New Jersey Nutrient Criteria Enhancement Plan 2018

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OVERVIEW

In 1996, the United States Environmental Protection Agency's (USEPA) *National Water Quality Inventory: Report to Congress Executive Summary* cited nutrients (nitrogen and phosphorus) as one of the leading causes of water quality impairment in U.S. rivers, lakes, and estuaries. In June of 1998, USEPA followed up by publishing a National Strategy for the Development of Regional Nutrient Criteria, a key part of which is the expansion of efforts to reduce nutrient enrichment in the nations waters (see https://nepis.epa.gov/Exe/ZyPDF.cgi/20003NOU.PDF?Dockey=20003NOU.PDF. EPA's plan was, and is, to require states to develop nutrient criteria plans which outline each state's process to adopt nutrient criteria into state water quality standards. EPA's national strategy was followed in 2001 by an EPA memo providing additional guidance to states on developing nutrient criteria plans and the role of these plans in the adoption of nutrient criteria (see https://www.epa.gov/sites/production/files/2014-08/documents/nutrient-memo-nov142001.pdf). New Jersey responded to this USEPA effort by releasing its first nutrient criteria plan in 2009 which inventoried New Jersey's nutrient monitoring efforts and plans to enhance them. This plan was revised in 2013 (see http://www.state.nj.us/dep/wms/bears/docs/2013_final_nutrient_plan.pdf), wherein a series of projects were designed to provide the data necessary to develop nutrient criteria for lakes, streams, rivers, and coastal waters of the state. This current 2018 revision of the Plan prepared by the New Jersey Department of Environmental Protection (Department) provides an updated status of these projects and discusses new projects to fill information gaps identified in the intervening years. This 2018 New Jersey Nutrient Criteria Enhancement Plan (Plan) was prepared with the input of a multi-disciplinary team from within the Department. Upon completion of projects identified in previous and subsequent plans findings will be used as appropriate to form the technical basis for any proposed nutrient criteria.

New Jersey's Surface Water Quality Standards (SWQS) establish designated uses and the water quality criteria designed to protect those uses. Each waterbody in the state is assigned a surface water classification that specifies the uses to be protected. Designated uses of New Jersey waters are categorized as aquatic life, recreation, drinking water supply, and fish and shellfish consumption. Designated uses potentially affected by excessive nutrients are aquatic life, recreation, and drinking water supply. For rivers, streams, and coastal waters, the Nutrient Criteria Enhancement Plan initially focuses on addressing the impacts of nutrients on the aquatic life use. The Department will concurrently evaluate whether the aquatic life criteria are protective of the other nutrient sensitive uses. It should be noted that nutrients by themselves are not toxic to aquatic life but in excess may cause enhanced phytoplankton growth which may lower the dissolved oxygen in the water column and/or induce other changes in the ecological system thereby endangering aquatic life. For lakes, aquatic life protection will be evaluated in concert with recreational uses. This current nutrient criteria plan does not evaluate impacts on drinking water use; however, it should be noted that the Department's current nitrate standard is set for the protection of drinking water uses in Fresh Water 2 (FW2) waters and in Pinelands (PL) to protect the existing surface water quality. This Plan will be revised in the future to serve as a technical basis in support of the development of nutrient criteria protective of the drinking water use which is not under review in this Plan.

New Jersey's Surface Water Quality Standards at N.J.A.C. 7:9B[1] (SWQS) currently contain narrative nutrient criteria that apply to all waters of the State, as well as numeric phosphorus criteria for freshwater lakes/ponds and rivers/streams (USEPA, 1976). New Jersey also has numeric nitrate criteria for waters classified as FW2 and PL. These provisions were promulgated in 1981. The current narrative criteria are as follows:

> "Except as due to natural conditions, nutrients shall not be allowed in concentrations that render the waters unsuitable for the existing or designated uses due to objectionable algal densities, nuisance aquatic vegetation, diurnal fluctuations in dissolved oxygen or pH indicative of excessive photosynthetic activity, detrimental changes to the composition of aquatic ecosystems, or other indicators of use impairment caused by nutrients."

The State numeric criteria are as follows:

Phosphorus

Freshwater Streams: Concentrations of total P shall not exceed 0.1 mg/L (100 µg/L) in any stream, unless watershed-specific translators are established pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable in accordance with the narrative criteria stated above.

Lakes: Concentrations of total P shall not exceed 0.05 mg/L (50 µg/L) in any lake, pond or reservoir, or in a tributary at the point where it enters such bodies of water, unless watershed-specific translators are developed pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable in accordance with the narrative criteria stated above.

Nitrogen

PL waters: Nitrate-Nitrogen of 2 mg/L shall be maintained in the surface waters unless it is shown that a lower level must be maintained to protect the existing surface water quality.

FW2 waters: Nitrate (as N) of 10 mg/l.

[1] http://www.nj.gov/dep/rules/rules/njac7_9b.pdf

Site specific nutrient criteria may be developed in order to maintain the dissolved oxygen in the water column or to prevent excess eutrophication or increase in primary productivity. The dissolved oxygen criteria vary with the stream classifications and designated use and presented below.

Dissolved Oxygen:

FW2-TP (Freshwater trout production)	Not less than 7.0 mg/L at any time
FW2-TM (Freshwater trout maintenance)	24 hour average not less than 6.0 mg/L. Not less than 5.0 mg/L at any time
FW2-NT (Freshwater non-trout)	24 hour average not less than 5.0 mg/L. Not less than 4.0 mg/L at any time
SE1 (Saline Estuarine)	24 hour average not less than 5.0 mg/L. Not less than 4.0 mg/L at any time
SE2 (Saline Estuarine)	Not less than 4.0 mg/L at any time
SE3 (Saline Estuarine)	Not less than 3.0 mg/L at any time
SC (Saline Coastal)	Not less than 5.0 mg/L at any time
Tidal portions of FW2-NT tributaries to the Delaware River, between Rancocas Creek and Big Timber Creek inclusive	Not less than 4.0 mg/L at any time
FW2-TM, FW2-NT, SE1	Supersaturated dissolved oxygen values shall be expressed as their corresponding 100 percent saturation values for purposes of calculating 24 hour averages.

Since these criteria were promulgated, significant state-wide as well as nationwide research has been conducted. These studies have expanded the knowledge base about the general and site-specific factors that cause or contribute to nutrient impairment nation-wide as well as in New Jersey's waterways. This revised Plan provides detailed descriptions of the Department's strategy for reviewing and, if necessary, enhancing the existing nutrient criteria for freshwaters making use of these new data. This Plan also aims at developing nutrient criteria for coastal waters through a combination of cause–response relationships (e.g. benthic invertebrate condition versus total nitrogen) as well as eutrophication models. New Jersey's revised Plan provides information on the following steps to support and enhance this effort:

1. Continued enhanced monitoring of rivers and coastal waters for nutrients and response variables;
2. The assessment of causal relationships for nutrients and their associated response variables;
3. The methodology for developing ecoregional nutrient reference levels;
4. The development of new assessment methodologies to define thresholds of use impairment based on response variables;
5. The development of new/enhanced criteria; and
6. The promulgation of the new and revised criteria through amendments to the Surface Water Quality Standards.

This revised Plan explains the details of each of these steps by waterbody type, including priorities, project descriptions, and where possible, timelines for criteria development or further study. Also included in this 2018 edition at EPA's request are task-progress charts with milestones and completion dates (both targeted and actual), organized by waterbody type (Table 1).

For estuarine waters, Barnegat Bay was identified by the Department as a priority area in 2010 and is serving as the model for estuarine nutrient criteria development for estuarine waters throughout the state. Under the Governor's Comprehensive Action Plan to enhance the Bay (see https://www.state.nj.us/dep/barnegatbay/bbfh.htm), component number 7 is "Adopt more rigorous water quality standards." The approach for this area is set forth in the section on Estuaries. Moreover, the Department is moving science into action in the Barnegat Bay watershed and has recently released the draft Barnegat Bay Restoration, Enhancement, and Protection Strategy which is built upon the data, modeling results, and research of the Phase One Barnegat Bay Ten-Point Plan. The Department expects to utilize this model approach, which relies heavily on extensive partner involvement in developing the scientific basis for nutrient management, including the establishment of target nutrient levels or loadings, as part of a regional watershed approach for monitoring, assessment and management. See http://www.nj.gov/dep/barnegatbay/index.htm for additional information.

This Plan is a "living" document that is periodically updated as the Department learns from the projects and literature reviews, as well as in response to program priorities and availability of resources. The Plan is updated every three years as per an agreement with EPA Region 2. In addition, the Department expects to continue to submit to USEPA annual progress reports that provide information and status on individual projects identified in the Plan.

I. Background

As stated in the Overview, USEPA's *National Water Quality Inventory: 1996 Report to Congress Executive Summary* cited nutrients (nitrogen and phosphorus) as one of the leading causes of water quality impairment in U.S. rivers, lakes, and estuaries. The report stated at the time that 40 percent of the U.S. rivers were impaired due to nutrient enrichment; 51 percent of the surveyed lakes and 57 percent of the surveyed estuaries were similarly adversely affected. More recently, the USEPA National Aquatic Resources Surveys (NARS) (https://www.epa.gov/national-aquatic-resource-surveys) program reports that 72 percent of streams in the lower 48 states exhibited impaired biota for which the most important stressors were *nutrients* and excess sedimentation. In the same study, 44 percent of lakes showed impaired biology largely brought about from poor lakeshore habitat and *nutrients*. Nutrients have also been implicated with respect to the large hypoxic zone in the Gulf of Mexico, hypoxia observed in several East Coast States, and *Pfiesteria*-induced fish kills and human health problems in the coastal waters of several East Coast and Gulf States. Closer to home, although a recent USGS long term trend assessment (https://doi.org/10.3133/sir20165176) has shown declines in phosphorus and nitrogen levels within New Jersey freshwaters over the past 30 years (USGS 2016), the New Jersey 2014 Integrated Report **(**http://www.nj.gov/dep/wms/bears/2014_integrated_report.htm**)** identified nutrient related parameters, particularly total phosphorus, as the primary cause of general aquatic life use impairments.

USEPA has avoided a single national approach to nutrient criteria development believing it to be inappropriate due to regional variations in geology, vegetation, climate, and soil types that exist and the lack of a clear technical understanding of the relationship between nutrients, algal growth, and other factors such as flow, light, and substrata under local conditions (USEPA 2000a, USEPA 2000b). In response, New Jersey, as other states, has begun developing numeric nutrient criteria for waterbodies lacking such criteria and enhancing already existing numeric criteria, as describe earlier on page 5 of this Plan, based upon the unique regional characteristics of this state.

Section 304(a) of the federal Clean Water Act directs USEPA to develop and publish criteria guidance to assist states and authorized tribes in developing water quality standards that are protective of designated uses. In addition, water quality criteria developed under Section 304(a) are based solely on data and scientific judgments and do not consider economic impacts or the technological feasibility of meeting any specific level of water quality in ambient water. USEPA determined that, to better protect water quality from the adverse impacts of nutrient over-enrichment, ecoregional variations must be considered when setting water quality criteria for a particular waterbody. Therefore, in January 2001, the USEPA published recommended water quality criteria for nutrients under Section 304(a) of the federal Clean Water Act (see 66 F.R. 1671). From EPA's perspective, establishing water quality criteria reflective of minimally impacted locations is protective of existing and designated uses; therefore, USEPA's recommended ecoregion nutrient criteria were developed based on the lower 25th percentile of water quality conditions within ecoregions. The USEPA intended for states to consider using the recommended 304(a) criteria to support the development of more localized, waterbody-specific state and tribal nutrient criteria that would provide a basis for controlling discharges or releases of pollutants and ultimately result in the protection of aquatic life and recreational uses.

