance" only use, or to protect for full aquatic life use, or to something in between. Under reduced uses, such as those established for zones 3, 4, and parts of 5 since 1967, more lenient and less protective nutrient or nutrient-related criteria could be possible. Under full aquatic life use goals, nutrient or nutrient-related criteria would have to support a healthy and balanced ecology within these zones of the estuary. Thus, without completion of the attainability process, the goals on any nutrient criteria development efforts would remain poorly defined and could become contentious. For both the near-term restoration of dissolved oxygen in the estuary and for the long-term process of developing nutrient criteria, this first track to establish the highest attainable use will therefore be a vital first step in this Nutrient Criteria Plan.

The following outlines the anticipated steps needed to evaluate dissolved oxygen dynamics in the estuary and the process of establishing and implementing the Highest Attainable Use. Table 1 provides a timeline for these tasks.

Task E-1.a Develop Estuary Eutrophication Models

One or more models are needed to accurately capture both the hydrodynamics of the estuary as well as the water quality interactions that control dissolved oxygen concentrations. Using a Modeling Expert Panel to help guide model selection and development, DRBC staff will develop these models for implementation in-house. A number of the key tasks toward model development will require additional financial support:

- model calibration, including ambient data collection
- tributary data collection
- technical support

Task E-1.b Evaluate Relative Source Contributions to Dissolved Oxygen Sag

The models developed in Task E-1.a will be used to determine the relative roles of the major drivers of dissolved oxygen dynamics in the estuary. These major drivers are expected to include, but may not be limited to, the following: point source and non-point source loading of CBOD and NBOD; phytoplankton production and respiration; SAV production and respiration; sediment oxygen demand; and combined sewer overflow (CSO) direct and indirect effects.

Sub-Tasks:

- compile and assess point source monitoring data
- assess data on tributaries and model boundaries; collect additional data where needed
- assess non-point source loading data

Task E-1.c Utilize Expert Panel to Identify Incremental Biological Benefits to Increases in Dissolved Oxygen Conditions

Although multiple dissolved oxygen criteria recommendations exist (e.g., USEPA 1986, USEPA 2000a, USEPA 2003), the Highest Attainable Use process will require a synthesis of the existing literature and existing criteria documents to specify the biological benefit for each increment (e.g., 0.5 mg/L increase) in dissolved oxygen restoration for the Delaware Estuary. Such a synthesis will be critical for the cost-benefit evaluation to determine the final policy recommendations and regulation revisions. To accomplish this task, DRBC will convene a Dissolved Oxygen Expert Panel consisting of a small group of biologists with expertise in the dissolved oxygen requirements of different estuarine species. This expert panel will review the relevant literature and provide a readily-accessible summary of the ecological benefits to different levels of dissolved oxygen restoration in the Delaware Estuary.

Task E-1.d Explore Scenarios to Remediate Dissolved Oxygen Sag

Combining the results of Tasks E-1.b and E-1.c, and utilizing the estuary models, DRBC will evaluate whether dissolved oxygen conditions can be improved in the estuary, and to what extent, by remediating both individual and combinations of the main causes of the dissolved oxygen sag. In particular, DRBC will evaluate whether each of the incremental dissolved oxygen steps evaluated in Task E-1.c can be achieved by one or more remedial activities. Because many permutations of management actions could achieve similar dissolved oxygen outcomes, DRBC expects the range of options explored through this process will be developed through advisory committee sessions and through discussions with key stakeholders.

Task E-1.e Evaluate Technical and Economic Feasibility of Attaining Candidate Uses & Criteria

DRBC will evaluate the technical and economic feasibility of implementing one or more of the remediation steps identified in Task E-1.d. Both the technical and the economic analyses required for this task will require partnerships with other state and federal agencies, drawing on their background and specialization in these areas to evaluate the attainability of multiple alternatives. Like the previous task, this will involve significant input and guidance from advisory committees and from estuary stakeholders.

Task E-1.f Recommend Revisions to Regulations ("Uses" and Criteria) for Highest Attainable Uses & Associated Criteria

To the extent that higher "uses" are attainable, and working through the Water Quality Advisory Committee, DRBC will propose revised regulations to the estuary "use" designations with attendant revisions to the dissolved oxygen criteria that both support those revised uses and which have been shown to be attainable. The revisions to DRBC regulation may involve either re-allocation of CBOD or an allocation of BOD or NBOD if the results from earlier modeling efforts are confirmed. An alternative approach is to use the integrated assessment process under Section 303(d) of the Clean Water Act.

Table 1. Estuary Tasks & Timelines Associated with Initial Dissolved Oxygen Track

Task	Description	Completion Goal*
E-1.a	Develop Estuary Eutrophication Models	June 2015
E-1.b	Evaluate Relative Source Contributions to Dissolved Oxygen Sag	June 2016
E-1.c	Utilize Expert Panel to Identify Incremental Biological Benefits to Increases in Dissolved Oxygen Conditions	June 2016
E-1.d	Explore Scenarios to Remediate Dissolved Oxygen Sag	January 2017
E-1.e	Evaluate Technical and Economic Feasibility of Attaining Candidate Uses & Criteria	June 2017
E-1.f	Recommend Revisions to Regulations ("Uses" and Criteria) for Highest Attainable Uses & Associated Criteria	January 2018

* - all dates are targets based on available resources and staff workloads; dates subject to change

C. Effects-Based Nutrient Criteria for the Delaware Estuary

Elevated nutrient loading and concentrations have long been recognized as components of the strong human influence in the Delaware Estuary (Jaworski 1981, Sharp et al. 2009). Yet hypoxia in the estuary has primarily resulted from direct BOD loading rather than nutrient stimulation of excessive primary production (see above). In addition, fish kills and harmful algal blooms are not typically associated with the Delaware Estuary (Bricker et al. 2007, USEPA 2007). Thus, the elevated nutrient regimes for the Delaware Estuary have not been linked to the worst possible hyper-eutrophic symptoms of such high nutrient loading.

Yet the Delaware Estuary is unequivocally recognized as a high-nutrient estuary, and evaluations of the estuary's health routinely demonstrate moderate to strong signs of poor condition. These include degraded assemblages of benthic invertebrates (Hartwell and Hameedi 2006, Hartwell et al. 2011, USEPA 2007, USEPA 2012) and high algal biomass in spite of large areas of low water clarity (Pennock 1985, Pennock and Sharp 1994, Bricker et al. 2007). As a result, nutrients have been linked to this poor ecological condition and are among the primary stressors acknowledged within the estuary (USEPA 2007, Ianuzzi et al. 2009, PDE 2012). The specific pathways for nutrient effects, and their causative links to ecological condition, have not been well-established for the Delaware Estuary. Moreover, the spatial and temporal scales of elevated nutrients closely match those of other stressors, limiting scientists' ability to separate nutrient effects from the effects of these other factors. As a result, isolating the effects of the elevated nutrient regime on the aquatic life within the estuary will be a significant challenge, and likely more difficult that similar estuaries within the region. The tasks and the timelines for effects-based nutrient criteria in the Delaware Estuary, therefore, will be more broadly defined and will extend far into the foreseeable future.