The USEPA also provided two other options for states to develop and adopt nutrient criteria: 1) develop criteria that reflect localized conditions and protect specific designated uses, pursuant to the USEPA technical guidance documents; 2) use other scientifically defensible methods and water quality data to develop criteria protective of designated uses. An example of a scientifically defensible method may include a nutrient response study.

The Department has been developing/enhancing numeric nutrient criteria using a multiple line of evidence approach. Much of the work focuses on relationships between nutrient levels in state waters and how they relate to indicators of detrimental changes to aquatic ecosystems, such as undesirable levels in dissolved oxygen (DO), excessive algal growth, and/or impaired aquatic communities. The goal is to determine nutrients levels that result in a high likelihood that desirable biological communities will be maintained over time, and the allowable frequency and duration above this concentration that may occur while not impairing the biological community. In lakes and wadeable streams, this approach is being supplemented by assessments of reference nutrient levels in waters characterized by minimal anthropogenic inputs. For rivers, streams, and coastal waters the Department plans to use representative biota (algae, fish, benthic invertebrates, chlorophyll *a*, diatoms) as appropriate, as indicators of the aquatic ecosystem health. Because methodologies for fish, and benthic invertebrate assessments have not yet been developed for New Jersey lakes, the Department is using of chlorophyll *a* levels and the likelihood of cyanophyte dominance within the phytoplankton communities as biotic endpoints for nutrient management. Data analysis is ongoing in the Barnegat Bay, which will be used as a model to develop assessment approaches and criteria development methodologies applicable to other estuaries in the State. A benthic macroinvertebrate index for New Jersey's near shore marine waters is undergoing the final stages of development by the Department. Lastly, further analyses are required to formulate an approach for some tidal portions of rivers not covered by Total Maximum Daily Load assessments (TMDLs). Note that a TMDL is a plan for restoring impaired waters that identifies the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards.

As stated above, in the context of criteria development, nutrient ranges within reference conditions representing ranges associated with undisturbed or minimally disturbed conditions can be useful in determining whether the nutrient levels derived from stressor-response studies are achievable; hence it is important that they be documented as part of the nutrient enhancement strategy. Once protective numerical thresholds are established for a nutrient, the frequency at which nutrient concentrations can be exceeded and for what duration these exceedances can occur and still support uses will be determined.

Overview of Progress to Date

Since 2009, when the initial Nutrient Criteria Enhancement Plan was developed, the Department has continued to develop a significant database of nutrient and nutrient response data from freshwater lakes, wadeable streams, and coastal waters to support the Department's criteria development effort. Extensive monitoring and biological indicator development have been ongoing in coastal waters, rivers/streams, including the addition of diatom community condition indicators as they relate to nutrient enrichment in wadeable streams. Advancements in diatom assessments by the Academy of Natural Sciences of Drexel University has led to paleolimnological assessments of historic nutrient levels in natural lakes based upon diatom remains taken from lake cores. Diatom community assessments in wadeable streams have supplemented the Department's bio assessments of fish and invertebrates for the purpose of nutrient impact assessment. Still lacking however, are biotic indices to assess the aquatic life conditions for lakes and tidal freshwaters. Also, currently needed are more detailed data on nutrient levels and corresponding response indicators for reference lakes, lakes reflecting a minimal degree of anthropogenic impact. The Department is currently collecting data to address this data gap.

In the recent past, New Jersey coastal biological assessments were limited to the NY/NJ Harbor using a biological community metric developed by the USEPA. To correct this assessment gap, biological indicators for nearshore ocean waters and the Barnegat Bay have or are being developed through the efforts of the Rutgers Institute of Marine and Coastal Sciences and the Academy of Natural Sciences of Drexel University. A benthic macroinvertebrate indicator (IBI) for the nearshore ocean has been under development and is nearing completion. In addition, as of 2016, development of IBI for Barnegat Bay has been completed. Both these IBIs were developed by Rutgers. Concurrently, the Academy of Natural Sciences has studied the alterations of phytoplankton communities within Barnegat Bay along a nutrient gradient. The goal of this study is to determine the influence of nutrients on primary productivity and phytoplankton growth and develop numerical nutrient thresholds for the applicable nutrients.

To improve this Department's understanding of the impacts of nutrients on the aquatic life conditions in wadeable streams, a diatom-based Biological Condition Gradient (BCG) was developed (Hausmann et al., 2016) intended to characterize diatom communities based on their degree of alteration from their natural undisturbed condition. These communities, and their position on the BCG continuum, can identify the use attainment status of waters as mandated by the goals of the Federal Clean Water Act along a nutrient disturbance gradient. The BCG was developed and then subsequently enhanced as a cooperative effort between the Academy of Natural Sciences of Drexel University and Tetra Tech, Inc.

Nutrient impacts in Barnegat Bay are being examined through a coupled hydrodynamic-water quality model developed by the USGS. Impairments of low dissolved oxygen and high turbidity within certain portions of the Bay are under investigation as to what degree does primary production caused by nutrient inputs contribute to these conditions. The Department plans to combine these findings along with the biological (invertebrate and phytoplankton studies) to make recommendations as to levels of nutrients within the Bay and its tributaries that would protect its designated and existing uses. This water quality study may result in site specific criteria for nitrogen and chlorophyll a for Barnegat Bay.

New Jersey's Water Resources in the Context of Nutrient Criteria Development

Lakes

Lakes are defined by the Department for the purpose of monitoring to be at least five acres in surface area, one meter in depth, and nontidal. New Jersey has about 870 named lake/impoundments that are at least five acres in size. Lakes are monitored by the Department through both a probabilistic and a newly designed deterministic network. Many New Jersey lakes are shallow impoundments, formed by damming streams and rivers which renders them highly susceptible to accelerated eutrophication. As a result, many New Jersey lakes have exhibited water quality problems for decades, primarily with respect to nutrient over-enrichment and siltation. This predisposition is enhanced in lakes with large watersheds.

The Department has developed phosphorus TMDLs for the 56 lakes in New Jersey where water quality data indicated eutrophic conditions. In developing these lake TMDLs, water quality models predicted that some lakes could never attain the current numeric TP criterion of 0.05 mg/l, even if there were no anthropogenic inputs, because of the large size of the contributing drainage area relative to the impounded volume. For these lakes, reference conditions (determined by assuming that 100% of the land use within the lakeshed was either forest or water) were used as "end points" for calculating phosphorus reductions consistent with the SWQS provision that allows naturally occurring conditions to prevail over numeric criteria.

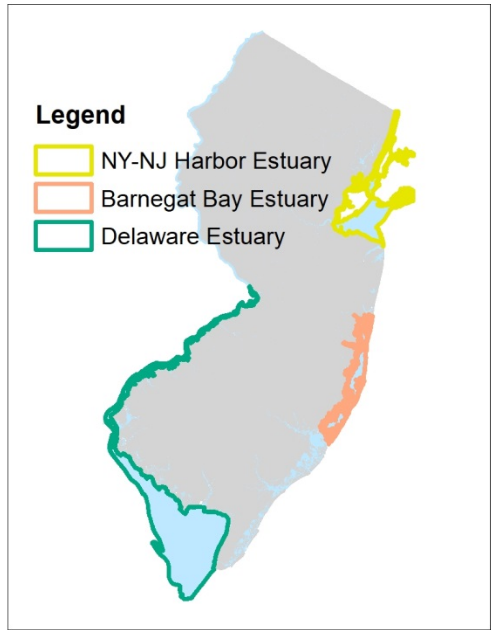
Freshwater Streams and Rivers

There are roughly 18,000 miles of rivers and streams in New Jersey (at 1:24,000 mapping scale of resolution), of which approximately 12,000 miles are non-tidal. For the purposes of this Plan, streams are considered "wadeable" and rivers are considered "non-wadeable." "Wadeable" means that the waters are shallow enough to be monitored on foot, rather than by boat or by bridge. Most of New Jersey's non-tidal streams are wadeable and conversely almost all non-wadable rivers in New Jersey are tidal. The only notable exception is the lower Salem River which is both nontidal and non-wadable. There are another 6,000 stream miles that are tidal and are addressed as large rivers and estuaries (see Tidal Rivers and Estuaries immediately below). Since streams comprise the majority of New Jersey's freshwaters, enhancing the existing numeric phosphorus criteria and assessing nutrient impacts based on the narrative nutrient criteria remains a priority.

Tidal Rivers and Estuaries

Freshwater tidal portions of rivers represent transitional waters as one moves from freshwater non-tidal, to saline/estuarine conditions. New Jersey has an extensive network of estuaries representing some 260 square miles. Three of the major estuarine systems in or bordering on New Jersey are part of the National Estuary Program (https://www.epa.gov/nep/overview-national-estuary-program) and as such are designated as estuaries of national significance. They are the New York-New Jersey Harbor Estuary Program, the Barnegat Bay Partnership, and the Partnership for the Delaware Estuary (see Figure 1). Each program has developed a Comprehensive Conservation and Management Plan (CCMP) that establishes priorities for the long term management of the estuaries including environmental protection, land use, research, and funding.

Figure 1: New Jersey Estuaries managed through National Estuary Programs



Regarding the application of nutrient water quality standards to these estuarine waters, currently the 0.1 mg/l limit for total phosphorus is applied to non-tidal freshwaters but not to tidal freshwaters. Note that tidal freshwaters are covered by the narrative criteria (see page 5) which apply to all New Jersey waters. From the perspective of the Nutrient Criteria Enhancement Plan, the fresh water portions of tidal rivers have been a low priority due to the relative complexity of modeling these waters require. In addition, TMDLs have been developed for most of the non-tidal fresh water streams (FW2) that are impaired for total phosphorus.

The DO management in NY/NJ Harbor and the promulgation of TMDLs for nitrogen and carbon was being led by the Harbor and Estuary Program (HEP) through the Nutrient Work Group, which comprised of representatives from EPA, states, environmental protection advocates, interested citizens, and permitted stakeholders. Even though extensive monitoring and modeling analyses was conducted, the planning wasn't fully completed and there were still pending questions related to the interpretation and impact analyses of the temporal and spatial extents of DO deficits. Furthermore, modeling of projected scenarios indicated that even with the municipal treatment plants upgraded to Limit of Technology for treatment (LOT), there would still be subregions where EPA's DO criteria would not be met. The HEP is currently housed at Hudson River Foundation and is in process of adopting the Comprehensive Conservation and Management Plan. As per the draft action plans (http://www.harborestuary.org/pdf/HRF-ActionAgenda-draft-0517.pdf) , HEP will provide a forum to discuss role of nutrients in DO impairments and the need to consider nutrient loading reduction. Simultaneously, the primary municipal discharger, Bergen County

Utilities Authority (BCUA), in Hackensack River is conducting a water quality study in lower Hackensack River estuary since late 2000's to develop modeling tools to inform TMDL.

The lower Toms River and other tributaries to Barnegat Bay are being addressed under the Barnegat Bay Restoration, Enhancement, and Protection Strategy (NJDEP, 2017). Further, sanitary discharges to tidal freshwaters are limited. Except for one minor discharge in the northern portion of the state near the Meadowlands, all other tidal municipal wastewater treatment plants discharging to tidal freshwaters either discharge directly to the tidal Delaware River or to tidal portions of the tidal Delaware tributaries. To address impairments in the tidal portions of the Delaware River, the Delaware River Basin Commission (DRBC) is modeling these portions of the Delaware River. Here the DRBC, in cooperation with the Department, will analyze the relationships between nutrients, river DO, and primary production ultimately (among other things) to guide the nutrient limits assigned to the tidal freshwater tributaries to the Delaware River in New Jersey.