Among the challenges for understanding the fate and effects of the elevated nutrient loading in the Delaware Estuary is an absence of an integrated biological assessment for the estuary. Historically, efforts to understand the status or condition of species or groups of species in the estuary have focused primarily on species of economic importance. Such key species from a human perspective have included shellfish (particularly oysters & blue crabs) and finfish (e.g., shad, striped bass, weakfish). The long time-series of data collected through the DRBC and DNREC "Boat Run" surveys has included selected summary indicators of the ecological condition (e.g., algal biomass, primary production) rather than detailed measures of the biological system. Recent efforts, however, have begun to examine a broader array of estuarine species and species assemblages. Both EPA and NOAA have included the Delaware Estuary in regional efforts to assess the status of estuaries, with ecological endpoints such as benthic invertebrates and sediment toxicity included in the overall assessments (Hartwell and Hameedi 2006, USEPA 2007). Similarly, the Partnership for the Delaware Estuary (PDE) has conducted intensive surveys of benthic invertebrates (2008 DEBI project), freshwater mussels (begun in 2010), and tidal wetlands. EPA's Region 3 (Philadelphia) office has also begun studying the distribution and abundance of submerged aquatic vegetation (SAV) in the freshwater zones of the estuary.

These recent efforts, however, have not been designed to assess the full direct and indirect effects of elevated nutrients on the Delaware Estuary and the varied suites of species and habitats represented in the estuary. As a result, they provide a starting point for understanding the current ecological conditions in the estuary, but do not provide the necessary information to assess whether elevated nutrients are causing negative ecological effects. In order to understand the status of the estuary, and any effects from elevated nutrients, a targeted and integrated program of ecological measurements will be needed. Such a program may draw heavily on existing efforts to measure different biological components of the estuary (e.g., fishery resources, freshwater mussels) but will likely need, at minimum, supplementary data collection in order to complement the existing efforts.

The following steps summarize the expected process of assessing the ecological health of the Delaware Estuary, identifying the effects from elevated nutrient regimes, and selecting appropriate nutrient or nutrient-related criteria for the estuary.

Task E-2.a Summarize Prior Studies on Ecological Endpoints

Prior to identifying ecological endpoints for use in nutrient criteria, DRBC staff will collate and summarize relevant ecological and water quality studies for the Delaware Estuary to identify what work has been done, what work is on-going, and where gaps exist in our understanding of the estuary's ecology. A number of similar syntheses have been completed recently, including the Technical Report for the Delaware Estuary and River Basin (PDE 2012) and an ecological summary for the DuPont-funded stressor study (BBL 2006). While these syntheses will greatly assist in this task, the questions addressed in this current evaluation will focus on evaluating the need for new or expanded assessments of the Delaware Estuary's ecological health.

Task E-2.b Identify Specific Ecological Endpoints for Nutrient Criteria Process

Based on the results from the ecological summary, DRBC will work with partners and stakeholders in the estuary to identify the most relevant ecological endpoints for both assessing the health of the estuary and for developing nutrient or nutrient-related criteria. While an ideal and comprehensive program would monitor and assess all of the key ecological endpoint and vital ecosystem functions in the estuary, the DRBC recognizes that limited resources will mandate a strategic program to identify the highest priority and most informative ecological endpoints for assessment. DRBC further recognizes the wealth of expertise and knowledge about the estuary throughout the stakeholder community and expects this community to greatly inform and be integral to the process of endpoint identification.

Task E-2.c Initiate Monitoring for Under-Assessed Ecological Endpoints

Given the complexity of habitats, salinity regimes, and resulting ecological settings across the Delaware Estuary, DRBC expects that multiple ecosystem components will need to be assessed in order to adequately evaluate the role of elevated nutrient regimes on the health of the Delaware Estuary. One or more of these endpoints may be partly or completely included in the monitoring currently underway within the estuary. These existing efforts will likely serve as key building blocks in the collective effort to understand and evaluate the current nutrient regime in the estuary. Yet additional efforts will also be needed to fill gaps in the existing programs, particularly for ecological endpoints identified in the prior task but for which little or no data exist. DRBC will consider the various approaches for monitoring these under-assessed endpoints, and will work with partner agencies and organizations to design a program that yields a minimally sufficient understanding of the estuary's ecological health, particularly with respect to the elevated nutrient regime.

Task E-2.d Assess Ecological Status & Role of Elevated Nutrients

Once the ecological endpoints for evaluation are agreed upon and sufficient data are collected for evaluation, the combined data sets will be used to make a detailed assessment of the ecological status of the Delaware Estuary. Isolating the effects from elevated nutrients on this ecological status will be challenging given the prevalence of multiple stressors in this densely populated and industrialized estuary with heavy shipping traffic and associated maintenance activities (see Ianuzzi et al. 2009). Special studies may be required to isolate any nutrient-induced effects or to estimate their magnitude, but the nature and scope of such studies cannot be anticipated at this time.

Task E-2.e Identify Nutrient Regime Supportive of Aquatic Life Uses

After assessing the role of nutrients (if any) in limiting the ecological health of the estuary, DRBC staff will seek to identify a nutrient regime for the Delaware Estuary which would support the integrity of the estuary's aquatic life and which would minimize any risks from elevated nutrient regimes. This process will likely include use of special studies and the use of water quality and/or ecological models to simulate the nutrient dynamics and the resulting ecological responses under altered nutrient regimes. Based on these evaluations, DRBC will identify one or more sets of nutrient regimes that would minimize negative ecological effects from nutrients and which would therefore fully support the aquatic life uses of the estuary.

Task E-2.f Propose Nutrient or Nutrient-Related Criteria

Working through the WQAC, DRBC will propose water quality criteria for nutrients or nutrient-related parameters that protect the ecological integrity of the Delaware Estuary.

Table 2. Estuary Tasks & Timelines Associated with Effects Based Criteria

Task	Description	Completion Goal*
E-2.a	Summarize Prior Studies on Ecological Endpoints	June 2014
E-2.b	Identify Specific Ecological Endpoints for Nutrient Criteria Process	December 2014
E-2.c	Initiate Monitoring for Under-Assessed Ecological Endpoints	June 2015
E-2.d	Assess Ecological Status & Role of Elevated Nutrients	March 2018
E-2.e	Identify Nutrient Regime Supportive of Aquatic Life Uses	March 2020
E-2.f	Propose Nutrient or Nutrient-Related Criteria	December 2021

* - all dates are targets based on available resources and staff workloads; dates subject to change

Part 2. The Delaware River: Hancock (RM 331) to Trenton (RM 133)

A. Overview & Conceptual Approach

The Delaware River above the head-of-tide has been characterized as one of the least-impacted and highest-quality large rivers in the mid-Atlantic and northeastern United States (Benke and Cushing 2005). In part because of the high water quality exhibited throughout the non-tidal river, the DRBC has included the entire non-tidal length within its anti-degradation policy known as Special Protection Waters (SPW; DRBC 2010). Unlike most anti-degradation programs, this SPW program sets numerical targets for the major nutrient parameters on both the mainstem and tributaries to the non-tidal river. Such numerical nutrient targets serve as proactive requirements during the permitting process for point source facilities, ensuring that treatment facilities are designed to prevent any measureable change to nutrient conditions and other water quality parameters at the specified mainstem and tributary locations. Thus, although traditional numeric nutrient criteria have not yet been adopted for the non-tidal Delaware River, a more proactive program that prevents substantive increases in nutrient conditions has been implemented for the Delaware River and this innovative program provides a powerful tool for maintaining both the water quality and the ecological health of the non-tidal Delaware River.

In spite of these anti-degradation protections, substantial changes in water quality occur within the most downstream section of the non-tidal Delaware River referred to as the Lower Delaware (most of Zone 1D and all of Zone 1E; RM 133 to RM 210; see Figure 1). In particular, total nitrogen and total phosphorus concentrations roughly double in the area leading up to and below the Lehigh River confluence (RM 184). Increasing evidence suggests that the water quality changes at or around the Lehigh River lead to a number of major shifts in the biological condition of the Delaware River, including loss of sensitive species, reductions in dominant filter feeder abundance, and broad changes in the macroinvertebrate community (Munch 1993, Brightbill et al. 2010, DRBC 2012, E.L. Silldorff & H.S. Galbraith *unpublished*).