The DRBC manages water quality in the nontidal portion of the Delaware River by implementing the Special Protection Waters (SPW) program that maintains *no measurable change to existing effluent quality* (EEQ). Implementation includes management through permits, combined with monitoring to assess any changes to EEQ. DRBC is conducting intensive monitoring to determine any degradation of water quality in these waters (see https://elainepanuccio.shinyapps.io/specialprotectionwatersexplorer/).

The Department's efforts to develop nutrient criteria for estuaries are currently focused on the Barnegat Bay. There has been extensive work, still ongoing, assessing the potential impacts of nutrients to Barnegat Bay which is discussed beginning on page 32 of the Plan.

Nearshore Ocean: New Jersey has 127 linear miles of ocean coast. Historically, New Jersey's near-shore ocean has been monitored for a suite of parameters by means of USEPA helicopter grab samples through a coastal monitoring program. These data have documented chronic depressed DO within the lower portions of the water column off the coast for most of its length during quiescent periods of summer and early fall. These low DO conditions are to some degree brought about by the natural hydrodynamic conditions that occur during this period. These conditions are further exacerbated by the presence of summer upwelling nodes bringing in nutrient rich offshore waters which are associated with recurrent seasonal hypoxia. Storms and the onset of autumn bring about surface to bottom mixing resulting in a breakup of these low DO conditions until the onset of warmer temperatures again in June. To better understand the resulting biological impacts, the Department has worked with Rutgers, USEPA Region 2, USEPA Office of Research and Development (Narraganset), and the National Oceanic and Atmospheric Administration (NOAA) to develop a benthic community metric for near-shore ocean (marine) waters. Benthic samples were collected in 2007, 2009, and 2010 in support of this effort (see page 38 in this document for current progress).

As a separate effort, the Department's Marine Water Monitoring Bureau has deployed a slocum glider multiple times every summer since 2012 providing continuous DO, salinity, and temperature data along transects gathering data at various depths. The glider is released from Sandy Hook and is retrieved at Cape May. It travels near shore waters in a zig zag pattern as it makes its way south. The data from this glider have enhanced the Department's evaluation of the nature and spatial extent of the low DO regions in near-shore ocean waters. More information on this project is available at: http://highpoint.state.nj.us/dep/wms/BMWnew/glider.html). The Department plans to use these new tools to obtain a better understanding of the impacts of offshore upwellings on local nutrient budgets and subsequent resulting depressed DO levels.

II. CRITERIA DEVELOPMENT PROCESS

To support states in their effort to develop numerical nutrient criteria, USEPA published ecoregional reference values in January 2001 as 304(a) criteria recommendations upon which states could base nutrient criteria. USEPA also provided states the option to generate state specific reference values reflecting local conditions using two different approaches. In regions that are minimally developed, USEPA suggests establishing the 75th percentile of a cumulative frequency distribution of minimally disturbed sites as a potential reference value. In regions with more extensive development, USEPA has suggested that the 25th percentile of a distribution of sites throughout the region in question would provide a reference. The Department has concerns regarding both approaches as targets supporting criteria. Using the 25th percentile approach appears arbitrary and not directly tied to a designated use. The use of the 75th percentile approach is confounded by such questions as what constitutes "minimally disturbed" conditions which can vary significantly from ecoregion to ecoregion and can be defined in varying ways. One could also question the choice of the 75 percentile as opposed to a 90th percentile in regions where there is high confidence that true reference conditions can be identified.

In contrast to the reference condition approach, nutrient (stressor) - response variable assessments explore the relationship between nutrient levels and indicators of ecosystem health such as a biological index or other biologically relevant response indicators such as DO, pH, chlorophyll *a*. These assessments suggest the likelihood of obtaining a desired biological community (or some other measure of a desired endpoint) if nutrients are maintained at certain levels. The advantage of this approach is that it allows the development of numeric nutrient criteria based on and directly tied to desired outcomes (i.e. healthy biota) reflecting specific designated uses. This process first seeks to determine if there is in fact a relationship between nutrient levels and the response indicator(s) of concern. If a relationship exists, the approach explores whether altering the nutrient levels results in a corresponding change in the response variable in the desired direction.

The Department's goal is to determine the nutrient levels that would result in a high likelihood of desirable biological communities being maintained over time, and the frequency and duration associated with any excursions above this concentration that can be allowed while protecting the biological community. In moving from simple thresholds to final criteria, decisions need to be made as to where or in what specific waterbodies these criteria will apply. Factors such as waterbody size, retention time (lakes), stream order, geographic location, uses of the waterbody may influence these decisions. What follows provides an overview and description of the projects planned by waterbody type including the purpose of the project, the data used, and how each project fits into the overall Nutrient Criteria Enhancement Plan. Table 1 delineates the anticipated schedules for EPA-defined milestones for the overall nutrient effort by waterbody type. Tables 2 through 5 provide anticipated completion dates for specific projects in support of criteria development in lakes, streams, estuaries, and nearshore ocean waters.

Table 1. General and Administrative Tasks and Anticipated Completion Goals Based Upon EPA-Defined Milestones:

Lakes:

Tasks	Target Completion Date	Actual Completion Date*
Planning for criteria development		completed in 2016**
Collection of information and data	2019	
Analysis of information and data (criteria calculation)	2019	
Stakeholder Process	2020	
Proposal of draft criteria to EPA	2022	
Adoption of criteria into NJDEP's WQS	2023	

Streams:

Tasks	Target Completion Date	Actual Completion Date*
Planning for criteria development		completed in 2016**
Collection of information and data	2019	
Analysis of information and data (criteria calculation)	2019	
Stakeholder Process	2020	
Proposal of draft criteria to EPA	2022	
Adoption of criteria into NJDEP's WQS	2023	

Estuaries 1 (Barnegat Bay Only):

Tasks	Target Completion Date	Actual Completion Date*
Planning for criteria development		completed in 2016**
Collection of information and data	2019	
Analysis of information and data (criteria calculation)	2019	
Stakeholder Process	2020	
Proposal of draft criteria to EPA	2021	
Adoption of criteria into NJDEP's WQS	2022	

Estuaries 2 (Remaining Atlantic Coast Estuaries, Navesink River south to the eastern side of Cape May):

Tasks	Target Completion Date	Actual Completion Date*
Planning for criteria development	Ongoing, no completion date established	
Collection of information and data	2020	
Analysis of information and data (criteria calculation)	2022	
Stakeholder Process	2023	
Proposal of draft criteria to EPA	2023	
Adoption of criteria into NJDEP's WQS	2023-2025	

Ocean:

Tasks	Target Completion Date	Actual Completion Date*
Planning for criteria development	2017	completed
Collection of information and data	Please refer to the 2nd paragraph in the overview section under "Ocean" on page 38	
Analysis of information and data (criteria calculation)	Please refer to the 2nd paragraph in the overview section under "Ocean" on page 38	
Proposal of draft criteria to EPA	Please refer to the 2nd paragraph in the overview section under "Ocean" on page 38	
Adoption of criteria into NJDEP's WQS	Please refer to the 2nd paragraph in the overview section under "Ocean" on page 38	

* All dates are targets based upon available resources and staff workloads; dates are subject to change

** Planning for criteria development was initiated in the 2013 Nutrient Criteria Enhancement Plan and finalized in this current Plan

LAKES:

The following individual projects were identified in the 2013 Nutrient Criteria Enhancement Plan and were deemed necessary to complete nutrient criteria enhancement for lakes; this section provides descriptions and justifications for each effort. Anticipated completion dates are included in Table 2.

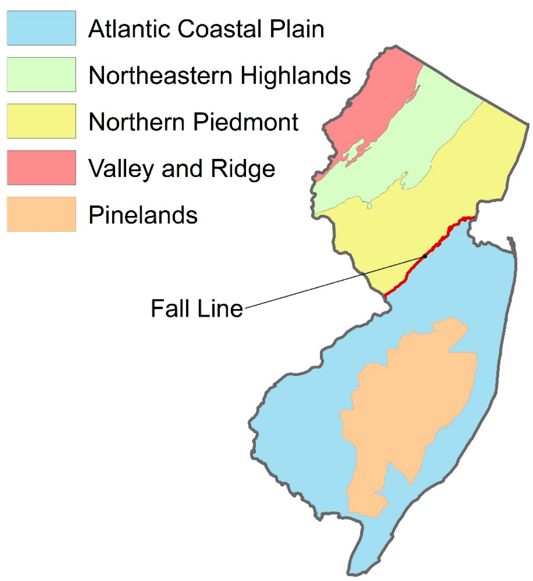
For purposes of criteria development, the Department is currently focused on lakes and impoundments *not* currently used for water supply. The Department assesses criteria towards the protection of aquatic life, primary and secondary contact recreation (swimming and boating), and aesthetics (regarded as an existing use). While waterbodies acting as sources to public water supplies are regularly monitored and managed for toxic substances resulting from cyanophytes or halogenated hydrocarbons, the Department has not yet considered drinking water supply at this time because end points for this use have not been determined and the effort will require coordinating with the State's water supply authorities. Drinking water supplies are often required to have low levels of organic carbon in the water column to control for halogenated byproducts that are the consequence of disinfection. This may require nutrient levels to be much lower than levels required to protect other uses. The Department will explore this option in the future as a separate effort. In addition, controlling for toxicity resulting from harmful algal blooms (HAB) may be difficult to control through nutrient criteria alone. The Department is none-the less focusing on the minimizing the presence and dominance of cyanophytes, the organisms responsible for algal based toxicity in fresh waters, through this criteria development process. The Department has also recently developed a Harmful Algal Bloom Strategy which includes standard operating procedures for reporting suspected HABs. Details are available at http://www.state.nj.us/dep/wms//bfbm/CyanoHABHome.html (please note this URL is case sensitive).

L1. Project Title: <u>Explore ecoregional nutrient ranges.</u>
Project Description: Goal of this project was to determine if ecoregions (see Figure 2) should be assessed separately or in combinations. Ecoregions showing similar nutrient ranges would be combined to enhance the statistical sample size. Ecoregions showing notably dissimilar nutrient ranges would be analyzed separately as this impacts the assessment of what nutrient levels are present in each ecoregion. This assessment will form the basis for all subsequent analyses. [2]

[2] The Lake Monitoring Network is based upon a 200 lake network randomly selected from a universe of 869 named New Jersey lakes of 5 acres or greater, excluding water supply reservoirs. The randomized site selection design creates an unbiased "snapshot" of lake conditions statewide representing a continuous disturbance gradient from pristine to degraded. As a result, the design supports an unbiased calculation of cumulative frequency distributions of lake water quality.

Status: This project is completed. Box and whisker plots of TN and TP ranges (see Appendix A) within the state's 6 ecoregions from data collected by the Department's lake monitoring network were generated to aid in assessing if ecoregions should be assessed separately or combined. Plots show the Piedmont Ecoregion to have consistently higher TP levels compared to the other NewJersey ecoregions. Total nitrogen levels were elevated in both the Piedmont as well as the southern Jersey Coastal Plain excluding the Pinelands. These data would suggest that in terms of phosphorus controls, the Piedmont should be managed separately from the other ecoregions.

Figure 2: Ecoregions with Pinelands



To further explore this question the Department investigated the possible contribution from the soils and geology of the Piedmont to high phosphorus and nitrogen within the Piedmont streams and lakes. Conversations with geologists from the New Jersey Geological and Water Survey (NJGS) indicate that the soil types and underlying geology would not explain why the Piedmont should have higher nutrient contributions in surface waters than any of the neighboring ecoregions.

The question was further explored in Project L7, Lake Paleo-limnology Investigations. The results of the study showed that estimates of lake pre-development phosphorus levels in the four principal ecoregions appeared to be within the same range. These observations are consistent with the NJGS statements that the pre-development conditions of all 3 northern ecoregions should show similar levels of phosphorus. It is the Department's belief that the higher nutrient levels observed in the Piedmont are likely the result of anthropogenic development within the Piedmont that exceeds levels of development observed in the other two ecoregions above the Fall Line (Figure 2).

L2. Project Title: Lakes Stratification Options: Lake size and Retention Time.

Project Description: The purpose of the study is to review the literature and decisions of other states regarding the significance of retention time in lake assessments and recommend thresholds for grouping lakes based on size and retention time. Lake retention time and nutrient cycling are strongly influence by lake size, bathymetry, and watershed drainage area. Lakes with relatively short retention times are less sensitive to the effects of phosphorus and may function more like riverine systems. Shallow lakes tend to be more nutrient enriched during the growing season than deep lakes**.** Proper stratification helps insure that criteria targets are achievable for the lake groups to which they are assigned.

Status: This project is in progress. For the purposes of nutrient criteria development, New Jersey is considering following EPA guidance which defines a lake as any impoundment of 10 aces or more having a retention time of 14 days or more. Beyond that definition, the Department has not seen sufficient evidence to justify differentiating among lakes of differing retention time. The behavior of nutrients within lakes is also partially a function of the lake's bathymetry and this exists along a series of continuous gradients whereby clear depth thresholds are difficult to establish. To compound the issue, some deeper lakes in the State have extensive littoral regions that can dominate in-lake nutrient exchanges making portions of a lake behave as a shallow lake. These issues remain under discussion within the Department.

L3. Project Title: <u>Northern New Jersey Lake Diatom Trophic Index.</u>
Project Description: Identification and enumeration of lake sediment diatoms to species level collected during the Department's routine monitoring of lakes for the Ambient Lakes Monitoring Network (see http://www.state.nj.us/dep/wms/bfbm/lakes.html). The current project was intended to enhance the database supporting the nutrient-diatom relationships described in the NJ Lake Trophic Diatom Index and to determine if the "stressor-response" relationships initially observed can be validated.

Status: The Department has decided that such investigations would not generate sufficiently useful information to justify the cost. This project was discontinued in 2016.

L4. Project Title: <u>Explore stressor-response relationships between nutrients and response variables (chlorophyll *a*, in-lake DO, and pH).</u>
Project Description: Using data from the Department's Lake Monitoring Network, graph and statistically explore in-lake nutrient species individually against the response variables chlorophyll *a*, DO, and pH to determine if there are predictable relationships between one or more nutrient parameters and response indicators. Evaluate whether the information can be used to enhance the Department's Carlson Trophic Index to better classify lake conditions. Based on the strength of the stressor-response relationship, determine what nutrient forms, and possibly the ratio of these nutrients, are most important to manage these response variables. All subsequent nutrient analyses will focus on those nutrient species determined most promising for effectively predicting changes in the identified response variables. The goal is to assess what nutrient levels correspond to the most desirable chlorophyll, DO, and pH targets for New Jersey lakes.

Status: Scatter graphs were generated for total N and Total P against chlorophyll *a* based upon data from the original 200 lake panel. Plots were segregated by ecoregion and were based upon discrete phosphorus recordings taken concurrently with chlorophyll recordings. Although there were positive relationships between nutrient and maximum chlorophyll levels, especially at low and moderate nutrient levels, the degree of correlation between discrete chlorophyll and total phosphorus levels appeared limited. The Department's approach was supplemented by literature studies of chlorophyll and nutrient data recorded over entire growing seasons (April through October). These literature-based data together with the Department's lake data suggest that as discrete recordings, elevated chlorophyll levels do not necessarily correspond with high nutrients and vice versa. More predictive of high algal productivity are overall growing season *average* nutrient levels compared to *average* chlorophyll levels over the same period (Cooke et al., 2005b). Momentary discrete high nutrient levels may not immediately trigger correspondingly high chlorophyll levels. Rather, algal productivity at any moment is the product of a complex of factors including (other than phosphorus and nitrogen availability) flushing rates, nutrient storage in the algal cells (luxury consumption), zooplankton grazing rates, etc. (Cooke et al., 2005a). The preponderance of literature confirms that assessing nutrient-chlorophyll relationships should be based on growing season averages based on monthly or (better) bimonthly recordings over multiple years.

The plots also suggested the following:

- New Jersey lakes are highly productive even at relatively low phosphorus levels, a finding supported by preliminary reference lake data;
- As a whole, with the exception of the Pinelands region, keeping *maximum* chlorophyll *a* levels below 20 µg/l (a level reflecting a moderate algal bloom) may be challenging in some lakes even when discrete TP recordings are below 20 µg/l.

Although these results may suggest limited predictability of low chlorophyll *a* levels with low total phosphorus levels in New Jersey lakes, the literature is replete with instances whereby reduction of phosphorus inputs to lakes have resulted reductions in lake overall productivity, especially when efforts are made to manage internal phosphorus loading (Cooke et al., 2005d). The impact of phosphorus reductions being more apparent in lower phosphorus systems in contrast to severely eutrophic systems (Cooke et al., 2005a).

The Department currently deems phosphorus control as the principal method to control lake primary production and resulting chlorophyll levels based on the predominance in the literature where phosphorus is the most efficient control vehicle to limit primary production (McCauley et al., 1989; Herlihy et al., 2013; Trimbee and Prepas, 1987; Schindler, 1974; Schindler et al., 2008; Schindler, 2012). Scenarios where nitrogen becomes limiting and necessary to control appear limited to hypereutrophic conditions where phosphorus is present in abundance (McCauley et al., 1989; Lewis and Wurtsbaugh, 2008), unusual conditions such as humic lakes (Jansson et al., 2001), or lake sheds upstream of coastal waters (Conley et al., 2009). The Program intends to prioritize the control of nitrogen in watersheds draining to coastal waters and may consider nitrogen controls in shallow lakes with abundant in-lake sediment stores of phosphorus (Lewis and Wurtsbaugh, 2008). Based on the findings regarding chlorophyll and phosphorus levels, and the decision to base the nutrient control strategy on the control of bluegreen algae blooms (see Project 6 below), the Program decided, for the purposes of state-wide criteria development, to defer the investigation of chlorophyll - nitrogen series relationships in fresh-water lakes at this time, and table the exploration of in-lake DO and/or pH against in-lake phosphorus levels as well. These decisions were further supported by observations that showed benthic DO levels to be commonly depressed even within reference lakes in New Jersey. The Department continues to monitor for all nutrient species.

L5. Project Title: Identify chlorophyll levels protective of various aquatic life uses.
Project Description: The Department's intent is to balance the conditions necessary to optimize a lake's recreational fisheries with those necessary to maintain a lake's contact recreational value when appropriate. To achieve this, the Department's target is to keep water column phytoplankton production relatively low and center primary production in submerged macrophytes (natural to the region, not invasive species). Macrophytes provide habitat for grazing zooplankton, forage fish, fry, and predatory game fish. These conditions along with a clear water column, combine to create the conditions favorable to stable populations of sport fish. In contrast, excessive phytoplankton production can lead to a clouding of the water, possible nuisance blooms, loss of submerged macrophytes, and a decline in the quality of the fishery from piscivorous species to one dominated by bottom feeders tolerant of high turbidity and low DO. These conditions will also severely diminish a lake's contact recreational quality. Although very low nutrient levels are more likely to maintain clear water conditions, some level of productivity is necessary to maintain the forage base needed to support higher trophic level predators (most sport fish). Hence, a balance must be met with nutrient inputs between water clarity and maintaining sufficient productivity to maximize recreational fishing potential, be it cold or warm-water. The goal is to identify a chlorophyll concentration that is appropriate for the type of fish community desired.

A review of lake criteria development in other states should be performed to determine what criteria levels (for nutrients and/or chlorophyll) are recommended to sustain healthy fish communities for recreational fishing including cold, cool, and warm water fisheries. In addition, work with the Department's Bureau of Freshwater Fisheries (BFF) to assess recreational fishery quality using a scale like Virginia's (Virginia Water Resources Research Center, 2005) and determine the nutrient/chlorophyll concentrations in lakes with excellent/good recreational fisheries and fair/poor recreational fisheries. Evaluate lakes in the probabilistically designed Ambient Lake Monitoring Network for which BFF has fishery assessments. These data can suggest target values to guide the balancing of recreational fish productivity with lake stability and balance competing uses. The goals are to assess what nutrient levels correspond with desirable chlorophyll, DO, and pH targets for New Jersey lakes based on the intended aquatic life use (warm vs cold water fisheries), the ecoregion and the other physical characteristics such as lake types (natural, impounded), lake size and depth.

Status: In addition to the steps delineated in the paragraph above, the Department completed a review of the fisheries literature for productivity and water quality conditions favorable to warm water sport fisheries. Analyses of lake water quality data from lakes deemed having high quality fisheries by the BFF is pending. In New Jersey, trout production lakes are limited to Round Valley and Merrill Creek Reservoirs. The bulk of the state's lakes are warm water fisheries and the principal game fish is the largemouth bass (BFF, personal communication). A review of fisheries literature reveal fish biomass to increase with increasing enrichment, however, this relationship is limited for many sport fish (Ney et al., 1990, Egertson and Downing 2004, Bachmann et al., 1996); whereby the density of sportfish begins to decline after an optimum level of primary productivity is reached within a lake.

Assessments of largemouth basses' tolerance of enrichment appear to vary; Kautz (1980) found Florida sport fish to reach maximum biomass and density at chlorophyll concentrations of 11 µg/l but declined with further enrichment while Maceina and Bayne (2001) found largemouth bass populations suffered when reservoir productivity was reduced from over 40 µg/l chlorophyll down to 9-17 µg/l. Stuber et al. (1982) states that largemouth bass are intolerant of high turbidity and suspended sediment.

Conclusions from the literature suggest that moderate levels of productivity, i.e. mesotrophic conditions or lower (see Carlson Trophic Index, in the Appendix B), may suppress to some degree New Jersey's in-lake bass populations. The mid-level eutrophic conditions may be the ideal for bass provided that the lake productivity is principally in macrophytes and not phytoplankton. In order to maintain these macrophyte dominated conditions, more mesotrophic to low end eutrophic levels may need to be maintained. In contrast, lack of proper lake management leading to hyper-eutrophic conditions or the opposite - excessive nutrient reductions to oligotrophic productivity levels (unlikely in New Jersey in most cases) may reduce the overall recreational quality of the state's bass fisheries. The Department still needs to assess the nutrient and chlorophyll levels in lakes deemed as superior recreational fisheries by the BFF.

L6. Project Title: <u>Identify in-lake N:P ratios and other factors that render lakes susceptible to cyanobacterial blooms.</u>

Project Description: Low N:P ratios may create favorable conditions for cyanobacteria. The presence of cyanobacteria can threaten a healthy fishery, degrade a waterbody's contact recreational value as well as an impoundment's drinking water use through cyanotoxin release. Review literature to determine if N:P ratios and other factors related to nutrients have been identified that increase the likelihood of cyanobacteria growth and blooms.

Status: Literature review on cyanophyta is completed. Microcystin monitoring is ongoing. Cyanobacteria can severely impair a multitude of designated uses in lakes including potable use, recreation, aesthetics, and aquatic life. They are well known to cause unsightly, sometimes bad smelling blooms and can produce toxins that kill aquatic animals, pets, livestock, and on occasion humans. When toxins are present they can also accumulate in shellfish which can cause illness when they are consumed (see https://www.epa.gov/nutrient-policy-data/health-and-ecological-effects#how1). Cyanobacterial metabolites produce taste and order problems that elude conventional drinking water treatment (Dokulil, M.T. and Teubner, K. 2000; Downing, J.A., et al., 2001).