Because of both the innovative anti-degradation program for the entire non-tidal Delaware River and the marked contrast in nutrient regimes within the Lower Delaware compared to the Upper Delaware (RM 255 to RM 331) and Middle Delaware (RM 210 to RM 255), this Nutrient Criteria Plan addresses nutrients in markedly different ways between the Middle/Upper and the Lower Delaware. For the Middle/Upper Delaware, DRBC's anti-degradation targets correspond closely to EPA's recommended criteria for the relevant ecoregions (USEPA 2000b, USEPA 2000c, USEPA 2001b). As a result, DRBC will explore the use of these anti-degradation targets for nutrient criteria in the Upper and Middle Delaware River. For the Lower Delaware, DRBC will more closely study the biological and chemical changes occurring within this reach of river to determine effects-based nutrient or nutrient-related criteria.

B. Utilization of Anti-Degradation Targets for Nutrient Criteria

EPA's recommended nutrient criteria for the three ecoregions spanning the mainstem, non-tidal Delaware River (i.e., Appalachian Plateau, Ridge & Valley, Piedmont) range from 10 μg/L to 37 μg/L Total Phosphorus and from 0.31 mg/L to 0.69 mg/L Total Nitrogen (USEPA 2000b, USEPA 2000c, USEPA 2001b). Given the relatively undisturbed condition of the upper Delaware, it is perhaps not surprising, then, that the anti-degradation targets for the Upper Delaware River and Middle Delaware River (referred to as Existing Water Quality or EWQ by DRBC) for both Total Phosphorus and Total Nitrogen fall precisely within these ecoregional recommended critera: 29 μg/L to 31 μg/L for Total Phosphorus and 0.45 mg/L to 0.57 mg/L for Total Nitrogen as upper confidence limits (DRBC 2010). More sophisticated modeling efforts, where the proportion of land within each ecoregion factors into a river segment's numeric criteria recommendation, likewise show broad agreement between EPA's recommendations and the existing distribution of nutrient data for both the Upper Delaware and Middle Delaware River (J.R. Yagecic *unpublished*).

This broad agreement between EPA's initial numeric nutrient criteria recommendation and DRBC's anti-degradation targets for nutrients creates a situation where the recognition or codification of DRBC's targets would provide protective nutrient criteria while simultaneously reinforcing the anti-degradation status of the Upper and Middle Delaware River.

The following tasks lay out the steps DRBC will take to further explore this broad agreement and to then recommend protective nutrient criteria.

Task R-1.a Explore Use of Anti-Degradation Targets in Nutrient Criteria

DRBC will examine the various combinations of EPA's recommended ecoregional nutrient criteria along with updated analyses of nutrient concentration data collected in recent years for the Upper and Middle Delaware River to determine the degree of match and the extent to which nutrient distributions correspond to the targets and recommendations. DRBC will then explore whether the existing anti-degradation targets would provide sufficient strength for recognition as nutrient criteria by the basin states and by EPA. DRBC will also explore one or more numeric nutrient criteria options for the Upper and Middle Delaware River that more closely match traditional numeric water quality criteria. Because of the many ways that the current anti-degradation targets could be recognized, the ultimate direction for this task will be determined largely through consultation with our state counterparts.

Task R-1.b Recommend Nutrient Criteria Approach

Based on the evaluations conducted in Task R-1.a (above), DRBC will recommend one or more approaches for recognizing the anti-degradation nutrient targets and/or implementation of these targets as traditional numeric nutrient criteria.