It is evident that managing cyanophyte dominance in lakes represents an important goal in lake management. It is generally accepted that controlling nutrient levels in lakes will likely control for most cyanobacterial problems as well as minimize blooms of other algal forms. Watson et al. (1997) in studying the shifts in algal taxonomic groups over a wide nutrient gradient in 91 north temperate lakes found that all taxonomic groups increased in overall biomass as TP increased. At low levels of overall lake productivity as reflected in chlorophyll levels, cyanophyte dominance as a proportion of the algal community was low whereas beyond a specific chlorophyll threshold, cyanophyte dominance increased sharply. This relationship has been observed in numerous lake algal studies. The reverse has also been demonstrated, that reducing nutrient inputs, especially phosphorus, will reduce algal productivity (Cooke, et al., 1993d, Schindler, 2012) and concurrently the likelihood of cyanophyte dominance (Watson et al., 1997, Dokulil and Teubner, 2000) and abundance (Trimbee and Prepas, 1987, Jeppesen et al., 2005).

<u>Cyanophyta Dominance and N:P Ratios</u>

In the early 1980's a hypothesis circulated based on lake observations (Smith, 1983) and other researchers that low nitrogen to phosphorus ratios favor the dominance of cyanobacteria. Smith 1983 stated that the relative proportion of cyanophytes in lake phytoplankton was dependent on the TN:TP ratio whereby at ratios greater than 29:1 cyanophytes tended to be rare. He further recommended controlling this ratio as a means of controlling lake cyanophytes. Low ratios of N/P in concert with high nutrient levels have been associated with cyanobacterial dominance in many studies (Soranno, 1997; Schindler, 1977; Dokulil and Teubner, 2000); specifically those ratios below 30:1.

Downing et al. (2001) explored this hypothesis and found that although ambient N:P ratio could predict the likelihood of bluegreen dominance (>50% of phytoplankton biomass being cyanophytes), it was a poorer predictor of BG dominance than simple concentrations of P. The single *best predictor* of cyanophyte dominance was overall phytoplankton biomass. Next was concentration of P & N, last was ratio of N:P. These authors base their finding on 269 observations taken from 99 north temperate zone lakes. Schreurs, 1992 also found overall lake productivity as reflected in chlorophyll levels as the single best predictor of overall cyanophyte dominance.

Cyanophyta Dominance and Phosphorus

Perhaps more important to the purpose here, Downing's study further states that cyanophyte dominance was limited to 0-10 percent between TP levels of 0 to 30 µg/l (expressed as a summer mean). When TP levels ranged between 30 to 70 µg/l, the risk of cyanophyte dominance abruptly rose then became asymptotic at near 80 percent at about 100 µg/l P. Trimbee and Prepas (1987) observed similar results as Downing stating that after studying 19 Alberta lakes they concluded that TP was a much better predictor of cyanophyte biomass that either TN concentrations or TN:TP ratios." The paper also stated that "there are many examples in the literature where decreases in phosphorus loadings have resulted in decreases in bluegreen algae." Watson et al. (1997), mentioned earlier, examined cyanophyte dominance as a function of mean summer TP and found that cyanophytes showed the lowest biomass (and percent dominance of the algal community) in lakes with average summer TP of less than 10 µg/l. At 10 µg/l there is notable increase in cyanophyte biomass. Between TP of 10 and about 25 µg/l there was little in the degree of cyanophyte dominance. Somewhere between 25 and 50 µg/l cyanophyte dominance begins to increases rapidly till about 100 µg/l at which time blue greens could completely dominate the algal community.

Cyanophyta Dominance and Chlorophyll Levels

Downing et al. also observed that when water column chlorophyll levels were below 10µg/l, the risk of cyanophyte dominance was 10 percent or less. When summer mean chlorophyll levels exceeded 10 µg/l, the risk of cyanophyte blooms increased sharply. The authors also stated that the 10 µg/l threshold is regarded as a "known" breakpoint where nuisance blooms occur at high frequency. This conclusion is supported by Walker (1985) who compared mean chlorophyll levels to the probability of nuisance blooms occurring of varying intensity characterized as chlorophyll *a* levels of 20, 30, and 40 µg/l. He found that below a mean chlorophyll level of 10 µg/l bloom frequencies are minimal. These bloom frequencies rise sharply as mean chlorophyll levels exceed 10 µg/l. The World Health organization in its recommendations towards keeping the risk of health effects from cyanotoxins to a relatively low level recommended guidelines for chlorophyll levels to not exceed 10 µg/l *when there is a dominance of Cyanophyta in the phytoplankton community* (WHO, 2003).

These results may be influenced by overall lake depth and the cyanophyte species comprising the overall cyanophyte community. Schreurs (1992) when studying shallow eutrophic lakes in the Netherlands, found that cyanophyte dominance declined notably as chlorophyll *a* declined below 100 mg/m^3 (fig 10.3 in Shreurs, 1992:) and that cyanophyte biomass declined steadily with overall algal biomass. However, when the same analysis was applied to deeper Norwegian lakes, he observed no relationship between productivity and cyanophyte dominance. Caution is advised in interpreting these results, however, in that the Norwegian sample size was small compared to the Dutch lake data. Schreurs also observed that degrees of dominance within Oscillatoria populations were very responsive to lake productivity levels whereas Microcystis dominance was not.

Other Factors Observed to Favor Cyanophyte Blooms:

Cyanobacteria are often abundant in water with elevated temperatures, stable water columns with minimal vertical mixing, low N/P ratios as stated earlier, and high overall nutrients (Dokulil and Teubner, 2000; Soranno, 1997). Some species have high phosphorus storage capacities and have evolved strategies to inhibit zooplankton grazing through the use of various toxins (Dokulil and Teubner, 2000; Soranno, 1997). They also do well in waters where water transparency is compromised (Downing, et al. 2001). Chen et al. (2003) states that wind speed & direction can enhance the perception of bloom conditions due to the wind induced accumulation of floating cells such as those of Microcystis into bays and other shore-line areas. Cyanophytes are also known to bloom and create turbid conditions and then exploit a competitive advantage over green algae under these conditions (Scheffer, M. et al., 1997). Gophen et al. (1999) observed conditions characterized by N-deficiency and P sufficiency to favor cyanophyte dominance, especially nitrogen fixing forms in an Israeli lake. They recommended reducing P loading to control cyanophyte in concert with allowing increases in N in the water column to enhance N:P ratios.

In summary, these studies show that there is strong support in the literature to maintain chlorophyll *a* levels at 10 µg/l or lower as a mean value and total phosphorus no higher than 30 µg/l. Controls on N are controversial. There is concern that reducing N will provide a competitive advantage to N fixing cyanophytes, especially in relatively clear lakes. The literature suggest maintaining N:P rations (by mass) no lower that 29:1. Cyanophyta are a big issue with recreational and water supply lakes; less of an issue for fishing lakes. Criteria consideration need to address climate change where blue green events appear to be on the rise from rising and longer lasting summer temperatures. Criteria levels may need to be made more restrictive in view of this growing problem specially with recreational lakes.

Cyanotoxin Monitoring

Beginning in 2013, the Department added the capacity to analyze surface waters for cyanotoxins, specifically microcystins, anatoxin-a, and cylindrospermopsin. These capabilities allow the Department to confirm the presence of cyanobacteria and concentrations of toxins to provide accurate guidance regarding recreational action levels and health advisories. This analysis was initially performed in routine lake monitoring to gauge the levels and frequency of occurrence of cyanotoxins in New Jersey lakes at levels of concern. The Department has completed a Cyanobacterial Harmful Algal Blooms (HABs) Freshwater Recreational Response Strategy and Guidance which can be viewed at: http://www.state.nj.us/dep/wms//bfbm/NJHABResponseStrategy.pdf. The Strategy provides a unified statewide approach to responding to HABs in recreational waters and sources of drinking water and to protect the public from risk associated with these toxins. Part of this strategy is a HAB alerting system whereby the public can alert the Department to a suspected HAB and the Department in turn can coordinate an appropriate response with State and local public health authorities. Details on the alerting system are available at: (please note that both of these URLs are case sensitive).

L7. Project Title: Paleo-limnology Investigations.
Project Description: Diatoms in lakes and streams have long been regarded as sensitive indicators of nutrient levels as well as other disturbance factors in waterways. An academic contractor is exploring the use of diatom frustules taken from lake sediment cores to infer nutrient levels in lakes going potentially as far back as pre-European settlement.

In theory, examining evidence of historical algal communities can infer historical in-lake nutrient levels that reflect pre-European settlement nutrient profiles thereby providing an alternative method to explore lake reference conditions. This would be accomplished by comparing sediment diatom frustules in the upper sediment layer, representing current conditions, with those contained within deeper core layers, reflecting historical conditions. Layer dating would be accomplished by isotope dating or more economically by the presence/absence of ragweed pollen indicating the boundary line of European settlement. A significant limitation of this effort is it only applies to natural lakes (approx. 60) and a limited number of manmade lakes in the state.

Status: Effort encountered technical difficulties in diatom frustule identification and in developing the inference models. The Department is investigating whether to correct the problem or cancel the effort and rely solely on reference lake data instead. The results obtained do suggest that there is no significant difference between Ecoregions in terms of ancestral total phosphorus levels suggesting that all New Jersey lakes can be assessed and managed as a single population and that stratification is unnecessary. These results are currently regarded, however, with caution.

L8. Project Title Recommend nutrient criteria to protect aquatic life uses or identify additional research needs.
Project Description: Review assessment results from the preceding work in the context of a multiple line of evidence approach. Based on these results, determine if assessment results are

sufficiently robust to support scientifically defensible criteria and if so, recommend numeric nutrient criteria for lakes to protect aquatic life use and minimize exposures to cyanobacteria. The recommended criteria will specify frequency, magnitude, and duration where applicable. If there are insufficient data to support a criterion proposal, recommendations for additional data gathering and analysis to enhance the database will be provided.

Status: In applying a multiple line of evidence approach from the perspective of the Department's literature review presented here, the data suggest that a chlorophyll value not exceed 10 µg/l, possibly expressed as a summer average and Total Phosphorus values to not to exceed 25 to 30 µg/l, again possibly expressed as a summer average. Since the Department is not currently considering the deeper cold-water fishery/water supply reservoirs here, these target chlorophyll and total phosphorus levels suggest a lake target to be a mesotrophic-low eutrophic condition. Cooke et al. (2005c) report that using a lake trophic model, they found lakes with a total phosphorus of 25 µg/l represented a high probability of being mesotrophic but had an equally low probability of being either oligotrophic or eutrophic. These observations then lead to the question as to how attainable are these suggested chlorophyll and phosphorus targets in New Jersey lakes which subsequently resulted in Project L9 below.

It can be noted that The Department's Passaic TMDL (http://www.nj.gov/dep/wms/bears/docs/passaic_tmdl.pdf) recommended chlorophyll *a* targets of 10 µg/l as summer average for the Wanaque Reservoir and 20 µg/l in Dundee Lake, a shallow riverine impoundment exhibiting a very brief residence time of 1.4 days. These TMDL targets are based on best professional judgment as to reasonable productivity levels expected in a deep water-supply reservoir and a shallow river run impoundment.

L9 New Project: **Assess reference lake nutrient and chlorophyll nutrient ranges.**

Project Description: Collect in-lake data on nutrient, chlorophyll, and DO levels in reference lakes. Because of the difficulty in finding true reference condition in New Jersey for the larger deeper lakes, this effort may involve modeling reference conditions for some lakes. Since EPA guidance does provide states the option of setting lake nutrient criteria to represent the 75th percentile of reference lake distribution, these data will provide both an understanding of what limits are achievable if applied to New Jersey lakes and the resulting frequency distributions can be employed to generate alternative chlorophyll and phosphorus limits.

Status: The Department began recording the chemical/physical profiles of reference lakes in the spring of 2016 to understand the nutrient and productivity ranges of undisturbed New Jersey lakes. Data collection is still ongoing. Current list of reference lakes, with a few exceptions, are relatively shallow. The Department is currently planning to model some of the larger lakes to simulate conditions without anthropogenic influences.

Table 2. Projects Associated with Lake Criteria Development

Project	Description	Start Date	Status/Completion Goal*
L1	Explore ecoregional nutrient ranges	July 2013	Completed
L2	Lake Stratification: Lake size & Retention Time	Fall 2015	2018
L3	NJ Northern Lake Diatom Trophic Index	March 2013	cancelled
L4	Explore Lake stressor-response relationships	2012	completed
L5	Chlorophyll levels protective of fisheries	July 2013	On going
L6	(1) N:P Ratios and cyanobacterial bloom. (2) Microcystin Monitoring	June 2013	Item 1 completed; item 2 ongoing
L7	Paleo-limnology Investigations	2010	Under review (2020)
L8	Recommend nutrient criteria/additional research needs for lakes	Not determined	2020
L9 New Project	Explore reference lake nutrient, chlorophyll and DO levels	2016	2020

* All dates are targets based upon available resources and staff workloads; dates are subject to change

STREAMS:

The Department collects benthic invertebrates and finfish in streams to assess the aquatic life use. See http://www.state.nj.us/dep/wms/bfbm/index.html for descriptions of the networks. These data have been recently supplemented with limited diatom data in non-tidal wadeable streams outside the Pinelands. These biological data are collocated with chemistry data allowing the Department to 1) assess nutrient–response relationships between nutrients and all three biological communities as well as with chemical responses such as DO and pH; 2) provide nutrient data to support calculating cumulative frequency distributions reflective of the distribution of chemical conditions within the wadeable streams of the state; and 3) using data from reference streams to calculate cumulative frequency distributions of nutrients within reference streams. The utility of these three assessments in the context of nutrient criteria development are discussed within the first two paragraphs of section II, “Criteria Development Process” earlier in this document.

The following projects are designed to collectedly provide the information necessary to enhance wadeable stream nutrient criteria; anticipated completion dates are provided in Table 3.

S1. Project Title: <u>Explore ecoregional nutrient ranges.</u>
Project Description: For the purpose of nutrient assessment, the Department will explore the nutrient ranges within each of the six ecoregions to determine if any can be combined or need to be assessed separately. Preliminary data suggest that the nutrient rich Northern Piedmont may require an assessment separate from the other two northern ecoregions. As with lakes, stream nutrient data from the Ridge and Valley and Highlands ecoregions will be reviewed to see if these two ecoregions should be treated as a single entity or kept separate. A similar assessment will be performed to see if portions of the coastal plains (as discussed in the lake section) also require separate assessments.

Graphically review TN and TP ranges within the state's ecoregions from the data collected by the randomly-sampled portion of the ambient monitoring program. Ecoregions showing similar ranges should be combined to enhance the statistical sample size while ecoregions possessing dissimilar ranges should be analyzed separately as this impacts what nutrient levels are determined to be attainable within each ecoregion. This assessment forms the basis for all subsequent ecoregional analyses.
STATUS: May not be necessary based on conversation with NJGS. See L1.

S2. Project Title: <u>Explore stressor-response relationships between nutrients and response variables (in-stream biological condition, DO and pH).</u>
Project Description: The biological condition as measured using the index scores recorded by the biomonitoring program for fish (IBI) and benthic invertebrates (HGMI, CPMI, PMI, etc.) represent a response variable in the context of nutrient-response analyses. These indices are not calibrated to nutrient levels alone but to an overall anthropogenic footprint that includes a wide range of environmental degradation. The Department will explore whether there are nutrient levels below which biological impairment is unlikely with the understanding that nutrient levels do correlate to other anthropogenic stressors that negatively impact biota. The Department will also explore whether there are nutrient thresholds above which the biological condition and nutrient relationship abruptly change. Thirdly, the Department will examine the individual biometrics for both invertebrates and fish (e.g. Hilsenhoff Biotic Index, number of scraper genera, etc.) to determine whether these metrics provide a strong nutrient response relationship.

The Department will initially review cause-response relationships with nutrients using scatter plots possibly followed up by regression and/or classification/ordination techniques. Using scatter plots, graph the nutrient species (TP, PO4, NO3, NH4, TKN, etc.) individually against the response variables including individual biological metrics and indices, DO, and pH to determine if there are predictable relationships between one or more nutrient parameters and response indicators. This analysis is limited to those sites that have both chemical and biological data.

Therefore, to enhance diversity of sites with both biological data and physical/chemical data, additional monitoring will be conducted over the next three summers. The Department will collect biological samples at the newly established statewide probabilistic rivers and stream network. This network consists of 50 sites scheduled for quarterly sampling for physical/chemical parameters from July 2013- June 2015.

STATUS: BFWBM has modified its biological monitoring such that a chemical/physical sample is taken concurrently with biological sampling. This will allow a discrete nutrient value to accompany each discrete biological measurement. Analysis is expected to begin in early 2018 once sufficient data has been collected.

S3. Project Title: <u>Identify nutrient levels determined to be protective of aquatic life uses in other states</u>.

Project Description: Review information from other states to inform establishing nutrient target values (criteria or translators) that protect aquatic life uses.

Status: On going. This Project is closely tied to the outcomes in S2.

S4. Project Title: <u>Continue exploring relationships between instream nutrient levels and diatom community condition measurements (Biological Condition Gradient or BCG).</u>

Project Description: This effort will show the relationship between instream nutrient levels and the presence or absence of desirable diatom communities. Details are contained in the 2010 Progress Report under "Biological Condition Gradient" (page 11). Preliminary work overseen by the Academy of Natural Sciences of Drexel University in 2012 using a selected number of stations in northern New Jersey identified nutrient thresholds above which diatom communities significantly degrade based upon a preliminary biological condition gradient. The Academy recommended that additional monitoring be conducted to expand the range of stations sampled to improve the model. Diatom/nutrient data from an additional 40 to 80 sites will be assigned to their respective BCG categories and used to supplement existing data to enhance the exploration of nutrient-BCG relationships.

Status: Project is completed (see Hausmann et al., 2016)**.** The Academy of Natural Sciences of Drexel University and Tetra Tech, Inc. performed a series of workshops in 2014 wherein a panel of diatom experts built upon earlier work in 2012 to develop a diatom BCG. The assessment was initially developed using sites in northern New Jersey then validated with additional sites located from New York south to Virginia. The investigation reinforces initial findings when the more limited 2012 study was performed.

S5. Project Title: <u>Determine the natural variability of phosphorus concentration at selected diatom sites.</u>

Project Description: The Department will collect weekly phosphorus samples for an extended period at diatom sites exhibiting low to moderate BCG categories. The Department will seek support from monitoring partners to collect and analyze samples for phosphorus concentrates at these targeted sites. Data will be used to establish the frequency and duration for the recommended phosphorus criterion.

Status: Project is currently on going. Field sampling is completed and all data is collected. Data analysis is expected to be completed by spring of 2018. An important aspect of this study is to compare nutrient data expressed as seasonal or annual means as seen in Project S4 to the same ranges expressed as "not to exceed" values or as percentiles of a distribution.

S6. Project Title: <u>Recommend numeric nutrient criteria for wadeable streams to protect aquatic life use or identify additional research needs.</u>

Project Description: Review assessment results from the preceding work in the context of a multiple line of evidence approach. Based on these results determine if assessment results are sufficiently robust to support a scientifically defensible approach to criteria development and if so, recommend numeric nutrient criteria for streams in NJ to protect and enhance aquatic life. The recommended criteria will specify frequency, magnitude, and duration and where the criteria would be applicable. If analysis results lack sufficient robustness, recommendations are made regarding additional data gathering and analysis necessary to enhance the database needed to develop scientifically defensible criteria.

Status: The Department is currently looking to make criteria recommendations in 2022 (see Table 3, below).

Table 3. Projects Associated with Stream Criteria Development

Project	Description	Start Date	Status/Completion Goal*
S1	Explore ecoregional nutrient ranges	2017	2017
S2	Explore stream stressor-response relationships	2017	2018-2020
S3	Nutrient levels protective of fisheries	2017	2018
S4	Continue diatom collection and enhancement to TDI and BCG	July 2013	completed
S5	Evaluate natural variability in phosphorus	winter 2014	Spring 2018
S6	Recommend nutrient criteria/additional research needs for streams	Not determined	2022

* All dates are targets based upon available resources and staff workloads; dates are subject to change

ESTUARIES, INCLUDING TIDAL RIVERS (BARNEGAT BAY AS MODEL)

The approximately 260 square miles of New Jersey estuaries contribute significantly to the state's 3.4 billion dollar shore economy (from American Littoral Society). The 75 square miles of Barnegat Bay represents a significant portion of the state's estuarine resources. Facing the growing public concerns on the health of Barnegat Bay, the Governor instituted a 10-point plan (Plan) (see http://www.nj.gov/dep/barnegatbay/docs/barnegat_bay_10-ptsGOV.pdf) to restore the ecological health of the Bay. A detailed water quality assessment on the Bay and its tributaries using chemical and sanitary data can be viewed at (http://www.nj.gov/dep/barnegatbay/docs/barnegat_bay_interim_assessment_06_26_2014.pdf). A significant component of the nutrient criteria development effort for estuaries will take place in the context of this Plan which represents a broad management strategy to address a suite of problems including sea level rising, overfishing, excessive sea nettles, shellfish population loss, boating impacts, concerns surrounding aquatic vegetation, and other issues. Comprehensive information on the Department's efforts in the Bay including the Plan are described at http://www.nj.gov/dep/barnegatbay/. Action 7 of the Plan is "Adopt more rigorous water quality standards" which can be achieved through the development of numeric criteria, load limits, or surrogates in the form of response indicators. Although conceived independent of Action 7, Action 9 "Fill in gaps in research" provides important stressor-response assessments involving benthic invertebrate and phytoplankton communities along nutrient-centered disturbance gradients providing additional support to the criteria development process.

On national and regional scales, estuaries within the United States can vary significantly from one another in terms of benthic substrates, fresh and salt water hydrology, climate as well as other factors making each one unique. In view of this, reference condition approaches may not be practical for Barnegat Bay because no other estuary in the eastern US share the site-specific conditions sufficient to serve as reference conditions for other estuaries. The development of the nutrient criterion for Barnegat Bay is dependent on the stressor-response relationships specific to this waterbody.

Developing the site-specific nutrient target for the Barnegat Bay involves a multi-faceted approach. Since 2011, the Department has been conducting a comprehensive water monitoring program along the tributaries and throughout the Bay. Data revealed some regions of the Bay violating the applicable Dissolved Oxygen (DO) and turbidity criteria. Data collected primarily between June 2011 and June 2013 were used to construct a complex coupled hydrodynamic – water quality model to simulate the Bays water circulation patterns, the distribution of salinity and temperature, their impacts on the transport and fate of nutrients, primary productivity (chlorophyll a), and dissolved oxygen levels in the water column. Additionally, the water quality model simulates interaction of DO and nutrients between the water column and the sediment.

The water quality model is expected to clarify the relationship between pollutant loads and water quality condition. Combining the modeling outcomes with an understanding of the biological responses to the nutrient concentration gradients will result in a suite of restoration measures designed to achieve full aquatic life support within the Bay. The findings in Barnegat Bay and the analytical approach developed through this effort will provide tools to utilize in other New Jersey estuaries.

The following Barnegat Bay projects are designed to provide the information necessary to establish site-specific nutrient criteria for Barnegat Bay. Current status is provided in the paragraphs below and anticipated completion dates are provided in Table 4.