Table 3. Tasks & Timelines for Upper and Middle Delaware River

Task	Description	Completion Goal*
R-1.a	Explore Use of Anti-Degradation Targets in Nutrient Criteria	March 2015
R-1.b	Recommend Nutrient Criteria Approach	December 2015

* - all dates are targets based on available resources and staff workloads; dates subject to change

C. Effects-Based Nutrient Criteria for the Lower Delaware River

Substantial changes in the geology and land use occur as the Delaware River transitions out of the Appalachia Plateau province into the Ridge and Valley, New England, and Piedmont provinces below the Delaware Water Gap. As a result of these natural and anthropogenic changes, major shifts occur in the water chemistry of the Delaware River in this section referred to as the Lower Delaware (RM 133 to RM 210). Among the water quality changes are a roughly two-fold increase in total dissolved solids and specific conductance (DRBC 2010), demonstrating the broad changes to water chemistry through this zone. As described above, nutrient concentrations also double in this transition zone, particularly below the Lehigh River. Yet for both the broader water quality changes and the increases in nutrients, the simultaneous change in the natural geology and the human use of the land and water preclude simple identification of the relative roles of natural processes and human influence on these profound water quality changes.

Even with the substantial changes to nutrients and other water quality parameters, the DRBC has recognized the high water quality of this section and has adopted the entire Lower Delaware as part of its anti-degradation Special Protection Waters program. But particularly below the Lehigh River, a number of biological investigations have shown signs of weakened ecological health, suggesting the anthropogenic contribution to the water quality changes may indeed be exceeding the river's ability tolerate the existing changes (Munch 1993, Brightbill et al. 2010, DRBC 2012, E.L. Silldorff & H.S. Galbraith *unpublished*).

This ambiguity in the ecological condition of the Lower Delaware, and the role of elevated nutrient concentrations in this compromised health, provides a challenging setting for the development of nutrient or nutrient-related criteria. DRBC has therefore identified the following tasks as key elements in developing effects-based nutrient or nutrient-related criteria for the Lower Delaware River.

Task R-2.a Reconcile Assessments of Biological Condition for the Lower Delaware

The DRBC currently uses an interim protocol for conducting biological assessments of the Delaware River (Silldorff and Limbeck 2009, DRBC 2012). This protocol relies on benthic macroinvertebrate collections, analyzed and converted into a 100-point scale, to determine whether the aquatic life use of the Lower Delaware River (as well as the Upper and Middle Delaware) meet both DRBC's criteria and the goals of the Clean Water Act. Because this protocol remains an interim methodology, the assessment decisions do not lead to "listings" on the 303(d) list of impaired waters submitted by the states to EPA.

In order to assess whether the aquatic life use has been impacted by nutrients, the DRBC protocols (or alternative protocols) need to be reviewed, revised, and adopted by the respective basin states so that broad agreement exists on whether the aquatic life use is supported in the various sections of the Lower Delaware River.

If the states, EPA, and DRBC can agree that the Lower Delaware fully attains its aquatic life use designation, a similar approach to the anti-degradation recommendations outlined in Tasks R-1.a and R-1.b can be followed for the Lower Delaware River. However, if the states, EPA, and DRBC agree that the ecological changes in the Delaware River constitute an impairment of the aquatic life use, a more rigorous study of the role of elevated nutrients and the possible thresholds for nutrient-related effects will need to be conducted.

Task R-2.b Explore & Recommend the Use of Anti-Degradation Targets in Nutrient Criteria

The implementation of this task depends on the outcome from Task R-2.a. Specifically, should the states, EPA, and DRBC agree that the Lower Delaware fully attains its aquatic life use designation, this task will exactly parallel Tasks R-1.a and R-1.b for evaluating and adopting DRBC's anti-degradation targets as numeric nutrient criteria.

Task R-2.c Identify the Role of Elevated Nutrients in Ecological Impairment

The implementation of this task likewise depends on the outcome from Task R-2.a. Specifically, should the states, EPA, and DRBC agree that the Lower Delaware River's aquatic life use has been impaired, this and subsequent tasks will be implemented.