B1. Project Title: Development of Barnegat Bay Hydrodynamic Model.
Project Description: Using data collected from the Barnegat Bay Comprehensive Monitoring Project's flow gages, chemical monitoring, and bathymetric measurements, develop a hydrodynamic model of the Barnegat Bay. This model will simulate the movement of water and particles throughout the system. It will be linked with a water quality model to allow simulation of what happens to nutrients, sediment, and other inputs to the Bay as a result of the physical, chemical, and biological processes that occur in that system.

Status: The hydrodynamic model of the Barnegat Bay has been completed and is based on Regional Ocean Modeling Systems (ROMS), a component within the Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST) System modeling suite (Warner et al., 2010, see also: https://woodshole.er.usgs.gov/operations/modeling/COAWST/). The model simulates the movement of water within the Bay and predicts the water level and tidal discharges as well as the changing temperature and salinity profiles within the bay. The outcome of the hydrodynamic model is passed to the water quality model (Project B2), via a specially-built linkage file. This in turn drives the simulation of water quality components, such as nutrients, DO, Chlorophyll *a,* and Total Suspended Solids, by integrating the impacts of the physical, chemical and biological processes that occur in that system. The hydrodynamic model is also being used to simulate some assumptive conditions, such as rerouting wastewater treatment plant discharge back to the Bay and possible future weather or climate conditions.

B2. Project Title: Development of the Barnegat Bay Water Quality Model.

Project Description: As a concurrent and follow-on project to the hydrodynamic model, develop a water quality model to simulate the fate and transport of key parameters related to water quality standards and designated use attainment. This model will be used, along with the findings from the scientific projects described below, to establish water quality or pollutant load thresholds that are consistent with restoring the health of the Bay, with respect to water quality. It is recognized that other stressors, not related to nutrients, play an important role in the observed condition of the Bay.

Status: Applying the hydrodynamic model output, a water quality model is built on EPA's Water Quality Analysis Simulation Program (WASP) model and makes use of an advanced eutrophication module to utilize point and non-point loadings, oxygen demands and simulate nutrient fate and transport, and phytoplankton dynamics. The fate and transport of key parameters, such as nitrogen, phosphorus, silica, DO, and Chlorophyll *a* are simulated. The calibration of the water quality model is on-going. Modifications and adjustments are being made to provide the satisfactory simulation of all the water quality parameters of concern and is critical to evaluate the overall health of the Barnegat Bay system. The model calibration is expected be completed by the end of 2019.

Outcomes from these model simulations, along with the findings from the scientific projects described below, will provide an understanding of the cause and effect relationships for the water quality impairments. This in turn allows the establishment of water quality targets or pollutant load thresholds that are consistent with restoring the ecological health of the Bay from a water quality perspective.

B3. Project Title: Complete research projects designed to collect necessary data on various ecosystem variables (phytoplankton, zooplankton, fish, crabs, and other benthic invertebrates).

Project Description: This represents the ten research projects overseen by the Department's Division of Science, Research, and Environmental Health (DSREH) focused on biological properties of the Bay designed to fill in information gaps.

Status: The DSREH within the Department oversaw the following ten research projects focused on investigating the biological properties of the Bay and filling information gaps.

Barnegat Bay Comprehensive Research (2011 – 2015)

- Benthic Invertebrate Community Monitoring and Indicator Development
- Algal Diatoms as Environmental Indicators
- Assessment of Hard Clam Populations
- Assessment of the Distribution and Abundance of Stinging Sea Nettles (Jellyfishes)
- Baseline Characterization of Phytoplankton Communities and Harmful Algal Blooms (HABs)
- Baseline Characterization of Zooplankton Communities
- Assessment of Fish and Crabs
- Multi-Trophic Level Modeling
- Tidal Freshwater and Salt Marsh Wetland Studies of Changing Ecological Function and Adaptation Strategies
- Ecological Evaluation of Sedge Island Marine Conservation Area

Project summaries may be found at http://www.nj.gov/dep/barnegatbay/plan-research.htm. From the perspective of nutrient criteria development, two projects stand out: *project number one - the development of a benthic invertebrate biometric* and *project six - an investigation into the phytoplankton community.* Project one represents the development of a benthic invertebrate bio-metric and its subsequent use to assess the health of the community within the bay and its saline tributaries. All three reports are posted to: http://nj.gov/dep/dsr/barnegat/final-reports/benthic-invertebrate-reports.htm. The metric categorizes taxa into five ecological groups depending on their relative sensitivity, or lack thereof, to organic pollution (see Borja et al., 2000 for a description of the ecological groups). Preliminary findings (see Taghon et al., 2016) showed a decline in the predominance of "ecological group one," the sensitive or pollution intolerant taxa under conditions of increasing total nitrogen and increasing chlorophyll-*a* concentrations in the Bay water column. The inflection point suggest possibilities where TN levels might be maintained to minimize deleterious impacts to the benthic community. Additional biological and chemical data was collected in the spring/summer of 2016 and 2017 to validate the initial findings before final decisions are made regarding nutrient impacts on benthic communities.

Project number six investigates the phytoplankton communities within the Bay, looking at nutrient and other impacts as well as developing a phytoplankton Index of Biotic Integrity (IBI). Full reports may be viewed at http://nj.gov/dep/dsr/barnegat/final-reports/phytoplankton-reports.htm. Findings to date show increases in phytoplankton density as measured as chlorophyll *a* under enriched conditions which could be associated with undesirable light attenuation within the Bay's water column. Also observed are shifts in the phytoplankton community composition along a nutrient gradient which the Department is reviewing to see if these changes affect the phytoplankton community's ability to support higher trophic levels within the Bay. This work is still ongoing.

Summaries of all Barnegat Bay research can also be reviewed in the in the Fall 2017 edition of the Journal of Coastal Research, Special Issue #78 entitled "A Comprehensive Assessment of Barnegat Bay-Little Egg Harbor, New Jersey." The issue presents 20 peer-reviewed papers on the bay.

B4. Project Title: Identify stressors and develop stressor response relationships.

Project Description: Based upon results of the DSREH research projects described above and using the hydrodynamic/water quality model, identify relationships between anthropogenic stressors to the Bay and resulting biological condition, as relates to water quality. Use this information to establish numeric criteria and/or loading thresholds.

Status: Ongoing; see Projects B1 – B3 above.

B5. Project Title: Assess current conditions, identify problems areas and evaluate actions to restore conditions.

Project Description: Based upon acquired information, assess the current level of attainment, identify the sources of non-attainment, and develop a restoration plan for the Bay.

Status: A detailed water quality assessment on the Bay and its tributaries using chemical and sanitary data was released by the Department in 2014 (http://www.nj.gov/dep/barnegatbay/docs/barnegat_bay_interim_assessment_06_26_2014.pdf). These data identified exceedances of water quality criteria for DO within the central and lower-most portions of the Bay and exceedances of the turbidity criterion largely in the lower portions. Some portions were also exceeding sanitary criteria from the Toms River estuary northward, for recreation in some locations and shellfish harvesting criteria in others.

These chemical assessments have been supplemented by biological assessments using benthic macroinvertebrates and phytoplankton from research efforts outlined in project B3 above. Both a watershed wide restoration plan and a Total Maximum Daily Load (TMDL) analysis are currently being planned. Water Quality targets for the TMDL will be developed from the outcomes of projects B1, B2, B3, and B4 above.

B6. Project Title: Evaluate the applicability of the Barnegat Bay recommendations to other estuaries.

Project Description: The Department will evaluate the appropriateness of using the benthic macroinvertebrate index and other thresholds developed through the intensive research and monitoring conducted in Barnegat Bay to evaluate aquatic life conditions in other bays. Additional data collection, research, and analysis may be needed to refine the Barnegat Bay metrics to other coastal waters.

Status: The Department will be drafting a contract with Rutgers University to begin investigating the transferability of the macroinvertebrate IBI to other New Jersey estuaries. It is yet to be determined what other analytical methods employed in Barnegat Bay will be transferred to other estuarine assessments.

Table 4. Projects Associated with Estuarine (Barnegat Bay) Criteria Development

Project	Description	Start Date	Status / Completion Goal*
B1	Develop Hydrodynamic Model	2012	End of 2016
B2	Develop Water Quality Model	2012	2017
B3	Complete research projects designed to collect necessary data on various ecosystem variables	2011	2018
B4	Identify stressors and develop stressor response relationships	2012	2019
B5	Assess current conditions, identify problem areas and evaluate actions to restore conditions	2012	2019
B6	Evaluate the applicability of the Barnegat Bay recommendations to other estuaries	2018-2019	2022

* All dates are targets based upon available resources and staff workloads; dates are subject to change

OCEAN:

Overview: Low dissolved oxygen within the lower portions of the water column and adjacent to the ocean floor have been observed in the ocean off the New Jersey coast for several decades. In response, the Department listed the ocean in 2002 as impaired for aquatic life use based on the reported low DO. Data collection at that time, however, was limited to weekly or bi-weekly discrete data hence the Department was unable to evaluate the duration and frequency of these events nor was it able to assess the impacts on the local biology. New Jersey's nutrient investigations in ocean waters are currently focused on: 1) finalizing a biological indicator for near-shore ocean waters; 2) reviewing USEPA's recommended dissolved oxygen criteria for marine waters; and 3) enhancing the Department's monitoring capabilities to better evaluate the frequency and duration of low DO events for the purpose of developing an assessment methodology to evaluate New Jersey's near-shore DO conditions against EPA marine criteria.

Currently, the Department has no plans to develop nutrient criteria for the ocean waters under New Jersey's jurisdiction. It is the Department's view that nutrient criteria in ocean waters should be undertaken on a regional basis led by EPA, treating the ocean as an interstate contiguous waterbody, much the same way EPA developed marine DO criteria. Marine nutrient impacts are complex for several reasons. Controversies still surround what are the limiting nutrients in the marine environment (Downing, 1997). In addition, the influx of nutrients to nearshore waters in the continental US can be highly complex and represents a blend of tributary inputs encompassing several states combined with coastal upwellings. These inputs combined with concurrent denitrification in the nearshore sediments make estimating coastal nutrient budgets highly complex (Fennel et al., 2006) and beyond the resources of individual states to evaluate. In addition, adjacent states may derive different criteria based on varying methodologies. Tied to this effort should be a regional assessment of the degree that anthropogenic inputs are contributing the overall DO profiles observed in the near-shore ocean. Here again, in view of the spatial extent, overlap of multiple states' waters and complexity of the effort, EPA would be in the best position to oversee such analysis. New Jersey is looking forward to participating in both efforts.

A biological index has been developed by Rutgers University based upon benthic invertebrates to assess the condition of these near-shore communities. The metric still requires validation, however, preliminary results show almost no impairment to benthic biota in the near shore waters.

Concurrently, DO and other ocean data collected by submerged mobile continuous data recorders (slocum gliders) allow the Department to obtain a better understanding of the spatial extent and duration of the low DO regions and their relationship to wind patterns and ocean upwellings. To better assess these continuous data and more effectively implement EPA's regional DO criteria, the Department formed a Science Advisory Board (SAB) to aid the Department in these matters. Resulting recommendations from this SAB are available at http://www.state.nj.us/dep/sab/NJDEPSAB-Continuous%20Monitoring%20of%20Dissolved%20Oxygen_012616.pdf. In addition, the Department is seeking EPA assistance in processing the data and developing discrimination models.

The ocean is currently a low priority for nutrient impact assessments for the following reasons: 1) the Department believes the nutrient criteria development effort should be a EPA led regional effort; 2) the Department has as yet not encountered biological impairment in New Jersey's nearshore waters; 3) measuring duration of the low DO regions is expensive (e.g. each marine monitoring buoy is currently priced at $75,000 not counting the additional cost of maintenance/regular calibrations) and is technically difficult at this time, rendering EPA's DO criteria limited in its utility; 4) there is increasing evidence that the low DO observed in the near-shore waters is the result of the unique hydrodynamic conditions naturally present in these waters during the warm months of the year.