This task will employ both observational and experimental studies to isolate the effects of elevated nutrients on the ecology of the Lower Delaware River. These studies may span multiple organizational scales, from ecosystem functions to the structure of periphyton, invertebrate, freshwater mussel, and/or fish assemblages. The scope of these studies will depend on both the outcome of the initial task to evaluate the ecological condition of the Lower Delaware River (Task R-2.a) as well as the available staff and funding resources available to implement these studies.

Task R-2.d Identify Nutrient Regimes Supportive of Aquatic Life Uses

Like Task R-2.c, this task would only be implemented if the aquatic life use of the Lower Delaware was found to be impaired.

This task would be similar to Task E-2.e for the Delaware Estuary where the effects of nutrients, once identified and understood, would be used to evaluate various nutrient regimes that could lead to full attainment of the aquatic life use. Both modeling and empirical studies could be used in this evaluation.

Task R-2.e Propose Nutrient or Nutrient-Related Criteria

Like Tasks R-2.c and R-2.d, this task would only be implemented if the aquatic life use of the Lower Delaware was found to be impaired.

Following completion of Task R-2.d, where nutrient regimes leading to aquatic life use attainment were evaluated, DRBC would then prepare one or more alternatives for nutrient or nutrient-related criteria that would be more protective of the aquatic life use than the existing nutrient regimes.

Table 4. Tasks & Timelines for Lower Delaware River

Task	Description	Completion Goal*
R-2.a	Reconcile Assessments of Biological Condition for the Lower Delaware	March 2016
R-2.b	Explore & Recommend the Use of Anti-Degradation Targets in Nutrient Criteria *(if needed)***	March 2018
R-2.c	Identify the Role of Elevated Nutrients in Ecological Impairment *(if needed)***	December 2019
R-2.d	Identify Nutrient Regimes Supportive of Aquatic Life Uses *(if needed)***	December 2021
R-2.e	Propose Nutrient or Nutrient-Related Criteria *(if needed)***	December 2022

* - all dates are targets based on available resources and staff workloads; dates subject to change
** - the implementation of tasks b, c, d, e depends on outcome of Task R-2.a

Part 3. Nutrient Criteria Plan Mapping to EPA Guidelines

EPA currently recommends that Nutrient Criteria Plans originating from states, tribes, and interstate water pollution control agencies be organized into 5 main milestones categories. Although many of the tasks outlined in Part 1 and Part 2 of this plan intuitively fit within this EPA schema, Table 5 below provides an explicit mapping of this Nutrient Criteria Plan's tasks into the 5 milestones used currently by EPA.

Table 5. EPA Milestones Mapped to Delaware River & Delaware Estuary Nutrient Criteria Plan's Tasks & Timelines

	Estuary		River	
Milestone	Task	Deadline	Task	Deadline
Plan for Collection of Data	Development of Nutrient Criteria Plan	2013	Development of Nutrient Criteria Plan	2013
Collection of Info and Data	Task E-1.a	June 2015	Task R-2.a	March 2016
	Task E-2.a	June 2014		
	Task E-2.b	December 2014		
	Task E-2.c	June 2015		
Analysis of Info and Data	Task E-1.b	June 2016	Task R-1.a	March 2015
	Task E-1.c	June 2016	Task R-2.b	March 2018*
	Task E-1.d	January 2017	Task R-2.c	December 2019*
	Task E-1.e	June 2017	Task R-2.d	December 2021*
	Task E-2.d	March 2018		
	Task E-2.e	March 2020		
Proposal of Criteria	Task E-1.f	January 2018	Task R-1.b	December 2015
	Task E-2.f	December 2021	Task R-2.b	March 2018*
			Task R-2.e	December 2022*
Adoption of Criteria	Adoption of Criteria	(unpredictable)	Adoption of Criteria	(unpredictable)

* - the implementation of Tasks R-2.b, R-2.c, R-2.d, R.2.e depends on outcome of Task R-2.a

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