Ocean Nutrient Assessment Projects

What follows are the individual projects which were originally deemed necessary to complete nutrient criteria enhancement for New Jersey's Coastal Ocean and a description of their current status. Anticipated completion dates are provided in Table 5.

O1. Project Title: Finalize benthic biological index.

Project Description: Samples collected in 2010 and 2013 need to be reanalyzed after the index is further calibrated. These results will be used to validate the index. The completed index must be then reviewed by the Department in terms of what constitutes full and nonsupport of the aquatic life use and decide how the index will be used for assessment purposes. If these communities exhibit impairment, then the Department will work to determine if excess nutrients might be a contributor.

Status: Samples collected in 2010 and 2013 have been analyzed but further index calibration is pending. EPA ORD Narraganset has clarified for the Department how best to perform a final validation. The completed index must be then reviewed by the Department as to what constitutes full support and nonsupport of the aquatic life use and decide how the index will be used for assessment purposes.

O2. Project Title: <u>Evaluate continuous DO conditions and recommend a methodology to assess NJ marine waters against the EPA marine DO criteria.</u>

Project Description: Using DO data from glider transects, evaluate the current DO condition and recommend revisions to implement the EPA marine DO criteria.

Status: The Science Advisory Board has recommended methods on how to combine glider data in concert with fixed marine monitoring stations to quantify frequency and duration of marine DO profiles. The full report can be viewed at: http://www.state.nj.us/dep/sab/NJDEPSAB-Continuous%20Monitoring%20of%20Dissolved%20Oxygen_012616.pdf. This process is still ongoing.

The Department's Bureau of Marine Water Monitoring has performed a preliminary review of the spatial and temporal conjunction between near-shore ocean DO and local finfish reproduction cycles. The early reproductive states (egg, fry, juvenile) represent the more sensitive life stages in terms of oxygen requirements. The review indicated that although EPA and DEP/Rutgers data show that low DO cells clearly form in the lower-most portions of the water column in the summer months, the early reproductive stages of the fish species surveyed occur outside these low DO layers by avoiding them either temporally by being present in these waters only in the winter, spring, or fall or by utilizing the more oxygen rich waters outside the low DO cell (surface waters or migrating into the estuaries). Hence, data and accompanying literature review suggests that the low DO cells are the consequence of natural ocean processes and that the resident biota have long ago adapted to their presence.

O3. Project Title: <u>Assess ocean aquatic conditions and determine if additional work is needed.</u>

Project Description: Apply the nearshore ocean benthic index once finalized to assess the aquatic life status. Use this information along with findings on the DO condition to review the Department's decision to list DO on the 303(d) List. If results reflect preliminary findings and indicate nonimpaired aquatic life, the Department will move to delist the marine waters from the 303(d) list.

Status: Based on preliminary results, pending final decisions on the ocean IBI, the biological condition appears to be generally unimpaired.

Table 5. Projects Associated with Near Shore Ocean Criteria Development

Project	**Description**	**Start Date**	**Status/Completion Goal***
O1	Finalize ocean biological index	January 2013	December 2018
O2	Evaluate DO conditions from glider data and recommend methods to assess marine DO conditions against EPA marine criteria	Currently under discussion	
O3	Assess aquatic conditions using finalized bio metric	2013	2018

* All dates are targets based upon available resources and staff workloads; dates are subject to change

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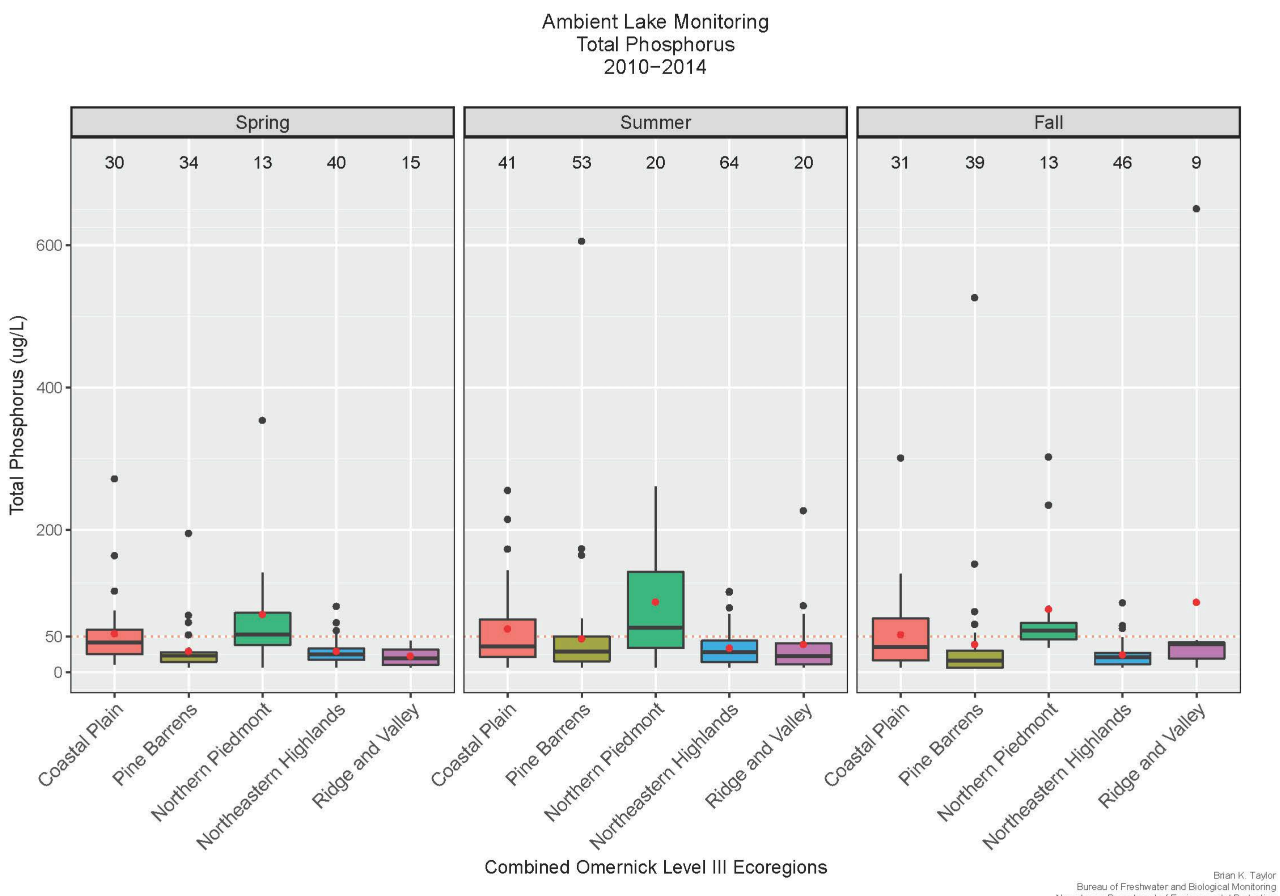
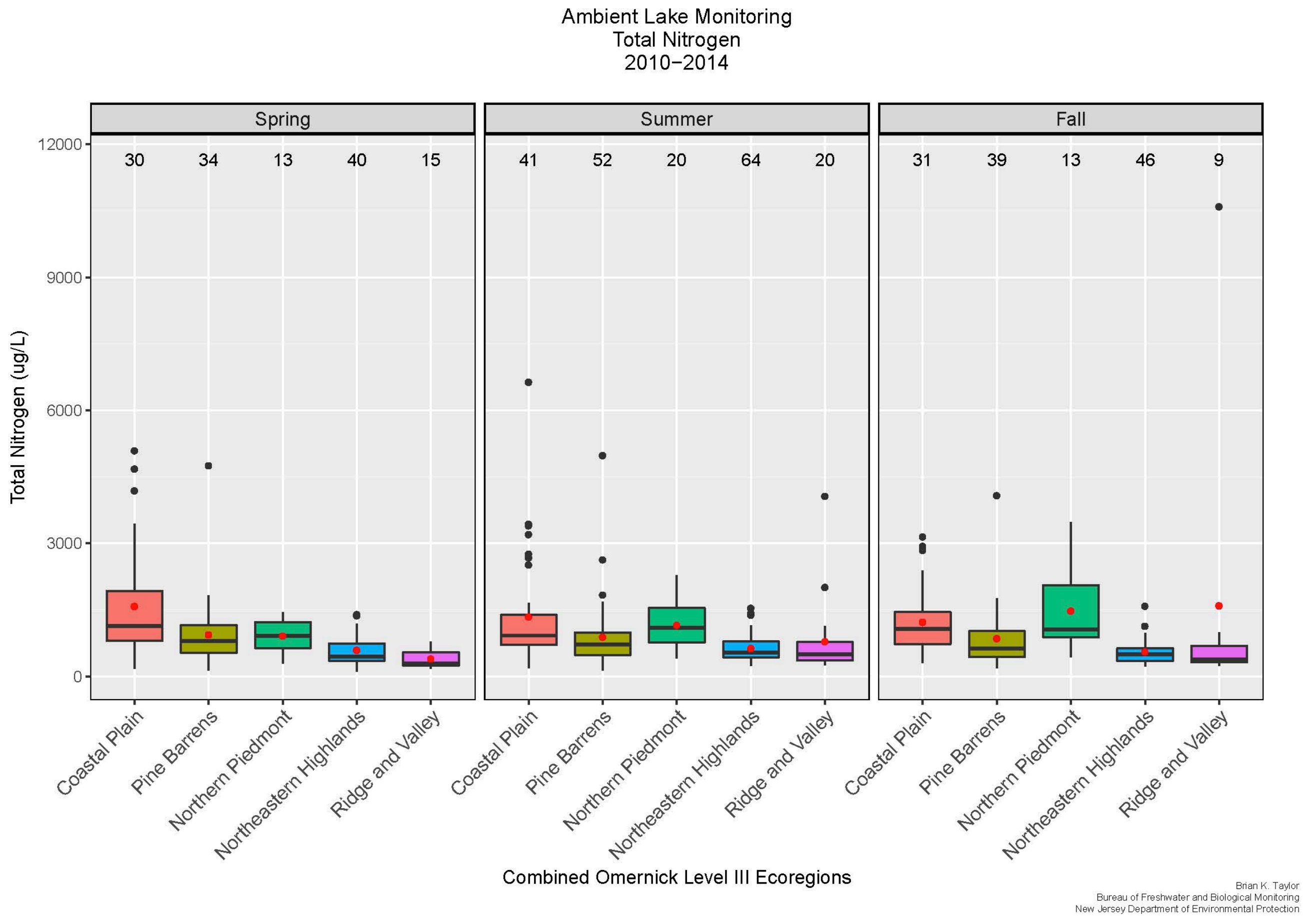
Appendix A

Box and whisker plots representing total phosphorus and total nitrogen ranges from New Jersey lakes by EPA Ecoregion. Data collected between 2010 and 2014 through the Lake Monitoring Network (http://www.state.nj.us/dep/wms/bfbm/lakes.html) overseen by the NJDEP, Bureau of Freshwater and Biological Monitoring.

Level III Ecoregions are delineated in Figure 2 on page 18 of this report. Boxes represent the 25th and 75th percentile of the nutrient range. Red points represent means, horizontal lines with in the boxes denote 50th percentiles. Vertical lines indicate the 5th to 95th percentiles; points above the horizontal lines are outliers (defined as values exceeding the 95th percentile).



Appendix A Continued:



Appendix B

Carlson Trophic State Index: